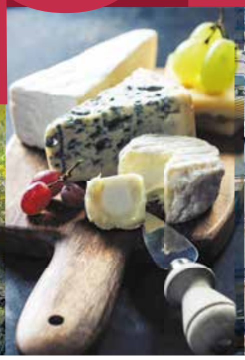

The regional assessment report on BIODIVERSITY AND ECOSYSTEM SERVICES **FOR EUROPE AND CENTRAL ASIA**

THE IPBES REGIONAL ASSESSMENT REPORT ON BIODIVERSITY AND ECOSYSTEM SERVICES FOR EUROPE AND CENTRAL ASIA

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For further information, please contact:
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
IPBES Secretariat, UN Campus
Platz der Vereinten Nationen 1, D-53113 Bonn, Germany
Phone: +49 (0) 228 815 0570
Email: secretariat@ipbes.net
Website: www.ipbes.net

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Technical Support
Amor Torre-Marin Rando
André Mader

Graphic Design
MOABI / Maro Haas, Art direction and layout
Zoo, designers graphiques, Figures design
Yuka Estrada, SPM figures

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MEMBERS OF THE MANAGEMENT COMMITTEE WHO PROVIDED GUIDANCE FOR THE PRODUCTION OF THIS ASSESSMENT:

Ruslan Novitsky, Marie Stenseke (Multidisciplinary Expert Panel); Senka Barudanovic, Robert T. Watson (Bureau).

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The regional assessment report on BIODIVERSITY AND ECOSYSTEM SERVICES FOR EUROPE AND CENTRAL ASIA

Edited by:

Mark Rounsevell
Assessment Co-Chair, University of Edinburgh/Karlsruhe Institute of Technology, UK/Germany

Markus Fischer
Assessment Co-Chair, University of Bern, Switzerland

Amor Torre-Marin Rando
Technical Support Unit, IPBES Secretariat/University of Bern, Switzerland

André Mader
Technical Support Unit, IPBES Secretariat/University of Bern, Switzerland

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FOREWORD

The Regional Assessment Report on Biodiversity and Ecosystem Services for Europe and Central Asia produced by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) provides a critical analysis of the state of knowledge regarding the importance, status, and trends of biodiversity and nature's contributions to people. The assessment analyses the direct and underlying causes for the observed changes in biodiversity and in nature's contributions to people, and the impact that these changes have on the quality of life of people. The assessment, finally, identifies a mix of governance options, policies and management practices that are currently available to reduce the loss of biodiversity and of nature's contributions to people in that region. The assessment addresses terrestrial, freshwater, and coastal biodiversity and covers current status and trends, going back in time several decades, and future projections, with a focus on the 2020-2050 period.

The Summary for Policymakers of this Assessment Report was approved by the sixth session of the Plenary of IPBES (Medellín, Colombia, 18-24 March 2018) and is included in this report. The chapters and their executive summaries were accepted at this same Plenary session. The chapters are available as document IPBES/6/INF/6/Rev.1 (www.ipbes.net).

The objective of IPBES, the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services, is to provide Governments, the private sector, and civil society with scientifically credible and independent up-to-date assessments of available knowledge to make informed decisions at the local, regional and international levels.

This regional and subregional assessment of biodiversity and ecosystem services for Europe and Central Asia has been carried out by 111 selected authors and 6 early career fellows, assisted by 149 contributing authors, primarily from this region, who have analyzed a large body of knowledge, including about 4750 scientific publications and other knowledge sources. It represents the state of knowledge about the Europe and Central Asia region and subregions. The chapters and their executive summaries were accepted, and the summary for policymakers was approved, by the 129 Member States of IPBES at the sixth session of the IPBES Plenary (18 to 24 March, 2018, Medellín, Colombia).

This report provides a critical assessment of the full range of issues facing decision makers, including the importance, status, trends and threats to biodiversity and nature's contributions to people, as well as policy and management response options. Establishing the underlying causes of the loss of biodiversity and nature's contributions to people provides policymakers with the information needed to develop appropriate response options, technologies, policies, financial incentives and behavior changes.

The assessment concludes that nature's contributions to people are critically important for a good quality of life, but are not evenly experienced by people and communities within the region, and are under threat due to the strong ongoing decline of biodiversity. While sustainability and conservation policies and actions have contributed to reversing some of the negative biodiversity trends, this


progress remains insufficient. The assessment also notes the reliance on imports of renewable resources from outside the region.

The major driver of the loss of biodiversity and ecosystem services to date has been land-use change, caused in part by production-based subsidies that led to unsustainable intensification of agricultural practices. However, the assessment notes that the impact of human-induced climate change is increasing and is likely to be one of the most important drivers in the future. The assessment also found that economic growth has, in general, not been decoupled from environmental degradation.

A continuation in past and present trends in the drivers that cause the loss of biodiversity is projected to inhibit the widespread achievement of the Sustainable Development Goals, the Aichi Biodiversity Targets and the Paris Agreement on climate change. Long-term societal transformations that focus on achieving a balanced supply of nature's contributions to people, coupled with participatory decision-making processes, are likely to be the most effective for moving towards a sustainable future.

The assessment identifies a mix of governance options, policies and management practices that is currently available to reduce the loss of biodiversity and nature's contributions to people, but recognizes that further commitment is needed to adopt and implement them. Most important is to include the conservation and sustainable use of biodiversity, and the provision of nature's contributions to people, into all sectoral policies (e.g. agriculture, energy, health, industry, transportation), plans, programmes, strategies and practices - an objective known as "mainstreaming biodiversity".

We would like as Chair and Executive Secretary of IPBES, to recognize the excellent and dedicated work of the co-chairs, Professors Markus Fischer (Switzerland) and Mark Rounsevell (UK and Germany) and of the coordinating lead authors, lead authors, review editors, fellows, contributing authors and reviewers, and to warmly thank them for their commitment, and for contributing their time freely to this important report. We would also like to thank Amor Torre-Marin Rando and André Mader, from the technical support unit located at the University of Bern, Switzerland, as well as Felice van der Plaat, coordinator of the implementation of the regional assessments, because without their dedication this report would not have been possible. We would also like to thank the Government of Switzerland for their generous support. Our thanks also go to members of the IPBES MEP and Bureau who provided guidance as part of the management committee for this report.

This regional assessment provides invaluable information for policymakers in Europe and Central Asia to make informed decisions regarding the conservation and sustainable use of biodiversity, the promotion of access to genetic resources, and the fair and equitable sharing of benefits arising from their use. It also provides valuable information for the ongoing IPBES global assessment, to be released in May 2019 and is expected to inform discussions regarding the post-2020 global biodiversity framework under the Convention on Biological Diversity, as well as to inform action on implementing the 2030 Agenda for Sustainable Development and the Sustainable Development Goals.

Sir Robert T. Watson
Chair of IPBES

Anne Larigauderie
Executive Secretary of IPBES

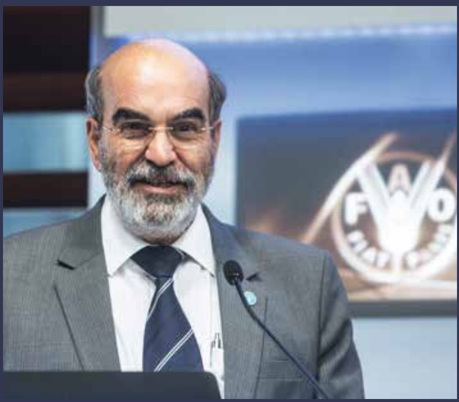
STATEMENTS FROM KEY PARTNERS

"The Sustainable Development Goals aim to "leave no one behind". If we don't protect and value biodiversity, we will never achieve this goal. When we erode biodiversity, we impact food, water, forests and livelihoods. But to tackle any challenge head on, we need to get the science right and this is why UN Environment is proud to support this series of assessments. Investing in the science of biodiversity and indigenous knowledge, means investing in people and the future we want."

Erik Solheim
Executive Director,
United Nations Environment Programme (UNEP)

"Biodiversity is the living fabric of our planet - the source of our present and our future. It is essential to helping us all adapt to the changes we face over the coming years. UNESCO, both as a UN partner of IPBES and as the host of the IPBES Technical Support Unit on Indigenous and Local Knowledge, has always been committed to supporting harmony between people and nature through its programmes and networks. These four regional reports are critical to understanding the role of human activities in biodiversity loss and its conservation, and our capacity to collectively implementing solutions to address the challenges ahead."

Audrey Azoulay
Director-General,
United Nations Educational, Scientific and Cultural Organization (UNESCO)



"The regional assessments demonstrate once again that biodiversity is among the earth's most important resources. Biodiversity is also key to food security and nutrition. The maintenance of biological diversity is important for food production and for the conservation of the ecological foundations on which rural livelihoods depend. Biodiversity is under serious threat in many regions of the world and it is time for policy-makers to take action at national, regional and global levels."

José Graziano da Silva

Director-General,
Food and Agriculture Organization of the United Nations (FAO)

"Tools like these four regional assessments provide scientific evidence for better decision making and a path we can take forward to achieve the Sustainable Development Goals and harness nature's power for our collective sustainable future. The world has lost over 130 million hectares of rainforests since 1990 and we lose dozens of species every day, pushing the Earth's ecological system to its limit. Biodiversity and the ecosystem services it supports are not only the foundation for our life on Earth, but critical to the livelihoods and well-being of people everywhere."

Achim Steiner

Administrator,
United Nations Development Programme (UNDP)

ACKNOWLEDGEMENTS

Three years of intense work have resulted in the IPBES Regional Assessment of Biodiversity and Ecosystem Services for Europe and Central Asia. This has been a pressured, but also highly enjoyable process thanks to everyone who has contributed to this important collective effort. As Co-Chairs we were privileged to work with so many outstanding experts from Europe and Central Asia. We warmly acknowledge the first-rate intellectual contributions and immense investment of time by all of our authors, review editors, and early-career fellows, as well as the various types of support from their respective funding organizations, institutions and Governments, which facilitated their participation. This Assessment would also not have been possible without the generous commitment of several other key individuals. We would first like to recognize the invaluable contributions of the two members of our Technical Support Unit (TSU), Amor Torre-Marin Rando and André Mader, whose enthusiasm, professionalism and dedication facilitated every aspect of the process. We also thank Eva Spehn of the Swiss Biodiversity Forum for helping to get us started by acting as a provisional TSU. We thank the IPBES Chair, Bob Watson, and the IPBES Executive Secretary, Anne Larigauderie, for their wise guidance and enormous support to the assessment team, with the other members of our assessment management committee, Senka Barudanovic, Ruslan Novitsky, Marie Stenseke as well as Felice van der Plaat, from the IPBES secretariat, and other members of the IPBES Multidisciplinary Expert Panel (MEP) and Bureau. We thank the IPBES secretariat as a whole for excellent support and collaboration throughout the process.

In addition, we thank all expert reviewers from Governments, stakeholders and the scientific community for their time, perspectives and valuable comments, which markedly improved the quality of both the Summary for Policymakers (SPM) and the chapters. On the technical side, we also thank our data visualization experts, Yuka Estrada and Maro Haas and team, for their work on the assessment figures and diagrams, and Mark Snethlage for his many contributions to data analysis and visualisation.

Our sincere appreciation is extended to the Swiss Government's Federal Office for the Environment for funding the TSU and to the University of Bern for hosting it. We also thank the Swiss Federal Office for the Environment for co-funding our lead author meetings


in Engelberg (Switzerland), Zadar (Croatia) and Prague (Czech Republic). We would further like to thank the Indigenous and Local Knowledge TSU of IPBES for organizing the "Europe and Central Asia Dialogue Workshop on Indigenous and Local Knowledge" in Paris (France) in 2016 and the IPBES Capacity Building TSU who supported the "Capacity Development Writing Workshop for IPBES Experts from Central Europe, Eastern Europe and Central Asia" held in Antalya (Turkey), in 2016 and a regional dialogue meeting in Vácrátót (Hungary) in 2017. We are also very grateful to the many publishers, too numerous to list here, who freely provided figures.

We acknowledge and appreciate the members and observers of the IPBES Plenary, whose suggestions during the 6^{th} session of the Plenary, held in Medellín, Colombia, in March 2018 led to significantly increased clarity and accessibility of the SPM. Finally, we express our sincere gratitude to Bureau members Ivar Baste and Senka Barudanovic for chairing the contact group at the 6th session of the IPBES Plenary with extraordinary professionalism, patience and sensitivity.

As we deliver the important results of this work, we are confident that the investment of so much time, passion, expertise and resources will pay exceptional dividends – informing better policies, decisions and action to protect the invaluable natural assets of our beautiful region for all the people of Europe and Central Asia.

Mark D.A. Rounsevell
Co-Chair

Markus Fischer
Co-Chair

PREFACE

WHAT IS AN ASSESSMENT?

An assessment is a critical evaluation of information, to inform decisions on a complex, public issue (MEA, 2005). An assessment does not generate new data, but seeks to create new understanding through summary, sorting and synthesis using different methods to manage complexity. It includes academic and grey literature, as well as insights from indigenous and local knowledge (ILK).

The IPBES Regional Assessment for Europe and Central Asia was conducted by a group of experts with a broad range of knowledge and skills, most of whom were nominated by Governments, and the remainder by organizations. The Assessment is supported by evidence, not based on advocacy, and relates to a particular time period (usually 1950-2050, but earlier or later where appropriate) and to the geographical domain of Europe and Central Asia.

THE IPBES CONTEXT FOR THE REGIONAL ASSESSMENT FOR EUROPE AND CENTRAL ASIA

Objective 2(b) of the IPBES work programme is to "strengthen the science-policy interface on biodiversity and ecosystem services at and across subregional, regional and global levels by producing "regional/subregional assessments on biodiversity and ecosystem services" for: Africa, the Americas, Asia-Pacific, and Europe and Central Asia (Decision IPBES-3/1: Work programme for the period 2014–2018: Annex IV-VII). The implementation of the Regional Assessment for Europe and Central Asia followed a scoping study that responded to requests by Governments, multilateral environmental agreements and other stakeholders in the formulation of key policy questions. These policy questions included: a) general questions relevant to all IPBES regional assessments and, b) questions specific to the Europe and Central Asia region. The scoping study resulted in a generic scoping report (Decision IPBES-3/1: Work programme for the period 2014–2018, Annex III: Generic scoping report for the regional and subregional assessments of biodiversity and ecosystem services (deliverable 2 (b))) and scoping reports for each of the four regions, which have guided the implementation of the Regional Assessment for Europe and Central Asia according to the timetable outlined in **Figure 1**. The IPBES Plenary approved the summary for policymakers, and accepted the chapters of the Assessment Report, at its sixth session in March 2018.

Each of the four regional IPBES assessments share the same generic policy questions and follow the same chapter structure, which maps onto the IPBES conceptual framework. All regional assessments also integrate relevant aspects of the IPBES thematic and methodological assessments (outlined below) and consider trans-regional teleconnections in nature, nature's contributions to people[1] and good quality of life, and in the underlying drivers. While the Regional Assessment for Europe and Central Asia focuses on the regional scale, it also considers subregional or finer scales where necessary. Many examples of drivers, biodiversity, ecosystem services, and good quality of life concern national to local scales. Moreover, the local scale often offers the best opportunity for the integration of indigenous and local knowledge and other knowledge systems. Thus, the general coarse-scale focus of this assessment is rooted in a synthesis of information across a range of scales from local to the Europe and Central Asia region as a whole. The outcomes of the regional assessments are stand-alone products that also inform the IPBES Global Assessment on Biodiversity and Ecosystem Services (deliverable 2c).

THE ASSESSMENT PROCESS

The Regional Assessment for Europe and Central Asia was undertaken by an expert team of 118 individuals comprising two assessment co-chairs, a further 12 coordinating lead authors, 85 lead authors, six fellows and 13 review editors. The experts were selected in 2015 by the co-chairs; representatives of the IPBES Bureau and multidisciplinary expert panel (MEP) from the region; and the IPBES secretariat, from nominations by Governments and organizations, to cover a spectrum of disciplines including indigenous and local knowledge. The selected expert

1. Nature's contributions to people encompass the positive contributions, or benefits, and occasionally negative contributions, losses or detriments, that people obtain from nature. The term resonates with the original use of the term ecosystem services in the Millenium Ecosystem Assessment (MEA, 2005), and goes further by explicitly embracing concepts associated with other worldviews on human–nature relations and knowledge systems.

team was supported by numerous contributing authors. The 13 review editors assessed the adequacy of author responses to reviewer comments. The evidence presented in the assessment was derived from the peer-reviewed and publicly available literature or correctly cited and publicly available grey literature, as well as indigenous and local knowledge (Roué and Molnár, 2016).

Implementation of the assessment followed eight procedural steps. A first draft of the report chapters was prepared by the author team (1). This draft was peer reviewed in an open and transparent process by Governments, other stakeholders and all interested experts who responded to an invitation by the IPBES Executive Secretary by registering and submitting review comments (2). This facilitated stakeholder engagement and provided a broad set of comments through which the assessment's legitimacy was enhanced. A second draft of the report chapters and first draft summary for policymakers (SPM) were prepared by the author team under the guidance of the review editors and the multidisciplinary expert panel, considering comments from the review (3). These two documents were reviewed a second time by Governments, and other stakeholders (4), leading to the preparation of the final draft of the report chapters and summary for policymakers by the author team under the guidance of the review editors and the multidisciplinary expert panel (5). The summary for policymakers was then translated into the six official languages of the United Nations, checked for accuracy by the author team, and prepared in formats suitable for

Figure 1 **The deliverables and time table of the first IPBES work programme 2014–2018.**

indigenous and local knowledge holders (6). The final draft of the report chapters and summary for policymakers were made available to, and reviewed by, Governments who provided written comments (7), culminating in the review and approval of the summary for policymakers, and the acceptance of the report chapters at the 6th session of the IPBES Plenary in Medellín in March 2018 (8).

THE RELATIONSHIP BETWEEN THE REGIONAL ASSESSMENT FOR EUROPE AND CENTRAL ASIA AND THE OTHER IPBES ASSESSMENTS

Besides the four regional assessments, the IPBES work programme (see **Figure 1**) encompasses completed or ongoing assessments including the Thematic Assessment on Pollinators, Pollination and Food Production; the Methodological Assessment on Scenarios and Models of Biodiversity and Ecosystem Services; the Thematic Assessment on Land Degradation and Restoration; and the Global Assessment on Biodiversity and Ecosystem Services. These assessments report at the regional to global scales, and also provide important case studies at the landscape scale. The summary for policymakers of the Thematic Assessment on Pollinators, Pollination and Food Production, was approved and its chapters accepted at the 4th meeting of the Plenary of IPBES in 2016 (IPBES, 2016). It assessed the role of, and status and trends in, animal pollinators and pollination networks and changes in pollination that underpins food production. The assessment informs policy responses to declines and deficits in pollination and contributes to Aichi Biodiversity Target 14 on safeguarding and restoring ecosystems that provide essential contributions to people. The Thematic Assessment on Land Degradation and Restoration provides information to support decision-makers in reducing the negative environmental, social and economic consequences of land degradation, and in restoring degraded land to enhance nature's contributions to people. The assessment identifies areas of concern and the potential solutions to the challenges posed by land degradation as well as highlighting critical knowledge gaps and priority areas for research and investment (Decision IPBES-3/1, Annex VIII: Scoping for a thematic assessment of land degradation and restoration (deliverable 3 (b) (i))). The IPBES Global Assessment on Biodiversity and Ecosystem Services synthesizes evidence based on biodiversity and nature's contributions to people (IPBES/4/INF/9: Guide on the production and integration of assessments from and across all scales (deliverable 2 (a))) from across the Earth. It is based strongly on the outcomes of the four regional and subregional assessments, but also reports on literature that uses methods applied at the global scale. Where appropriate and necessary, information elaborated during the progress toward these other IPBES assessments also contributed to the Regional Assessment for Europe and Central Asia.

THE POLICY CONTEXT

Almost all countries in Europe and Central Asia use (agreed-upon) relevant international frameworks to guide national strategy and action. The IPBES assessment of Europe and Central Asia was, hence, and as requested by the scoping document, undertaken in the context of the United Nations 2030 Agenda for Sustainable Development and Strategic Plan for Biodiversity 2011–2020. The assessment examines progress towards the Sustainable Development Goals of the 2030 Agenda and the Aichi Biodiversity Targets of the Strategic Plan. Its time frame covers current and projected trends corresponding with timelines for the 2030 Agenda (2030), and the Strategic Plan (2020) and its 2050 vision. The Strategic Plan for Biodiversity 2011-2020, in particular, exists in the broader context of the United Nations Decade on Biodiversity. In 2010, the Parties to the Convention on Biological Diversity invited the United Nations General Assembly to consider declaring 2011-2020 the United Nations Decade on Biodiversity (CBD, 2010), which the General Assembly did in a resolution in the same year, "with a view to contributing to the implementation of the Strategic Plan for Biodiversity for the period 2011-2020" (United Nations, 2011).

THE INVOLVEMENT OF DIFFERENT STAKEHOLDERS

Stakeholders can be considered in two groups, based on how they engaged with the Regional Assessment of Europe and Central Asia (Decision IPBES-3/4: Communications, stakeholder engagement and strategic partnership, Annex II: Stakeholder engagement strategy (deliverable 4 (d))):

1. *Contributors* - scientists, knowledge holders including indigenous and local knowledge holders, practitioners and others;

2. *End users* - regional governments, national Governments and multilateral environmental agreements, subnational and local governments, United Nations agencies, inter-governmental organizations, non-governmental organizations (NGOs), other practitioners within the private sector and the public.

As stakeholder engagement is an important element for the relevance, effectiveness, credibility and overall success of IPBES, stakeholder values, needs and concerns were embedded within the assessment process from the start. The Regional Assessment for Europe and Central Asia has engaged with the broader stakeholder community to better understand and communicate the causes of the loss of nature and nature's contributions to people, including the role of humans and the consequences for human well-being. Involving stakeholders is important in recognising their diverse conceptualisations of values, adding societal aspects when assessing drivers and scenarios and evaluating policy support tools. Although different stakeholders may have different priorities, they all aim to have their knowledge, views and values considered within the IPBES process, including its assessments. Stakeholders can bring complementary perspectives to those of Government, which also helps to identify and prioritize the most relevant knowledge gaps. Different stakeholder organizations can play an important role in the engagement of IPBES with different sectors of society. For these reasons, IPBES provides an opportunity for stakeholders to contribute to informing decision-making.

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BOSS

The regional assessment report on BIODIVERSITY AND ECOSYSTEM SERVICES FOR EUROPE AND CENTRAL ASIA

SUMMARY FOR POLICYMAKERS

AUTHORS:[2]

Markus Fischer (co-chair, Switzerland, Germany), Mark Rounsevell (co-chair, United Kingdom of Great Britain and Northern Ireland/Germany).

Amor Torre-Marin Rando (IPBES), André Mader (IPBES); Andrew Church (United Kingdom of Great Britain and Northern Ireland), Marine Elbakidze (Ukraine, Sweden), Victoria Elias (Russian Federation), Thomas Hahn (Sweden), Paula A. Harrison (United Kingdom of Great Britain and Northern Ireland), Jennifer Hauck (Germany), Berta Martín-López (Spain/Germany), Irene Ring (Germany), Camilla Sandström (Sweden), Isabel Sousa Pinto (Portugal), Piero Visconti (Italy/United Kingdom of Great Britain and Northern Ireland), Niklaus E. Zimmermann (Switzerland), Mike Christie (United Kingdom of Great Britain and Northern Ireland).

EXPERTS HAVING PROVIDED SUPPORT TO AUTHORS OF THE SUMMARY FOR POLICYMAKERS:

Sandra Brucet (Spain), Rodolphe Gozlan (France), Aveliina Helm (Estonia), Sandra Lavorel (France), Oksana Lipka (Russian Federation), Matthias Schröter (Germany), Mark Snethlage (the Netherlands/Switzerland), Vigdis Vandvik (Norway), Alexander P. E. van Oudenhoven (the Netherlands).

2. Authors are listed with, in parenthesis, their country of citizenship, or countries of citizenship separated by a comma when they have several; and, following a slash, their country of affiliation, if different from citizenship, or their organization if they belong to an international organization: name of expert (nationality 1, nationality 2/affiliation). The countries or organizations having nominated these experts are listed on the IPBES website.

KEY MESSAGES

KEY MESSAGES

A. A PRECIOUS ASSET: NATURE AND ITS CONTRIBUTIONS TO PEOPLE'S QUALITY OF LIFE IN EUROPE AND CENTRAL ASIA

Nature's contributions to people, which embody ecosystem services, are critically important for livelihoods, economies and a good quality of life, and are therefore vital to sustaining human life on earth. Nature has considerable economic and cultural values for societies. Nature also benefits, for example, human health through its role in medicines, the provision of food for varied diets and support to mental and physical health through green spaces. The knowledge and customary practices of indigenous peoples and local communities also enhance people's quality of life by fostering cultural heritage and identity. In Europe and Central Asia, which has an area of 31 million square kilometres, the regulation of freshwater quality has a median value of $1,965 per hectare per year. Other important regulating services include habitat maintenance ($765 per hectare per year); the regulation of climate ($464 per hectare per year); and the regulation of air quality ($289 per hectare per year).

Nature's contributions to people are under threat due to the continuing loss of biodiversity. Sustaining nature's contributions to people requires the maintenance of high levels of biodiversity. The continuing decline in biodiversity has had negative consequences for the delivery of many ecosystem services over the last decades. These include habitat maintenance, pollination, regulation of freshwater quantity and quality, soil formation and regulation of floods. These declines have occurred in part because of the intensive agriculture and forestry practices used to increase the provision of food and biomass-based fuels.

The region of Europe and Central Asia partially relies on net imports of renewable resources from outside the region. The population of Europe and Central Asia consumes more renewable natural resources than are produced within the region in spite of the increase since the 1960s in the production of food and biomass-based fuels. Central and Western Europe depends on food and feed imports equivalent to the annual harvest of 35 million hectares of cropland (2008 data), a land area the size of Germany.

Across Europe and Central Asia, nature's contributions are not evenly experienced by people and communities. In Europe and Central Asia, a combination of food provision and imports means that the region is currently food secure but, in some areas of Central Asia and Central and Eastern Europe, food security is threatened by exports arising from large-scale land acquisitions mainly by entities from both Western Europe and outside the region. Water security, which relies partially on nature's regulation of water quality and quantity, also varies across the region, with 15 per cent of people in Central Asia lacking access to safe drinking water. The decline of indigenous and local knowledge has negatively impacted on the heritage and identity of indigenous peoples and local communities.

B. THE BIODIVERSITY OF EUROPE AND CENTRAL ASIA IS UNIQUE BUT THREATENED

The biodiversity of Europe and Central Asia is in continuous strong decline. The extent of natural ecosystems has declined, e.g., wetland extent has declined by 50 per cent since 1970 and natural and semi-natural grasslands, peatlands and coastal marine habitats have been degraded. Ecosystems have considerably declined in terms of species diversity. Of the assessed species living exclusively in Europe and Central Asia, 28 per cent are threatened. Among all the assessed groups of species living in the region, particularly threatened are mosses and liverworts (50 per cent), freshwater fish (37 per cent), freshwater snails (45 per cent), vascular plants (33 per cent) and amphibians (23 per cent). Landscapes and seascapes have become more uniform in their species composition and thus their diversity has declined.

In recent years, national and international sustainability and conservation policies and actions have contributed to reversing some negative biodiversity trends. More sustainable management of fisheries and reduction of eutrophication has led to an increase in some fish stocks in areas such as the North Sea. Endangered habitats, such as Macaronesian woodlands, and species such as the Iberian lynx and European bison, have recovered substantially because of targeted conservation efforts.

Overall, progress towards healthy ecosystems is still insufficient. While some progress has been made in improving the status of biodiversity by safeguarding






ecosystems, species and genetic diversity, biodiversity status and trends remain negative overall. Increasing conservation efforts and the sustainability of the use of biodiversity would enhance the chances of meeting national and international biodiversity targets.

C. DRIVERS OF CHANGE IN BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE IN EUROPE AND CENTRAL ASIA

Land-use change is the major direct driver of the loss of both biodiversity and ecosystem services in Europe and Central Asia. Production-based subsidies have led to intensification in agriculture and forestry, and, together with urban development, have led to biodiversity decline. Increasing intensity often impinges on traditional land use. Ceasing traditional land use has reduced semi-natural habitats of high conservation value and associated indigenous and local knowledge, practices and culture across the region. Although protected areas have expanded in the region, protected areas alone cannot prevent biodiversity loss. Only where protected areas are managed effectively can they contribute to the prevention of biodiversity loss.

The impact of climate change on biodiversity and nature's contributions to people is increasing rapidly and is likely to be one of the most important drivers in the future. Trends in natural resource extraction, pollution and invasive alien species have led to considerable declines in biodiversity and ecosystem services, and are likely to continue to pose considerable threats, particularly in combination with climate change. Natural resource extraction is still a major pressure on biodiversity. Furthermore, despite effective regulations, pollution continues to pose a major threat to biodiversity and human health. Invasive alien species have increased in number – for all taxonomic groups across all the subregions of Europe and Central Asia – and this has severe effects on biodiversity and ecosystem services. The individual and combined effects of all the direct drivers have chronic, prolonged and delayed consequences for biodiversity and the provision of nature's contributions to people owing to considerable time-lags in the response of ecological systems.

Economic growth is generally not decoupled from environmental degradation. This decoupling would require a transformation in policies and tax reforms across the region. Economic growth, as measured through traditional gross domestic product (GDP), across Europe and Central Asia has indirectly reinforced drivers of biodiversity loss, which in turn has reduced nature's contributions to people. Across the region, a range of policies, including environmental taxation, have been implemented to decouple economic growth from detrimental drivers. Furthermore, there still exist policy instruments, such as harmful agricultural and fishing subsidies, which continue to impede transitions towards a sustainable future. Decoupling would be assisted by new indicators that incorporate well-being, environmental quality, employment and equity, biodiversity conservation and nature's ability to contribute to people.

D. FUTURES FOR EUROPE AND CENTRAL ASIA

The continuation of past and present trends in drivers to, and beyond, 2030 (as represented in business-as-usual scenarios) will inhibit the widespread achievement of goals similar to and including the Sustainable Development Goals. Future scenarios that focus on achieving a balanced supply of nature's contributions to people and that incorporate a diversity of values are more likely to achieve the majority of such goals. Trade-offs are indicated between different ecosystem services under different future scenarios for Europe and Central Asia. Ways of resolving these trade-offs depend on political and societal value judgements. Scenarios that include proactive decision-making on environmental issues, environmental management approaches that support multifunctionality, and mainstreaming environmental issues across sectors, are generally more successful in mitigating trade-offs than isolated environmental policies. Scenarios that include cooperation between countries or regions are expected to be more effective in mitigating undesirable cross-scale impacts on biodiversity and ecosystem services.

Long-term societal transformation through continuous education, knowledge-sharing and participatory decision-making characterize the most effective pathways for moving towards sustainable futures. These pathways promote resource-sparing lifestyles and emphasize community actions and voluntary agreements supported by social and information-based instruments as well as rights-based approaches. They support regulating ecosystem services and highlight a diverse range of values in comprehensively considering biodiversity and nature's contributions to people across sectors, and across spatial and temporal scales. Other actions, such as technological innovation, ecosystem-based approaches, land sparing or land sharing, could support and pave the way for these more transformational solutions.

E. PROMISING GOVERNANCE OPTIONS FOR EUROPE AND CENTRAL ASIA

A mix of governance options, policies and management practices is available for public and private actors in Europe and Central Asia, but further commitment is needed to adopt and effectively implement them to address the drivers of change, to safeguard biodiversity and to ensure nature's contributions to people for a good quality of life. Well-designed, context-specific mixes of policy instruments building on, for example, ecosystem-based approaches, have been effective in the governance of biodiversity and nature's contributions to people. While legal and regulatory instruments are the backbone of policy mixes, economic, financial, social and information-based instruments provide additional incentives to trigger behaviour change. Developing rights-based instruments would fully integrate the fundamental principles of good governance, equalizing power relations and facilitating capacity-building for indigenous peoples and local communities. The mobilization of sufficient financial resources would strengthen institutional capacities to support research, training, capacity-building, education and monitoring activities. The removal of harmful subsidies in various sectoral policies, such as agriculture, fisheries and energy, in Europe and Central Asia, reduces negative impacts on biodiversity and allows for a more cost-effective use of public funds.

Mainstreaming the conservation and sustainable use of biodiversity and the sustained provision of nature's contributions to people into all sectoral policies, plans, programmes, strategies and practices could be achieved with more proactive, focused and goal-oriented approaches to environmental action. Partial progress has been made in tackling the underlying drivers of biodiversity loss, by mainstreaming across government and society. Mainstreaming could be harnessed in a three-step process by: first, raising awareness of the dependence of good quality of life on biodiversity; second, defining policy objectives concerning the ecological, economic and sociocultural needs for achieving sustainable development; and, third, designing instruments and policy mixes to support the implementation of effective, efficient and equitable policy and decision-making for nature and a good quality of life.

Better integration across sectors to coordinate biodiversity governance and the sustainable delivery of nature's contributions to people would avoid negative outcomes for nature and people. Improved coordination would enable better consideration of biodiversity and ecosystem services, taking trade-

offs between different policy and economic sectors into account. There is, for example, ample room for further exploiting this potential for the agriculture, forestry and fisheries sectors and urban planning. Regarding an economy-wide perspective, this includes measuring national welfare beyond current economic indicators that take account of the diverse values of nature. Ecological fiscal reforms would provide integrated incentives and provide leverage to redirect activities that support sustainable development.

Increasing participation and stakeholder involvement will help to integrate various forms of knowledge in policymaking and decision-making while promoting shared responsibility. The importance of the effective involvement of different actors is recognized in Western and Central Europe and increasingly also in Eastern Europe and Central Asia. This involvement can be strengthened by careful monitoring and evaluation, taking various values into consideration, including those of indigenous peoples and local communities.

Box SPM 1 **Region of Europe and Central Asia.**

Table SPM 1 **Subregions and countries of Europe and Central Asia according to decision IPBES-3/1, annex VII.**

SUBREGION	COUNTRIES
WESTERN EUROPE	Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland
CENTRAL EUROPE	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, the former Yugoslav Republic of Macedonia, Turkey
EASTERN EUROPE	Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova, Russian Federation, Ukraine
CENTRAL ASIA	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan

Box SPM 1 **Region of Europe and Central Asia.**

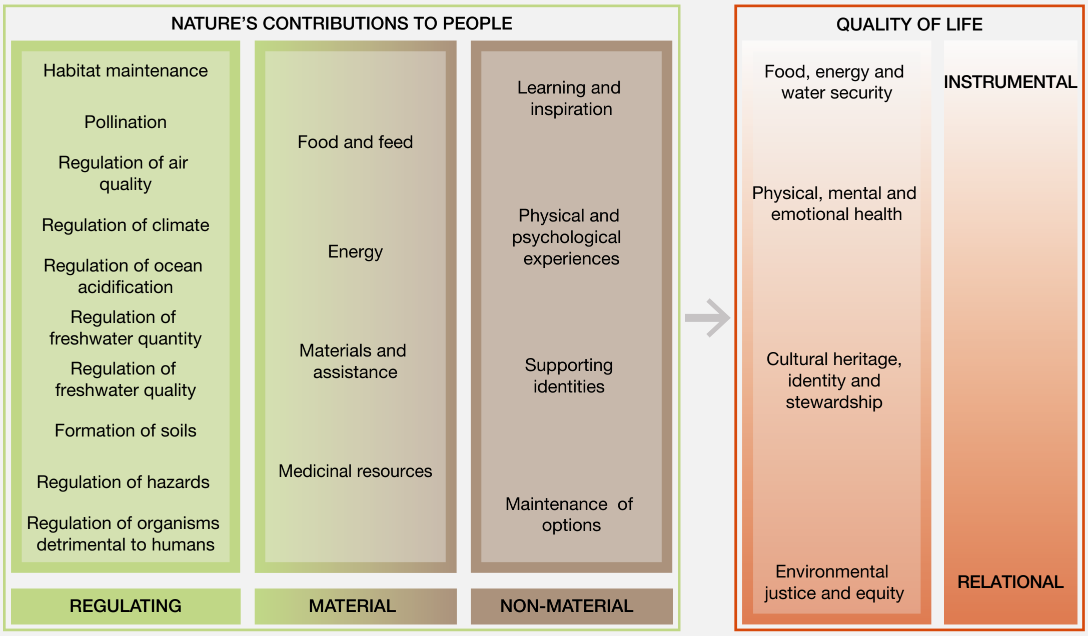
The Europe and Central Asia region encompasses 54 countries **(Table SPM.1)** in four subregions **(Figure SPM.1)**. These countries vary greatly in size, including the largest and smallest on Earth, and have diverse governance structures, cultures, economies, ecoregions and sectors. The seas of the region are heterogeneous in terms of temperatures, currents, nutrient availability, depths and mixing regimes. There are great differences in data monitoring and availability across the region.

Figure SPM 1 **Region of Europe and Central Asia with the four IPBES subregions and regional oceans and seas.**

Box SPM 2 **Nature's contributions to people.**

The regional assessment for Europe and Central Asia considers ecosystem services through the lens of nature's contributions to people (see appendix 2), which embodies both the scientific concept of ecosystem goods and services, and the notion of nature's gifts from indigenous and local knowledge systems. Nature's contributions can be beneficial or detrimental to people, depending on the cultural context, and are assessed from two complementary perspectives: one generalizing in nature and the other context-specific. The generalizing perspective includes 18 categories organized into three partially overlapping groups: regulating, material and non-material contributions **(Figure SPM.2)** {2.1.1}. The context-specific perspective includes geographical and cultural aspects of indigenous and local knowledge systems. The grading of green and brown colours in **Figure SPM.2** indicates whether nature's contributions to people are associated more with natural or with cultural systems. Instrumental values refer to the value attributed to something as a means to achieve a particular end. Relational values are positive values assigned to "desirable relationships", such as those among people and between people and nature.

Figure SPM 2 **Nature's contributions to people and their relation to quality of life in terms of instrumental and relational values.**



BACK-GROUND

BACKGROUND

A. Nature and its contributions to people's quality of life in Europe and Central Asia

A1 Nature provides valuable material (e.g., food), regulating (e.g., climate regulation and pollination) and non-material contributions to people (e.g., learning and inspiration) (Figure SPM.2). These contributions are essential for people's quality of life as they have substantial economic, social and cultural values *(well established)*[3] {2.3.5}.

The highest valued regulating contributions to people in Europe and Central Asia include: the regulation of freshwater and coastal water quality (estimated to have a median value of $1965[4] per hectare per year) *(established but incomplete)*; habitat maintenance ($765 per hectare per year) *(unresolved)*; the regulation of climate ($464 per hectare per year); and the regulation of air quality ($289 per hectare per year) *(established but incomplete)* {2.3.5.2}. Monetary values for regulating contributions to people, however, are site-specific and vary significantly across the Europe and Central Asia region depending on location, habitat, extent of contribution and valuation method used.

Nature's material contributions to people have important values that are partly reflected in conventional market prices. Agricultural production across the 28 member States of the European Union generates profits ranging from $233 per hectare per year (cereals) to $916 per hectare per year (mixed crops), while wood supply from forests generates profits of $255 per hectare per year {2.3.5.1}.

Nature's non-material contributions to people, which include physical and psychological experiences linked to tourism and recreation, are estimated to have a median monetary value of $1,117 per hectare per year *(unresolved)* {2.3.5.2}. Other non-material contributions, such as cultural heritage and identity, may be valued using non-monetary approaches *(established but incomplete)* {2.3.5.2, 2.3.5.3}. Such values are indicated through people's engagement with nature for leisure and tourism, spiritual and aesthetic experiences, learning, developing indigenous and local knowledge, and by their desire to conserve areas and iconic species *(well established)* {2.2.3}.

Nature and its contributions to people have value for human health *(well established)* {2.3.2}, including their role in contemporary and traditional medicine, dietary diversity *(well established)* {2.2.2.4, 2.3.2} and urban green spaces *(established but incomplete)* {2.3.2}. Unsustainable exploitation threatens the survival of, for instance some medicinal plants *(established but incomplete)* {2.2.2.4}.

Indigenous peoples and local communities hold distinct knowledge about nature and its contributions to people that have significant value for many local communities *(established but incomplete)* {2.3.3}. There has been, however, a loss of indigenous and local knowledge about ecosystems and species *(well established)* {2.2.3.1.2, 2.3.3} as well as declining trends of linguistic diversity (a proxy for indigenous and local knowledge) *(well established)* {2.2.3.1.2, 2.3.3}.

There is a range of monetary and non-monetary approaches to capture the multiple values of natures contributions to people. Novel approaches enable these values to be integrated into decision-making to maximize economic, social and quality-of-life benefits.

A2 There are negative trends for the majority of nature's regulating, and some non-material, contributions to people in the Europe and Central Asia region between 1960 and 2016 *(well established)* {2.2.1, 2.2.3, 2.2.5}. This has resulted partly from intensive agriculture and forestry practices used to increase the production of food and biomass-based fuels, which have had a negative impact on many regulating services, such as soil formation, pollination and the regulation of freshwater quality *(well established)* {2.2.1, 2.2.2, 2.2.5}. This continuing decline in regulating contributions can have

3. For explanation of confidence terms, see appendix 1.

4. These monetary values have been standardized to a common currency (the international dollar – $) and base year (2017). The standardization procedure adjusts values elicited in a particular currency and year to a standard currency and year using appropriate gross domestic product deflators and purchasing power parity (PPP) exchange rates.

Figure SPM 3 **Trends in nature's contributions to people (1960–2016) for Europe and Central Asia and the subregions.**

Trends are based on the evidence from publications and indicators reporting increasing, decreasing, constant or variable trends for each ecosystem service {2.2.5}. The higher level of confidence for the region of Europe and Central Asia compared with the subregions is the result of the extra publications that addressed the region as a whole. *Abbreviations:* WE = Western Europe, CE = Central Europe, EE = Eastern Europe, CA = Central Asia, ECA = Europe and Central Asia

		WE	CE	EE	CA	ECA
REGULATING NATURE'S CONTRIBUTIONS TO PEOPLE	Habitat maintenance	Decrease	Decrease	Decrease	Lack of evidence	Decrease
	Pollination	Decrease	Decrease	Decrease	Lack of evidence	Decrease
	Regulation of air quality	Variable	Increase	Increase	Variable	Increase
	Regulation of climate	Increase	Variable	Increase	Variable	Variable
	Regulation of ocean acidification	Lack of evidence	Lack of evidence	Lack of evidence	Lack of evidence	Variable
	Regulation of freshwater quantity	Decrease	Variable	Decrease	Decrease	Decrease
	Regulation of freshwater quality	Decrease	Decrease	Decrease	Lack of evidence	Decrease
	Formation and protection of soils	Decrease	Decrease	Decrease	Decrease	Decrease
	Regulation of coastal and fluvial floods	Variable	Decrease	Decrease	Variable	Decrease
	Regulation of organisms (removal of carcasses)	Increase	Variable	Increase	Increase	Increase
MATERIAL NATURE'S CONTRIBUTIONS TO PEOPLE	Food	Increase	Increase	Increase	Increase	Increase
	Biomass-based fuels	Increase	Stable	Stable	Lack of evidence	Increase
	Materials (wood and cotton)	Stable	Stable	Stable	Stable	Stable
NON-MATERIAL NATURE'S CONTRIBUTIONS TO PEOPLE	Learning derived from indigenous and local knowledge	Decrease	Decrease	Decrease	Decrease	Decrease
	Physical and psychological experiences	Variable	Decrease	Decrease	Lack of evidence	Variable
	Supporting identities	Lack of evidence	Lack of evidence	Lack of evidence	Lack of evidence	Variable

Increase · Stable · Lack of evidence · Decrease · Variable

Confidence level: Well established · Established but incomplete/ unresolved · Inconclusive

detrimental consequences for quality of life *(established but incomplete)* {2.3.1.1, 2.2.1.2, 2.2.1.5, 2.2.1.6, 2.2.1.7, 2.2.1.8, 2.2.2.1, 2.2.3.1}.

A total of 7 out of the 16 assessed nature's contributions to people are known to be declining in Europe and Central Asia, in particular regulating contributions and learning derived from indigenous and local knowledge *(well established)* {2.2.1, 2.2.3, 2.2.5}. These trends are consistent across the subregions of Europe and Central Asia **(Figure SPM.3)** *(well established)* {2.2.5}. Habitat maintenance, pollination *(established but incomplete)*, regulation of freshwater quantity and quality, formation and protection of soils and regulation of floods are declining because of land-use intensification designed to increase the production of crops, livestock, aquaculture, forest biomass and cotton, as well as urban development *(well established)* {2.2.1, 2.2.2, 2.2.5}. Trade-offs between material and regulating contributions have compromised food and water security in some areas {2.2.1, 2.2.2, 2.2.5}.

The Europe and Central Asia region is currently food secure because of food production in the region and trade, despite the degradation of several of nature's regulating contributions and loss of food-related indigenous and local knowledge *(well established)* {2.3.1.1, 2.2.1.2, 2.2.1.5, 2.2.1.7, 2.2.1.8, 2.2.2.1, 2.2.3.1}. Soil erosion has affected 25 per cent of agricultural land in the European Union and 23 per cent in Central Asia. Combined with a decline in soil organic matter, this might compromise food production *(well established)* {2.2.1.8}. At the same time, between 2000 and 2010, erosion control increased by 20 per cent on arable land in Western and Central Europe {2.2.1.8}. Since 1961, Mediterranean and Central Asian countries have increased their dependence on pollination by producing more pollinator-dependent fruits *(established but incomplete)* {2.2.1.2}. At the same time, however, the diversity and abundance of wild insect pollinators have declined since the 1950s and severe losses of the western honeybee have occurred in Europe since 1961 *(established but incomplete)* {2.2.1.2}. Continuing rural depopulation across the region and the loss of indigenous and local knowledge about traditional land use affects food availability, especially in remote areas *(established but incomplete)* {2.2.3.1.2, 2.2.3.2.1, 2.3.1.1, 4.5.5}. Wild fish catches have decreased since the 1990s, with more sustainable management practices being introduced only recently. Fish production from aquaculture increased by 2.7 per cent since 2000 *(established but incomplete)* {2.2.2.1.2}.

Water security depends partially on the regulation of water quality and quantity by ecosystems, which is impaired by pollution, decreasing floodplain and wetland area, overexploitation of freshwater bodies, and climate change *(established but incomplete)* {2.2.1.6, 2.2.1.7}. Nevertheless, 95 per cent of the people in Europe and Central Asia have access to safe drinking water, despite a 15 per cent decrease in water availability per capita since 1990 *(well established)* {2.3.1.3}.

A3 Nature's contributions to people, and their influence on quality of life, are not always equally experienced across different locations and social groups in Europe and Central Asia *(established but incomplete)* {2.3.4}.

Intra-regional equity in access to food and a balanced diet is largely achieved *(well established)* {2.3.1.1} as indicated by, for example, the average dietary energy supply, which ranges from 137 per cent in Western Europe to 121 per cent in Central Asia of the average dietary energy requirement for the population of the region {2.3.1.1}. However, large-scale land acquisitions in Central and Eastern Europe and Central Asia by entities from outside and within the region, mainly from Western Europe, may compromise the opportunities for certain groups of people to influence their own food systems *(established but incomplete)* {2.3.1.1}. Nature's contributions to people are factors in influencing the situation in which some 15 per cent of people in Central Asia, but only 1 per cent in Western Europe, lack access to safe drinking water *(well established)* {2.3.1.3, 2.3.4.2}. Within cities, inhabitants have unequal access to green spaces with consequences for public health and well-being *(established but incomplete)* {2.2.3.2, 2.3.4.2}. For example, residents in cities in the south of the European Union have less access to green space than residents of northern, western and central cities. Public access to forests for recreation is uneven across countries, with a high level of access (98–100 per cent) in Nordic and some Baltic countries and lower levels (under 50 per cent) in some other Western European countries *(well established)* {2.3.4.2}. There is also temporal inequity as today's generations are benefiting from nature's contributions to people at the expense of future provision *(established but incomplete)* {2.2.3.4}.

A4 The population of Europe and Central Asia uses more renewable natural resources than are produced within the region (Figure SPM.4) *(well established)* {2.2.4}. The region depends on net imports of both renewable natural resources and material contributions of nature to people *(well established)* {2.2.4}. Some of these imports to Europe and Central Asia negatively affect biodiversity, nature's contributions to people and food security in other parts of the world *(established but incomplete)* {2.2.4, 2.3.4}.

Measures of ecological footprint[5] and "biocapacity"[6] show that Central and Western Europe import more of nature's contributions to people than Eastern Europe and Central Asia *(well established)* {2.2.4} **(Figure SPM.4)**. While most of Western and Central Europe and Central Asia have a "biocapacity" deficit, in Eastern Europe and northern parts of Western and Central Europe high footprints are offset by even higher biocapacities *(well established)* {2.2.4}. This negatively affects biodiversity, nature's contributions to people and food security both within Europe and Central Asia and other parts of the world *(established but incomplete)* {2.2.4, 2.3.4}. For instance, according to the technical report 2013-063 funded by the European Commission, 10 per cent of the world's annual deforestation was the result of consumption by the then 27 member States of the European Union *(established but incomplete)* {2.2.4.1}.

Western Europe's ecological footprint is 5.1 global hectares[7] per person and its "biocapacity" 2.2 hectares per person; Central Europe's footprint is 3.6 hectares per person and its "biocapacity" 2.1 hectares per person; Eastern Europe's footprint is 4.8 hectares per person and its "biocapacity" 5.3 hectares per person; and Central Asia's footprint is 3.4 hectares per person and its "biocapacity" 1.7 hectares per person *(well established)* {2.2.4} **(Figure SPM.4)**.

Food availability in Central and Western Europe relies significantly on imports from countries, both outside and

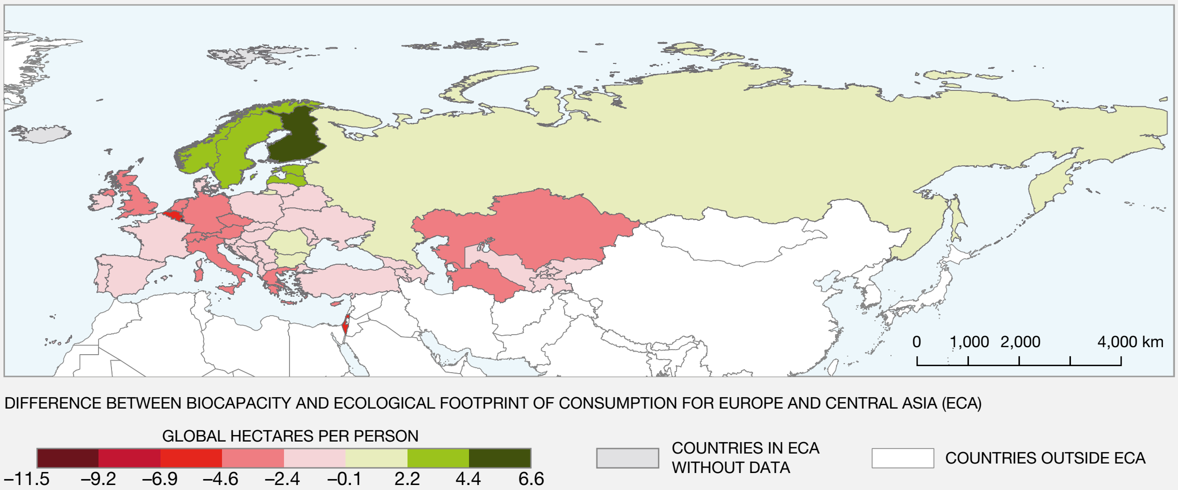
5. Ecological footprint has a variety of definitions, but is defined by the Global Footprint Network as "a measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices." The ecological footprint indicator used in this report is based on the Global Footprint Network unless otherwise specified.

6. The definition that follows is for the purpose of this assessment only: "Biocapacity" has a variety of definitions, but is defined by the Global Footprint Network as "the ecosystems' capacity to produce biological materials used by people and to absorb waste material generated by humans, under current management schemes and extraction technologies." The "biocapacity" indicator used in this report is based on the Global Footprint Network unless otherwise specified.

7. A global hectare is a biologically productive hectare with world average biological productivity for a given year and depends on the land type.

Figure SPM 4 **Difference between “biocapacity” (on average 2.9 global hectares per person in the region) and the ecological footprint of consumption (4.6 global hectares per person; average deficit 1.7 global hectares per person).**

The ecological footprint quantifies the area needed to produce on a sustainable basis the renewable resources it consumes and thus can be used as a proxy for the use of certain of nature’s material or regulating contributions to people and the area needed to assimilate CO_2 and other waste sustainably. “Biocapacity” refers to the capacity of a certain area to generate an ongoing supply of renewable resources and thus is a proxy for ecosystem productivity. A positive value (green) indicates a “biocapacity” reserve; a negative value (red) indicates a deficit. A deficit derives from the overuse of local renewable resources or the net import of renewable resources for consumption. Countries shaded in green have high “biocapacity”, so they have a reserve despite having a higher ecological footprint than many other countries. Source: Based on Global Footprint Network (2017).



within the region, of the product of 35 million hectares of cropland harvested per year (2008 data), particularly from Argentina, Brazil, China and the United States *(well established)* {2.2.4}. Western Europe became less self-sufficient in crop production between 1987 and 2008, while the rest of Europe and Central Asia became more self-sufficient *(well established)* {2.2.4}. Seafood exports from Europe and Central Asia increased over the period 1976–2009, with Norway, Spain and the Russian Federation being the main exporters *(well established)* {2.2.4}. Over the period 1997–2012, there was a stable pattern of imports to Western Europe of roundwood and wood products from Central and Eastern Europe *(well established)* {2.2.4}.

A5 Biodiversity loss impairs ecosystem functioning and, hence, nature’s contributions to people *(well established)* {3.2.1, 3.2.2, 3.2.3}. The sustained delivery of these contributions requires the maintenance of different levels of biodiversity, i.e., genetic diversity, species diversity, and the diversity of ecosystems and of landscapes and seascapes *(well established)* {3.2.4}. At each of these levels, the sustained delivery of multiple contributions generally requires higher diversity than the delivery of single contributions *(well established)* {3.2.5}.

Different organisms, species and communities differ in their contributions to ecosystem processes in Europe and Central Asia. Higher biodiversity therefore increases the capacity of terrestrial, freshwater and marine ecosystems to provide nature’s contributions to people, such as soil formation, pollination, regulation of hazards, regulation of air and water quality, or the provision of materials, learning and inspiration *(well established)* {3.2.1, 3.2.2}. Higher biodiversity also stabilizes ecosystem functioning and improves capacity for evolutionary adaptation *(well established)* {3.2.3, 3.2.4}. The higher the number of nature’s contributions to people to be provided, and the longer the time span and the larger the area of their provision, the more biodiversity is required *(well established)* {3.2.5}.

Ecosystem functioning is affected by genetic and phenotypic biodiversity within species, and by functional, taxonomic and phylogenetic diversity between species *(well established)* {3.2.4}. At the landscape and larger spatial scales, the increasing similarity of the sets of organisms found at different places, e.g., owing to the application of similar and intensive land use over large spatial scales, reduces nature’s overall contributions to people *(established but incomplete)* because different sets of organisms contribute to different contributions of nature to people *(well established)* {3.2.5}. Thus, the supply of multiple contributions of nature to people requires the maintenance and promotion of high biodiversity at the landscape level *(established but incomplete)* {3.2.5}.

B. Trends in biodiversity and attribution to direct drivers

B1 Of the assessed marine habitats and species, a high percentage are threatened *(established but incomplete)*, varying between marine areas *(well established)* {3.3.4.1–7} (Figure SPM.6). The abundance, range and habitat size of many marine species is shrinking under human pressures, including overfishing, climate change, pollution and invasive alien species *(well established)* {3.3.4.1–7, 3.4.6.1}.

Figure SPM 5 A **Extinction risk of species in Europe and Central Asia according to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species in 2015.**

EX: extinct, CR: critically endangered, EN: endangered, VU: vulnerable, NT: near threatened, DD: data deficient, LC: least concern. Species in categories CR, EN, VU are considered threatened. The blue bar is the best estimate of the proportion of threatened and extinct species, assuming that the same proportion of DD species is threatened or extinct as of species with sufficient data (i.e., EX, CR, EN, VU, NT, LC). Only species in comprehensively assessed taxonomic groups are considered. Source: IUCN (2017).[8]

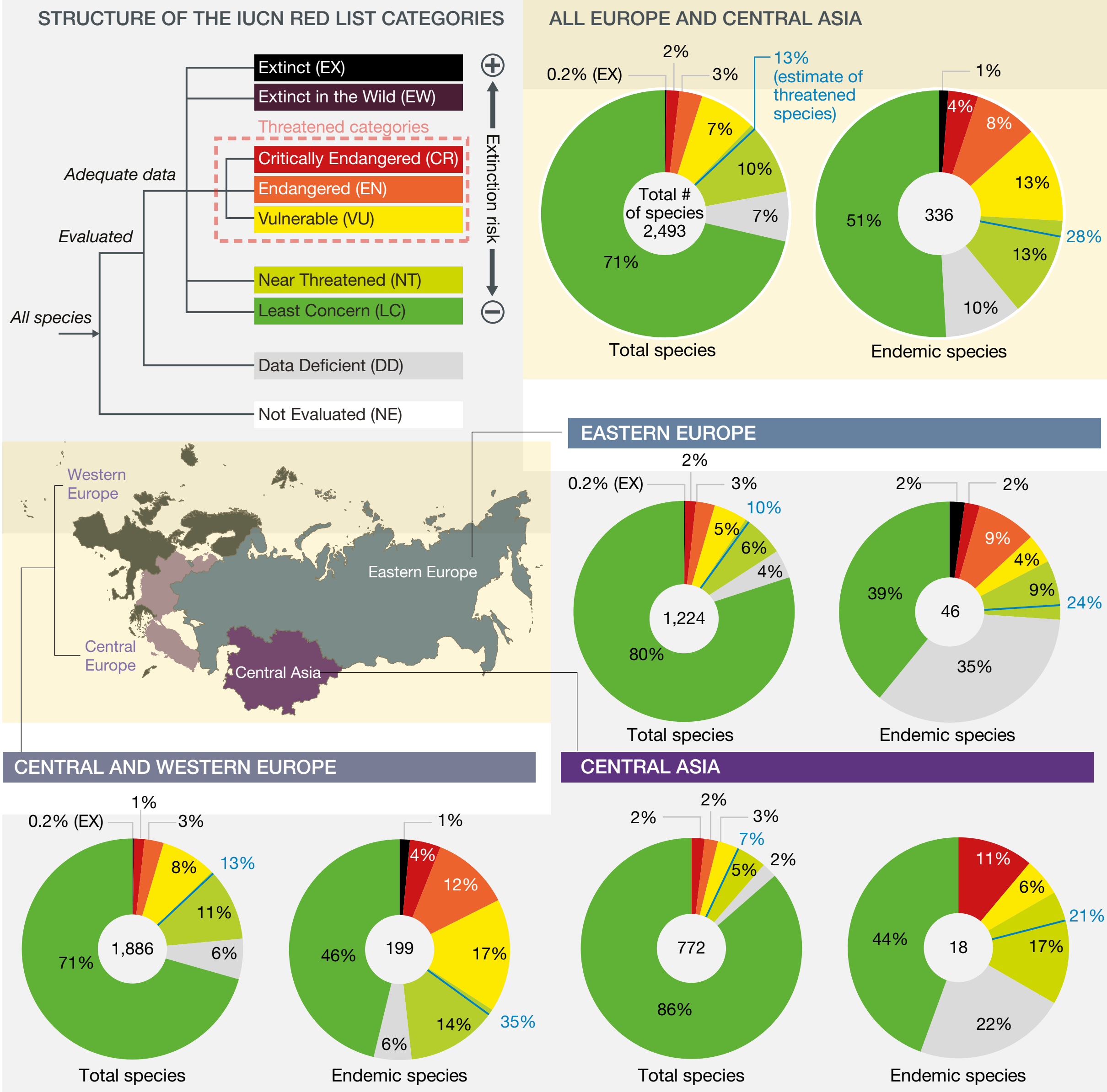
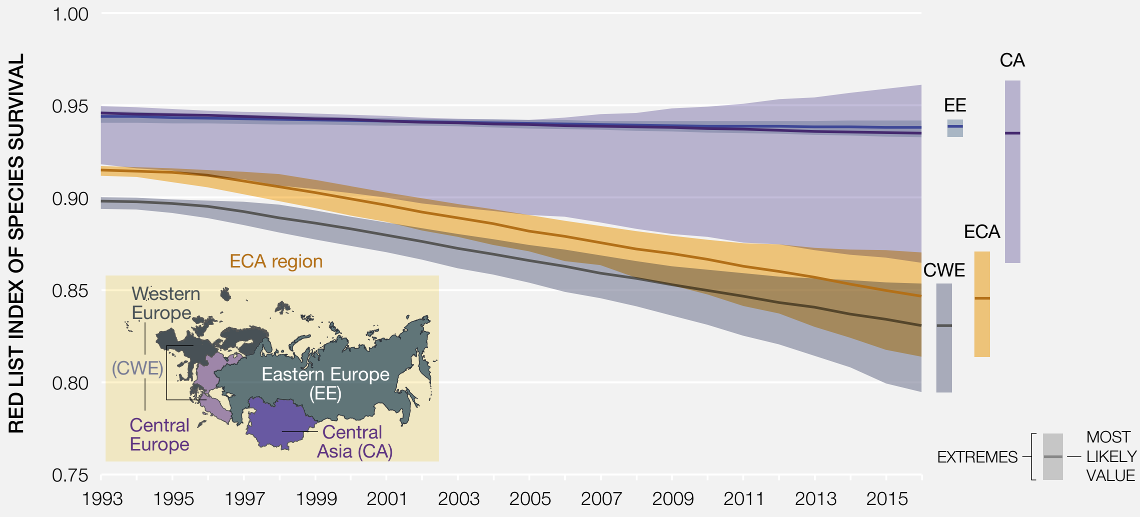


Figure SPM 5 B **Trend in Red List Indices of species survival weighted by the fraction of the distribution of each species within the region.**

The position on the vertical axis indicates the aggregate risk of extinction, the closer to one the lower the aggregate extinction risk. The slope indicates how rapidly this extinction risk is changing. For the region, the risk of extinction of species has increased over the last 20 years. Each line represents the most likely Red List Index value, considering uncertainty in the number of species threatened. The shading around each line represents the extremes, if all data deficient species were threatened with extinction (above the line), or if none of them were (below the line). Only birds, mammals and amphibians are considered here, as these are the only groups that have been comprehensively assessed at least twice. Source: IUCN, Red List of Threatened Species, version 2017-3.[8]



Present positive trends, mainly due to improved fishing practices, the establishment of marine protected areas and a reduction in eutrophication, include increases in some fish stocks in the North Sea and in plankton diversity in the Black Sea *(well established)* {3.3.4.1, 3.3.4.4}. However, monitoring data are generally missing for most marine habitats and species *(well established)* {3.3.4}.

In all, 53 per cent of the benthic shallow habitats in Western and Central Europe are data deficient. The corresponding figure is 87 per cent in the Black Sea, 60 per cent in the North East Atlantic, 59 per cent in the Mediterranean Sea and 5 per cent in the Baltic Sea *(well established)* {3.3.4.1–7}. Of the assessed benthic habitats, 38 per cent are classified as threatened (critically endangered, endangered or vulnerable), most of them in the Black Sea (67 per cent) and Mediterranean Sea (74 per cent), followed by the North East Atlantic (59 per cent) and the Baltic Sea (8 per cent) *(established but incomplete)* {3.3.4.1–7}. In the European Union, among assessments of the conservation status of species and habitat types of conservation interest covered by the European Union Habitats Directive, only 7 per cent of marine species and 9 per cent of marine habitat types show a "favourable conservation status". Moreover 27 per cent of species and 66 per cent of assessments of habitat types show an "unfavourable conservation status" and the remainder are categorized as "unknown" *(established but incomplete)* {3.3.4}.

In Europe and Central Asia, 26 per cent of the marine fish species have known trend data. Of those, 72 per cent are stable, 26 per cent have declining populations and 2 per cent have been increasing over the last decade *(well established)* {3.4.6.1}. Seabirds, marine mammals and turtles, and habitat formers, such as seagrasses and kelps, also declined in abundance *(well established)* {3.4.2–4}. The distribution or phenology of marine phytoplankton, zooplankton, algae, benthic invertebrates, fishes, seabirds and mammals has shifted *(well established)* {3.3.4.1}. In all, 48 per cent of marine animal and plant species with known population trends (436 decreasing, 59 increasing, 410 stable) have been declining in the last decade, increasing the extinction risk of monitored species **(Figure SPM.5)** *(established but incomplete)* {3.4.1}. Most of these present trends are consistent with the individual and combined effects of mainly overfishing, climate change, pollution and invasive alien species *(established but incomplete)* {3.3.4.1–7}. The impact of pollution by microplastics on ecosystems was not known until recently, and evidence of those impacts is only now being assessed {3.3.4}.

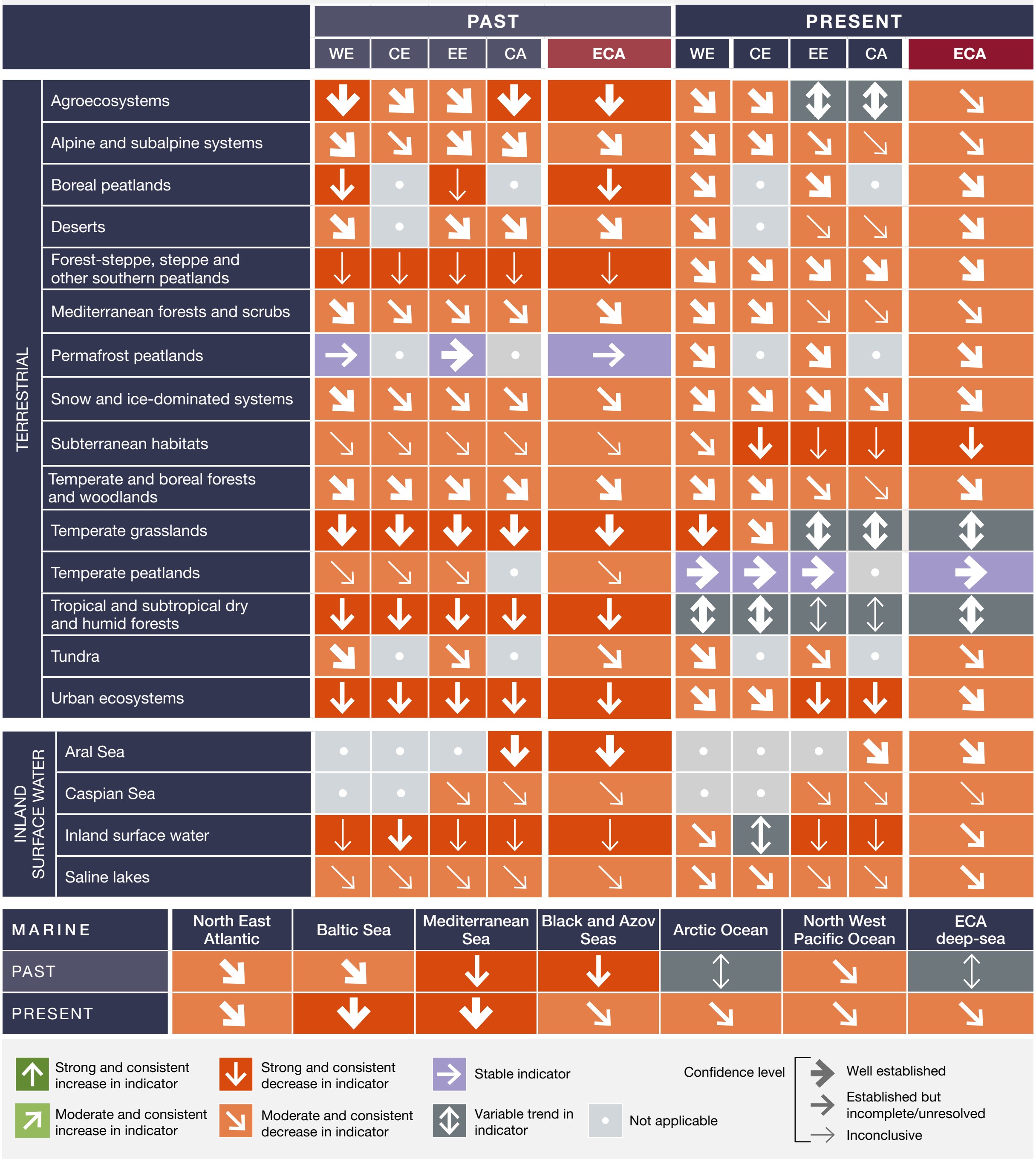
B2 Freshwater species and inland surface water habitats are particularly threatened in Europe and Central Asia *(well established)*. A total of 53 per cent of the European Union's rivers and lakes achieved

8. Available from www.iucnredlist.org.

good ecological status in 2015 as defined by the European Union Water Framework Directive. Similarly 30 per cent of water samples in the Russian Federation were above water quality standards *(well established)*. A total of 73 per cent of the assessments of the European Union's freshwater habitat types

Figure SPM 6 **Assessment of past (~1950–2000) and current (~2001–2017) trends in biodiversity status of marine, inland surface water and terrestrial ecosystems for the four subregions and the whole of Europe and Central Asia.**

The figure summarizes the trends in biodiversity status of the assessed units of analysis (habitat types). Biodiversity status represents the expert assessment of available indicators of habitat intactness, species richness and the status of endangered species. The trends are presented by unit of analysis and subregion for terrestrial and inland surface-water ecosystems, and by sea or ocean area for marine ecosystems {3.3; Box 3.3}. *Abbreviations:* WE = Western Europe, CE = Central Europe, EE = Eastern Europe, CA = Central Asia, ECA = Europe and Central Asia



show an unfavourable conservation status *(well established)* {3.3.3.1}. Across Europe and Central Asia, lakes, ponds and streams are altered and disappearing as a consequence of agricultural intensification, irrigation and urban development combined with climate change *(well established)* {3.3.3.1}. Notable is the case of the Aral Sea, once the fourth largest lake in the world, which has now almost disappeared owing to water abstraction for crop cultivation. The extent of wetlands in Western, Central and Eastern Europe has declined by 50 per cent from 1970, while 71 per cent of fish and 60 per cent of amphibians with known population trends have been declining over the last decade {3.3.3.1, 3.4.5, 3.4.6.2}.

Over 75 per cent of catchment areas in Europe and Central Asia are heavily modified and subject to multiple pressures. In 2015, good chemical status, as defined by the European Union Water Framework Directive, was not achieved for surface water bodies by 22 European Union member States and only 53 per cent of rivers and lakes had good ecological status as defined by the European Union Water Framework Directive despite some improvements {3.3.3.1}. In Western and Central Europe and the western parts of Eastern Europe[9] at least 37 per cent of freshwater fish and about 23 per cent of amphibians are currently threatened with extinction. In the same area, freshwater invertebrates are also threatened, with the most threatened group among those that are well monitored being gastropods (45–70 per cent of species threatened depending on whether or not data deficient species are considered threatened), followed by bivalves (20–26 per cent) and dragonflies (15–19 per cent) *(established but incomplete)* {3.4.5, 3.4.6.2, 3.4.8}.

Freshwater biodiversity trends are primarily driven by habitat destruction and modification caused by infrastructure for hydropower, navigation, flood protection, agriculture, urban development and water abstraction; pollution from agriculture and industry; the introduction of invasive alien species and their pathogens; and climate change *(established but incomplete)* {3.3.2.2, 3.3.3.4, 3.3.3.5.2}. Progress has been made in water protection in the European Union part of Western and Central Europe, in particular because of the European Union Water Framework Directive. The rate of natural habitat loss (e.g., wetlands) has slowed in Western, Central and Eastern Europe due to the implementation of binding nature conservation policies or the designation of conservation areas (e.g., Ramsar sites), *(established but incomplete)* {3.3.3.1}.

B3 Terrestrial species and habitats have long-term declining trends in population size, range, habitat intactness and functioning. This decline is mainly due to land-use change, for example unsustainable agriculture and forest management, infrastructure, urban development or mining, causing habitat loss, modification and fragmentation, and due to climate change *(well established)* {3.3.2, 3.4}. The conservation status of some habitats and species that benefit from targeted conservation actions (e.g., large felids or some species listed in the European Union Birds Directive) has improved in recent years *(established but incomplete)* {3.4.13}.

Across Europe and Central Asia, 14 out of 15 habitat types have been declining in extent and biodiversity status since the 1950s **(Figure SPM.6)** {3.3.2.5}. These declines are continuing, albeit at a slower rate, with some exceptions in the Macaronesian and Atlantic Boreal regions of Western and Central Europe, where recoveries in habitat conservation status have been reported. Grasslands, tundra, mires and bogs have been the most affected habitats since the 1950s *(established but incomplete)* {3.3.2}.

Systematic assessments of habitat conservation status exist only for the European Union. There, 16 per cent of terrestrial habitat assessments in the period 2007–2012 had favourable conservation status; 3 per cent had unfavourable, but improving trends; 37 per cent had unfavourable, but stable trends; 29 per cent had unfavourable and declining trends; and 15 per cent had unknown or unreported trends relative to the period 2001–2006 *(well established)* {3.3.2}.

Since the 1950s, various biodiversity indicators have shown a decline in response to both abandonment of, and intensified use of, agricultural land (*well established* for Western Europe and Central Europe; *established but incomplete* for Eastern Europe and Central Asia) {3.3.2.9}. From 1980 to 2013, the abundance of farmland common bird species decreased by 57 per cent in Western and Central Europe *(well established)* {3.4.3}. The species diversity of arable crops has decreased by 20 per cent since 1950 in Western and Central Europe, and the abundance of rare arable plants has also decreased *(established but incomplete)*. The genetic diversity of plants cultivated in situ declined until the 1960s, owing to the replacement of landraces by modern cultivars, and no further reduction or increase of diversity was observed after the 1980s *(well established)*. Europe and Central Asia has over half of all known breeds of domesticated mammals and birds, but 75 per cent of local bird breeds and 58 per cent of local mammal breeds are threatened with extinction. The numbers of at-risk breeds have declined slightly since 1999, but exact quantification is hampered by the changing number of documented local breeds *(established but incomplete)* {3.4.13}.

Across Europe and Central Asia, 42 per cent of terrestrial animal and plant species with known trends

9. The geographical scope here is continent-wide, extending from Iceland in the west to the Urals in the east, and from Franz Josef Land in the north to the Canary Islands in the south. The Caucasus region is not included.

have declined in population size over the last decade, increasing the extinction risk of monitored species *(established but incomplete)* **(Figure SPM.5)**. The main causes of this decline are habitat loss, degradation and pollution due primarily to unsustainable agriculture and forest management, natural resource extraction and invasive alien species *(established but incomplete)* {3.4, 3.3.2}. Monocultures, and all forms of homogenization of landscapes, such as the conversion of grasslands to crops, and agricultural intensification (especially the conversion of natural and semi-natural grassland to more intensively used pastures) have caused homogenization of ecological communities by supporting generalist species and impacting habitat specialists *(well established)*. Climate change is accelerating changes in species composition and local extinctions in all habitat types *(well established)*, contracting glaciers, shifting the nival belt to higher altitudes *(well established)*, replacing polar deserts with tundra *(well established)*, expanding arid areas, and causing shifts in forest habitat types *(well established)* {3.3.2}. National and international conservation efforts have shown the potential to reverse these trends. The long-term population trends of 40 per cent of the breeding bird taxa in Annex I of the European Union Birds Directive are increasing, compared with 31 per cent for all breeding bird taxa {3.4.13}. Charismatic mammalian megafauna, such as the Amur tiger, Far-Eastern leopard, Iberian lynx, and European bison, are all recovering from the brink of extinction because of dedicated conservation efforts {3.4.3, 3.4.13}.

C. Drivers of change in biodiversity and nature's contributions to people in Europe and Central Asia

C1 Land-use change, as one of the major direct drivers of change in biodiversity and nature's contributions to people in Europe and Central Asia, is often posing substantial risks for human well-being *(well established)* (4.2.1). There are examples of sustainable agricultural and forestry practices that are beneficial to biodiversity and nature's contributions to people in the region. However, the major trend is increasing intensity of conventional agriculture and forestry that lead to biodiversity decline *(well established)*. Ceasing traditional land use reduces semi-natural habitats of high conservation value *(well established)* and associated indigenous and local knowledge and practices *(well established)* {4.5.1, 4.5.5}. Protected areas have expanded, but this alone cannot prevent biodiversity loss *(well established)* {4.5.4}.

Despite the development of more sustainable agricultural policies and practices in recent years in some countries, such as organic farming, conventional intensive agriculture, especially related to the excessive use of agrochemicals {4.5.1.1} reduces natural and semi-natural habitats, with severe negative impacts on biodiversity and ecosystem function *(well established)* {4.5.1, 4.5.2, 4.5.5}. This jeopardizes the sustainable management of land and food production *(established but incomplete)* **(Figure SPM.8)** {4.5.1, 4.5.2}. Agri-environmental schemes, ecological restoration and sustainable approaches to agriculture, such as agroecology and agroforestry, mitigate some of the adverse effects of intensive agriculture *(established but incomplete)* {4.5.1, 4.5.2}. The efficiency of such measures depends also on the inclusion of traditional and local knowledge, and the consideration of biophysical and social-cultural contexts *(established but incomplete)* {4.5.1, 4.5.2, 4.5.3}.

Production-based subsidies have driven growth in agriculture, forestry and natural resource extraction, but this often impinges on traditional land users *(established but incomplete)* {4.5.1, 4.5.5}. The loss of traditionally managed semi-natural habitats has resulted in a decline and loss of associated biodiversity and ecosystem functions. Demographic trends, including urbanization, continue to diminish indigenous and local communities, with concomitant negative impacts on traditional land-use knowledge, culture and identities *(established but incomplete)* (4.5.5). The economic viability of indigenous and local communities can be supported by green tourism, demand for products derived from traditional practices and subsidies for traditional land uses *(well established)* {4.5.5}.

There are examples of sustainable forestry and agroforestry practices, however, the major trend across the region

Figure SPM 7 **Trends in the proportion of key biodiversity areas completely covered by protected areas in Europe and Central Asia.**

There are two types of key biodiversity areas, Important Bird and Biodiversity Areas (IBAs) and Alliance for Zero Extinctions sites (AZEs).

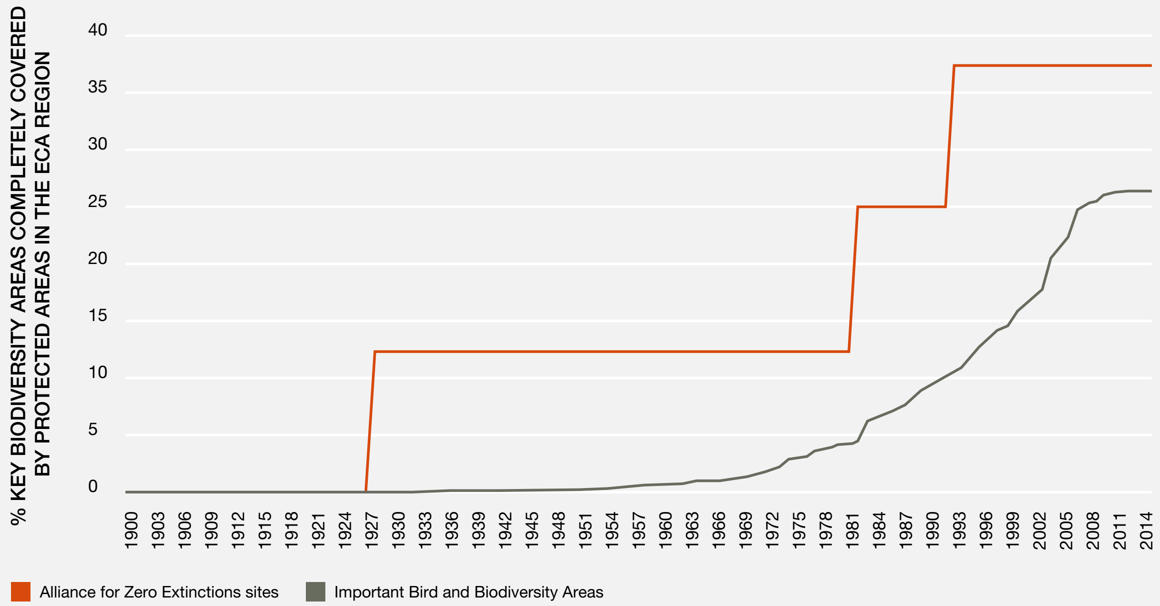
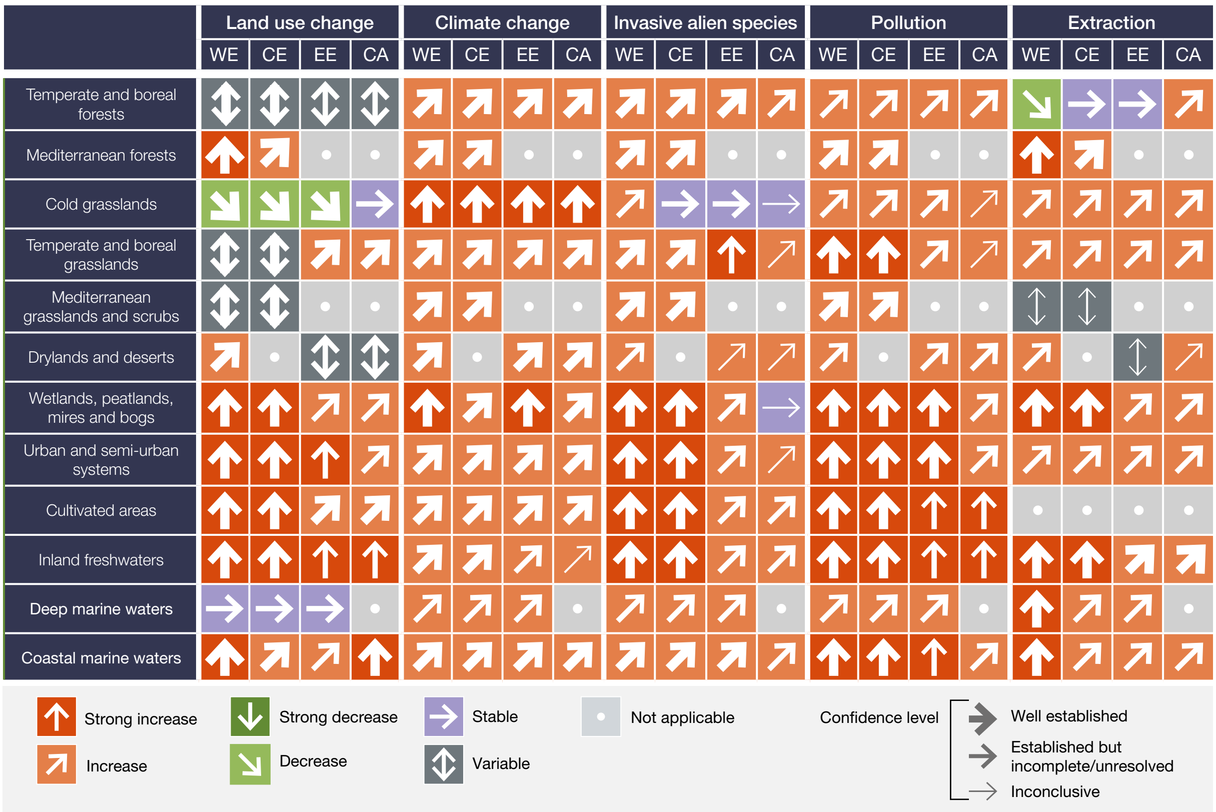


Figure SPM 8 **Trends in direct drivers of biodiversity and nature's contributions to people in the last 20 years.**

The figure summarizes the trends in the five direct drivers for each of the assessed units of analysis (habitat types). The trends are presented by unit of analysis and subregion {see 4.2.1, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9.2}. *Abbreviations:* WE = Western Europe, CE = Central Europe, EE = Eastern Europe, CA = Central Asia



is intensification of forest management that reduces biodiversity and many of nature's material and non-material contributions to people **(Figure SPM.8)**. Logging of intact forests continues across the region *(established but incomplete)* {4.5.3}. The trade-offs between the increasing intensity of forestry and delivery of multiple ecosystem services are recognized as a major challenge for forestry in Europe and Central Asia **(Table SPM.2)**.

Protected areas now cover 10.2 per cent of the region, 13.5 per cent of its terrestrial area and 5.2 per cent of its marine area *(well established)* {4.5.4} and their coverage of key biodiversity areas has been increasing **(Figure SPM.7)**. The prioritization and implementation of adequate legal frameworks for protected area development has largely been driven by the adoption of international agreements, as well as increasing public environmental awareness. The perceived trade-offs with economic development goals, however, have in many cases delayed the development of, or weakened, adequate nature conservation policies although this is variable across the region *(well established)*. The efficacy, connectivity and representativeness of protected areas are as important as their coverage, however, and conservation would also require fostering biodiversity outside protected areas *(well established)* {4.5.4, 3.3}. Eastern Europe and the Balkans have recently experienced armed conflicts, which negatively affect nature and its contributions to people {4.5.4.2}.

C2 The impact of climate change on biodiversity and nature's contributions to people is increasing rapidly and is likely to be among the most important drivers in the future, in particular in combination with other drivers *(established but incomplete)* {4.7.1, 4.7.2, 4.9.2}.

The region's climate is expected to be on average 1°C –3°C warmer in 2041–2060 than in 1986–2005, with larger increases in the north of the region *(well established)* {4.7.2.1}. Summers will be drier in the south of the region and winters wetter in the north, with increasing risks of extreme climatic events such as droughts and storms *(established but incomplete)* {4.7.1.2} **(Figure SPM.8)**. Indirect climate change effects, such as increased fire and flood risks and loss of permafrost, are already affecting biodiversity and nature's contributions to people *(well established)* {4.7.1.3, 4.7.2.5}. The extent of near-surface permafrost at high latitudes could decrease by between 37 and 81 per cent by 2100 *(established but incomplete)* {4.7.2.4}. In Arctic and alpine regions, permafrost melting will cause large greenhouse gas emissions, while short-term heat waves reduce biomass productivity and food availability for wildlife and livestock *(unresolved)* {4.7.1}.

Climate change shifts seasonal timing, growth and productivity, species ranges and habitat location, which affects biodiversity, agriculture, forestry, and fisheries *(well established)* {4.7.1.1, 4.7.1.3}. Many species will not migrate or adapt fast enough to keep pace with projected rates of climate change *(established but incomplete)* {4.7.1}. Droughts decrease biomass productivity, increase biodiversity loss and net carbon flux to the atmosphere, and decrease water quality in aquatic systems *(established but incomplete)* {4.7.1.2, 5.2}. Climate change causes ocean acidification, rising sea levels and changes ocean stratification, reducing biodiversity, growth and productivity, impairing fisheries and increasing CO_2 release into the atmosphere *(established but incomplete)* {4.7.1.1, 4.7.1.3}.

Global economic growth is the main indirect driver of greenhouse gas emissions and hence climate change *(well established)* {4.7.3}. In contrast to global trends, primary energy consumption and fossil CO_2 emissions within the region have declined since 1990. Small increases in GDP growth with simultaneously decreasing energy production and CO_2 emissions from 2011 to 2014 suggest the decoupling of CO_2 emissions from GDP growth *(well established)* {4.7.3}. These apparent decreases may be explained, however, by increased transportation-related emissions in other regions and their inter-regional flows to Europe and Central Asia *(inconclusive)* {4.7.3} **(Table SPM.2)**.

C3 Natural resource extraction, pollution and invasive alien species continue to reduce biodiversity and nature's contributions to people, and they increase with GDP and global trade. Recent policy intervention has reversed some negative impacts of these direct drivers.

Extraction of biotic and abiotic natural resources has continued to reduce biodiversity and nature's contribution to people both within Europe and Central Asia and beyond. For biotic resources, the demand for fish in Western and Central Europe, coupled with the European Union Common Fisheries Policy that restricts extraction, contributes to unsustainable fishing practices and resource depletion outside Western and Central Europe. While awareness of local resource shortages, such as fish in Europe, would be expected to be prompted by price increases, displacement from interregional imports masks these feedbacks *(established but incomplete)* {4.2.5, 4.3.1, 4.4.1}.

As an example for abiotic resources, trade liberalization and increasing world market prices have increased extraction of mineral resources in Central Asia. Although this has resulted in the mining industry being one of the largest contributors to GDP in the subregion, this has led to the depletion of mineral resources and the loss of ecosystem services important to human health and well-being *(well established)* {4.4.4.2}.

These examples demonstrate that the depletion of natural resources may not be immediately apparent, due to factors

Table SPM 2 **Impact of indirect drivers (rows) on direct drivers (columns) of biodiversity loss and nature's contributions to people in Europe and Central Asia.**

The colour shows the impact of an indirect driver on a direct driver's effect on biodiversity and nature's contributions to people along a gradient from negative to positive effects. *Abbreviations:* WE = Western Europe, CE = Central Europe, EE = Eastern Europe, CA = Central Asia

	LAND USE CHANGE															
	Agricultural land use				Forestry				Traditional land use				Protected area development			
	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
INSTITUTIONAL	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	~	~	✓	✓	~	~
ECONOMIC	~	~	~	~	✗	~	✗	~	✓	✓	✗	✗			✗	✗
DEMOGRAPHIC			~	~					✗	✗	✗	✗				
CULTURAL	✓	~	✗	✗	✓	✓	✓	✗	~	~	~	~	✓	✓	✗	✗
TECHNOLOGICAL	~	~	~	~												

	Climate change				Pollution				Natural resource extraction				Invasive alien species			
	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
INSTITUTIONAL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✗	✓	✓	~	~
ECONOMIC	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗		✗	✗	✗	✗	✗
DEMOGRAPHIC					✗	✗	✗	✗	✗	✗	✗	✗				
CULTURAL					~	~	~	~	~	~	~	~	✗	✗	✗	✗
TECHNOLOGICAL	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗				

✗ Negative ~ Both ways ✓ Positive (blank) Lack of evidence

such as global trade, which then masks or delays effective policy responses. In addition, harmful subsidies in the fishing and mineral industries reduce extraction prices and accelerate extraction levels despite declining stocks *(well established)* {4.4.1, 4.4.4}. The European Union and the Russian Federation continue to pay in total about $6 billion annually in such fishing subsidies *(well established)* {4.4.1.3}.

Recent regulations have reduced some pollution (for example, sulphur oxides, nitrogen oxides and heavy metals), but other pollution (ammonia, organic pollution and pesticides) and time-lag effects of pollution still threaten biodiversity. In Western and Central Europe terrestrial acidification has decreased since 1990 (from 30 per cent to 3 per cent of areas exceeding critical loads, while terrestrial eutrophication has decreased from 78 per cent to 55 per cent of areas exceeding critical loads *(well established)* {4.6.1, 4.6.3}. Marine and coastal eutrophication has decreased, but the proportion of marine dead zones due to oxygen depletion from nutrient and organic pollutants has increased markedly, reaching, for example, about 100 sites around Western European shores alone *(established but incomplete)* {4.6.1, 4.6.2}. Numbers of invasive alien species have increased for all taxonomic groups *(well established)* {4.8.2.1}. In Western and Central Europe, invasive alien species are increasing, although the recently adopted European Union regulation on invasive alien species could curb the trend in the future {4.8.2, 4.8.3}. In Eastern Europe and Central Asia, rates of invasion are lower than in Western and Central Europe, but are expected to increase with increasing GDP and trade *(established but incomplete)* {4.8.1, 4.8.2} **(Table SPM.2)**. As direct drivers can have chronic, prolonged and delayed consequences for biodiversity and ecosystem services, owing to time lags in ecosystem response *(well established)* {4.5.1, 4.9.1}, phosphorous and nitrogen (except ammonia) pollution is decreasing but, owing to time lags, many lakes, rivers and coastal areas in Western and Central Europe still do not have a good ecological status {4.6.1, 4.6.2}. Time lags also occur between the initial introduction of invasive alien species and their impact *(well established)* {4.8.1}.

C4 Economic growth is generally not decoupled from environmental degradation. This decoupling would require a transformation in policies and tax reforms across the region *(established but incomplete)* {4.3.1, 4.3.2, 4.3.4}.

There is evidence of growth in GDP across Europe and Central Asia *(well established)*. For example, since 2000, gross domestic material consumption has increased across European Union member States, much of which has been driven by growth-oriented policies *(well established)* {4.3.2}. However, this economic growth has indirectly reinforced drivers of biodiversity loss, which in turn has reduced nature's contributions to people. Such drivers have included land-use change, climate change, natural resource extraction, pollution and invasive alien species **(Table SPM.2)**.

Awareness of sustainability challenges has led to some institutional change in the region, including policies on climate agreements and a range of environmental policies. Furthermore, recent policy initiatives have suggested a focus on decoupling economic growth from environmental degradation {4.3.2, 4.3.4}. This decoupling would require a transformation in policies and tax reforms at the global and national levels. Across the region, a range of policies for resource efficiency, including environmental taxation, have been implemented. The total revenue from environmental taxes in the European Union has declined from 6.8 per cent of the total revenues derived from all taxes and social contributions in 2002 down to 6.3 per cent in 2016 *(well established)* {4.3.1, 4.3.2}. Furthermore, there still exist policy instruments, such as harmful agricultural and fishing subsidies, which continue to impede transitions towards a sustainable future *(established but incomplete)*. Decoupling would be assisted by new indicators that incorporate well-being, environmental quality, employment and equity, biodiversity conservation and nature's ability to contribute to people.

D. Futures for Europe and Central Asia

D1 Scenario studies for Europe and Central Asia, with time horizons up to 2100, show trade-offs between different ecosystem services with implications for biodiversity (Box SPM.3, Figure SPM.9) {2.2.6, 3.5, 5.3.3, 5.3.4}. Political and societal value judgements embedded within scenarios will determine how these trade-offs are resolved. Scenarios that assume proactive, environmental decision-making; promote environmental management approaches that support multifunctionality; and mainstream environmental issues across sectors, can mitigate undesirable trade-offs *(established but incomplete)* {5.3.3}. Moreover, scenarios that assume cooperation between countries or regions are more effective in mitigating negative impacts across geographic scales *(established but incomplete)* {5.3.3}. Such scenarios project more positive impacts across a broad range of indicators of biodiversity, nature's contributions to people and good quality of life than others *(established but incomplete)* {5.3.3, 5.6.1}.

Scenario studies (see **Box SPM.3** on scenario archetypes) suggest that reactive approaches to environmental issues will have mixed impacts. *Economic optimism* scenarios

Box SPM 3 **Scenario archetypes.**

The scenario and modelling studies in the literature {5.2.3, 5.3.3.} were mapped to six existing scenario archetypes {5.2.2; Box 5.3}, which represent diverse plausible futures for Europe and Central Asia:

- *Business-as-usual* assumes the continuation of past and current trends in indirect and direct drivers.
- *Economic optimism* assumes global developments steered by economic growth, resulting in a strong dominance of international markets with a small degree of regulation.
- *Regional*[10] *competition* assumes an increasingly fragmented world with a growing gap between rich and poor; increasing problems with crime, violence and terrorism; and strong trade barriers.
- *Regional*[10] *sustainability* assumes a shift towards local and regional decision-making that is strongly influenced by environmentally aware citizens. A proactive attitude to environmental management prevails, but poor international collaboration obstructs coordination to solve global environmental issues.
- *Global sustainable development* assumes an increasingly proactive attitude by policymakers and the public towards environmental issues, a high level of international cooperation and strong regulation.
- *Inequality* assumes increasing economic, political and social inequalities with power concentrated in a relatively small political and business elite who invest in green technology.

Each scenario archetype consists of different assumptions about future changes in direct and indirect drivers as shown in **Table SPM.3**.

Table SPM 3 Trends in indirect and direct drivers assumed in six scenario archetypes covering time horizons up to 2100.

Arrows in the table represent the expert interpretation of the magnitude of trends in drivers across all scenarios found within the archetypes. Colour coding represents the expert interpretation of the impact of the trend on biodiversity and nature's contributions to people {5.2.3}.

Scenario archetype	INDIRECT DRIVERS					DIRECT DRIVERS				
	INSTITUTIONAL (Environmental proactivity)	ECONOMIC (Gross domestic product)	DEMOGRAPHIC (Population)	CULTURAL (Sustainable consumption)	TECHNOLOGY	CLIMATE CHANGE (Temperature)	LAND USE CHANGE (Landscape homogeneity)	NATURAL RESOURCE EXTRACTION	POLLUTION	INVASIVE ALIEN SPECIES
Business-as-usual	↗ (Positive) ↘ (Negative)	↗ (Not interpreted)	↗ (Not interpreted)	↘ (Negative)	↗ (Positive) ↗ (Negative)	↗ (Negative)	↗ (Not interpreted)	↗ (Negative)	↗ (Negative)	↗ (Negative)
Economic optimism	↘ (Negative)	↑ (Not interpreted)	↑ (Not interpreted)	↘ (Negative)	↑ (Positive) ↑ (Negative)	↑ (Negative)	↗ (Not interpreted)	↑ (Negative)	↗ (Negative)	↗ (Negative)
Regional competition	↘ (Negative)	→ (Not interpreted)	→ (Not interpreted)	→ (Neutral)	↓ (Negative)	↗ (Negative)	↗ (Not interpreted)	↗ (Negative)	↗ (Negative)	↗ (Negative)
Regional sustainability	↗ (Positive)	↗ (Not interpreted)	↗ (Not interpreted)	↗ (Positive)	→ (Neutral)	↗ (Negative)	↘ (Not interpreted)	↘ (Positive)	→ (Neutral)	↘ (Positive)
Global sustainable development	↗ (Positive)	↗ (Not interpreted)	→ (Not interpreted)	↗ (Positive)	↑ (Positive)	↗ (Negative)	↗ (Not interpreted)	↘ (Positive)	↘ (Positive)	↘ (Positive)
Inequality	↘ (Negative)	↗ (Not interpreted)	↘ (Not interpreted)	→ (Neutral)	→ (Neutral)	↗ (Negative)		↗ (Negative)		

↑ Strong increase ↗ Increase → Stable ↘ Decrease ↓ Strong decrease

Positive Neutral Negative Not interpreted in terms of impacts Lack of evidence

generally lead to declines in biodiversity and regulating ecosystem services, but to increases in provisioning ecosystem services *(established but incomplete)* {5.3.3, 5.6.1}. *Regional competition* scenarios lead to the most negative impacts, particularly for non-material nature's contributions to people and indicators of good quality of life *(established but incomplete)* {5.3.3, 5.6.1}. In both types of scenarios, development is driven by economic growth, leading to strong positive effects for nature's contributions to people with market values and negative effects for contributions without market values *(established but incomplete)* {5.3.3, 5.6.1}. For example, scenarios for Western and Central Europe, which prioritize increases in food provision through agricultural expansion or intensification, lead to trade-offs with regulating contributions to people and biodiversity. Likewise, scenarios for Eastern Europe that focus on timber extraction lead to highly managed forests with decreased climate regulation and value for cultural or recreational purposes.

Sustainability-focused scenarios (e.g., *global sustainable development* or *regional sustainability*) assume a proactive approach to environmental issues that anticipates change and thereby minimizes adverse impacts and capitalizes on opportunities {5.1.1}. Such scenarios cause increases in most of nature's contributions to people and good quality of life, but have mixed biodiversity trends *(established but incomplete)* {5.3.3, 5.6.1}. Trade-offs occur in these scenarios, especially involving land and water use (such as the effects of reduced agricultural intensity or of increases in bioenergy cropland, on other land uses and biodiversity) {5.3.3, 5.6.1}.

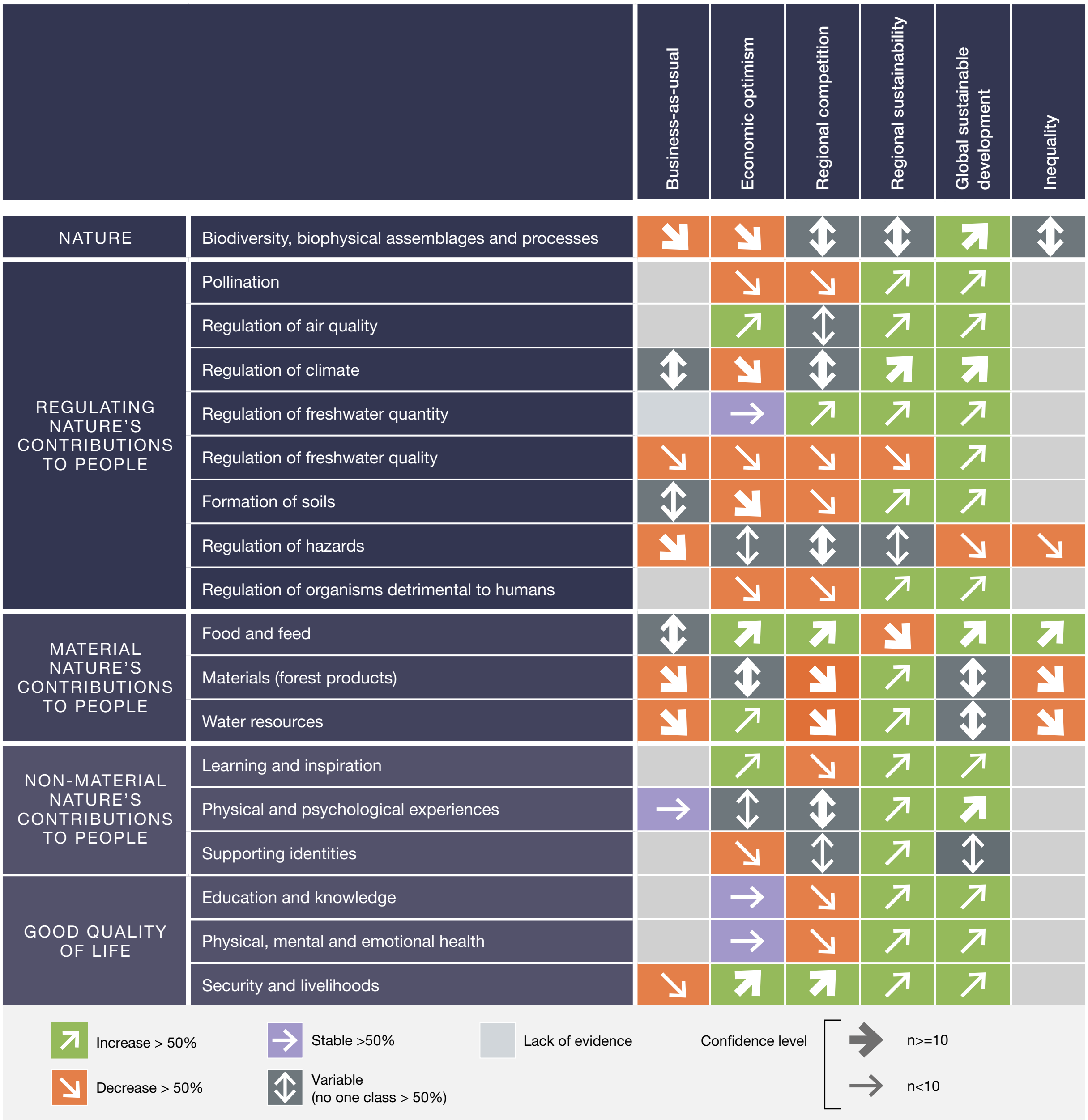
Impacts under *business-as-usual* scenarios are highly variable regionally. In general, the impacts on biodiversity, nature's contributions to people and good quality of life are more positive than for *economic optimism* and *regional competition*, but more negative than for *regional sustainability* and *global sustainable development* *(established but incomplete)* {5.3.3, 5.6.1}.

Scenarios considering climate change indicate increases in agricultural production for food, feed and bioenergy in the northern part of the European Union, but decreases in agricultural and timber production in the southern part **(Figure SPM.10)**. Major water shortages are projected in the

10. Here the term "regional" is not meant to denote "IPBES regions", but reflects a more general meaning across the assessed literature, where it is used with reference to subnational, national or larger areas.

Figure SPM 9 **Projected future impacts on biodiversity, nature's contributions to people and good quality of life according to six scenario archetypes for Europe and Central Asia up to 2100 (see Box SPM.3 for details of the scenario archetypes) {2.2.6, 3.5, 5.3.3}.**

Green symbols with upward arrow indicate an increase, purple symbols with horizontal arrow a stable trend, and orange symbols with downward arrow a decrease. Thick arrows indicate evidence from the literature based on ten or more model indicators per scenario archetype, thin arrows indicate evidence based on fewer than ten.

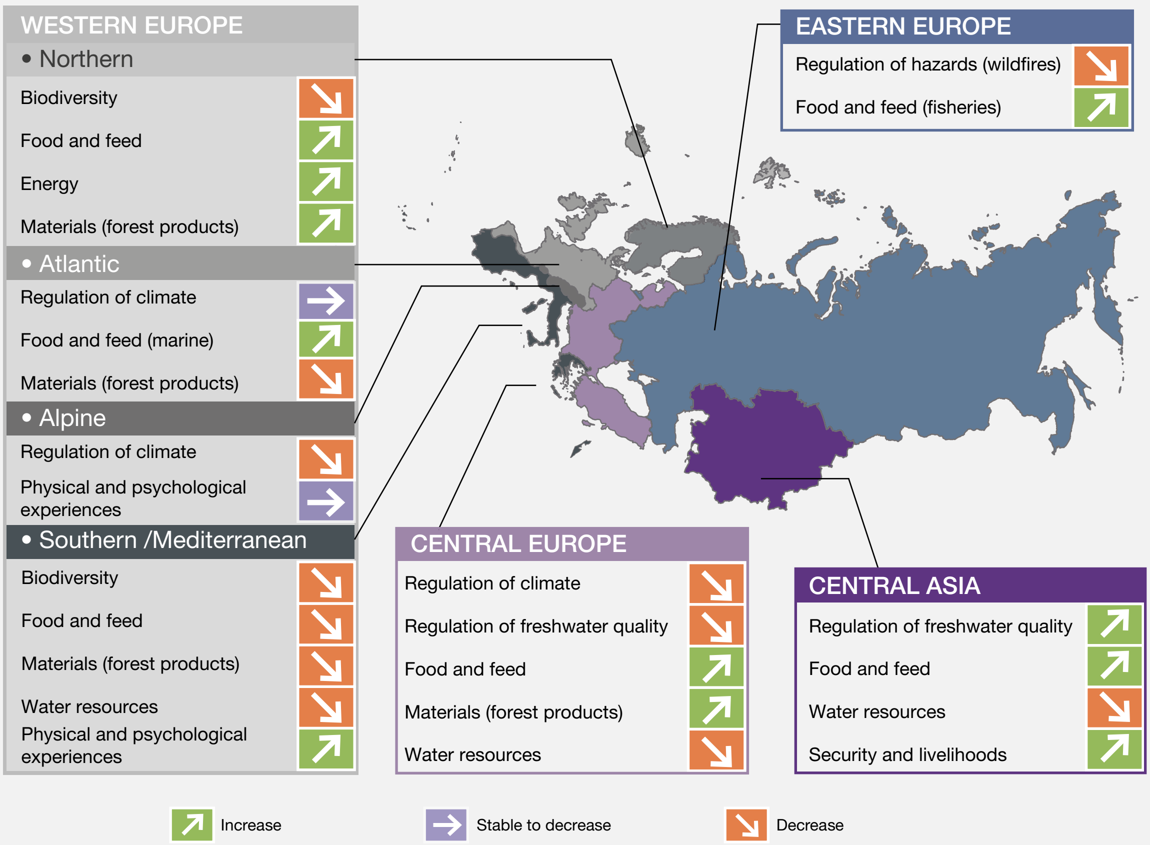


long term for Central Asia, parts of Central Europe, and the Mediterranean, leading to key trade-offs for water use and management in different sectors, including the maintenance of environmental flows *(established but incomplete)* {5.3.3}.

Trade-offs depend on scenario assumptions about lifestyle and consumption, which affect the demand for nature's contributions to people, and policies affecting the management and governance of resources. For example, *global sustainable development* scenarios assume changes in dietary preferences towards reducing meat consumption, behavioural changes to save water and energy, and the implementation of integrated and sustainable land and water management practices. These lead to positive outcomes for biodiversity, nature's contributions to people and good quality of life. Scenarios that assume strong international or

Figure SPM 10 **Trends in impacts on biodiversity, nature's contributions to people and good quality of life indicators that are consistent across most scenario archetypes (see Box SPM.3 for details of the scenario archetypes) {5.3.3}.**

The Western European region has been divided into four parts (northern, Atlantic, Alpine and southern), in view of the greater number of available studies.



transboundary coordination of adaptive measures between multiple stakeholders lead to more sustainable solutions across scales and regions. Scenario assumptions in *inequality* scenarios also affect how different social groups appropriate nature's contributions to people *(established but incomplete)* {5.2.3, 5.3.3}.

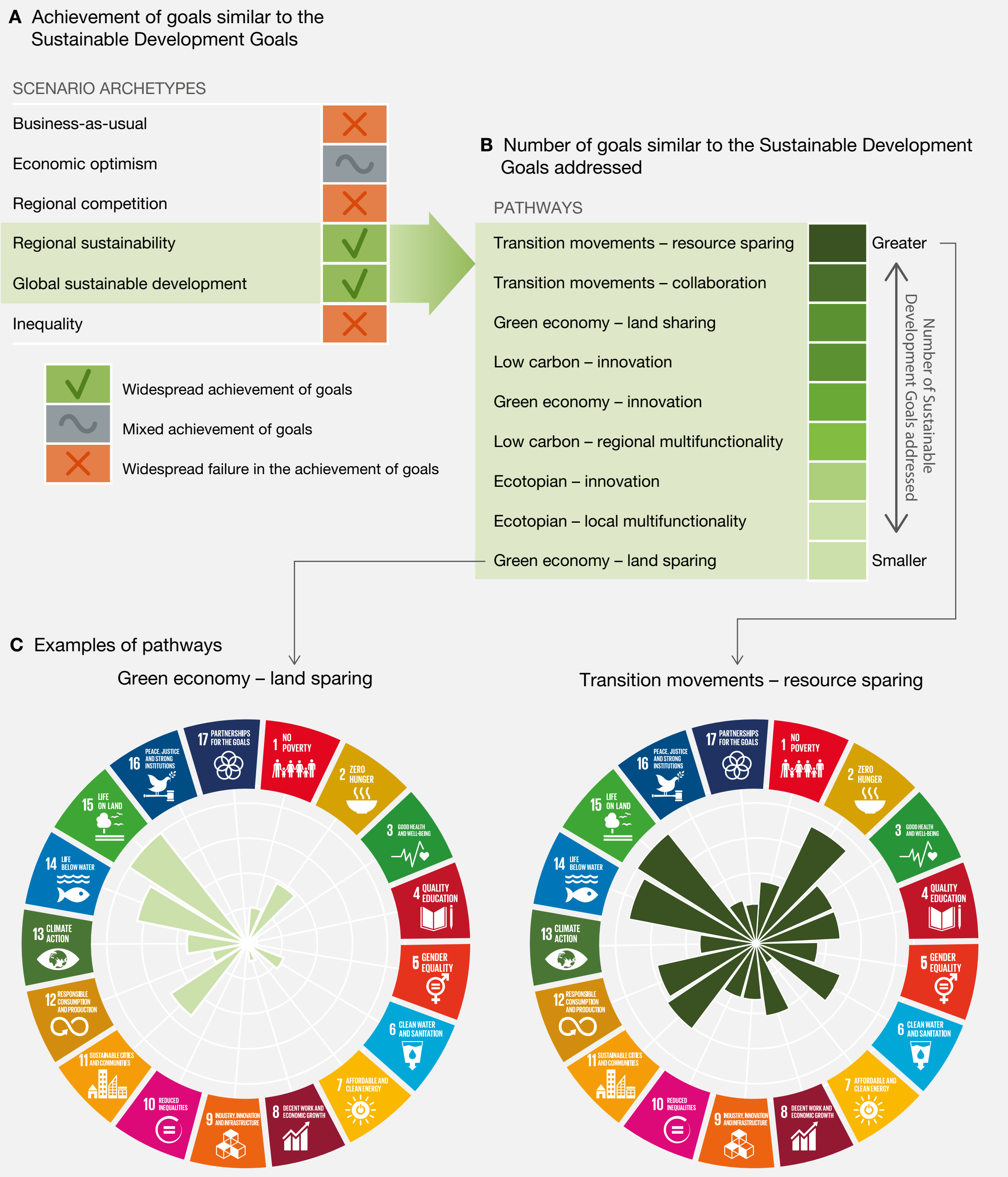
D2 Future impacts on biodiversity and nature's contributions to people are underestimated because most scenarios consider only a few drivers, notably climate change *(well established)* {5.2.2, 5.3.2}. Single-driver scenarios also fail to capture driver interactions *(well established)* {5.2.2, 5.3.2}. Single-driver and single-sector approaches are likely to misrepresent the direction, magnitude or spatial pattern of impacts on biodiversity and nature's contributions to people, leading to poor management or policy decisions *(established but incomplete)* {5.3.1}.

Many scenarios consider climate change as a single driver *(well established)*. The few multi-driver scenarios are largely based on the Special Report on Emissions Scenarios of the Intergovernmental Panel on Climate Change and, hence, focus on long-term climate change issues (to 2100). Pollution and invasive alien species are poorly represented in scenarios *(well established)* {5.2.2}. Land-use change is rarely considered as a direct driver of biodiversity and nature's contributions to people because land-use change scenarios focus more on the effects of indirect drivers (e.g., policy, social preferences and economics) on land use per se *(established but incomplete)* {5.2.1}. There are fewer scenarios of future land-use change impacts on biodiversity and nature's contributions to people than empirical studies of past trends *(established but incomplete).* Single-driver scenarios fail to capture feedbacks and synergies between and amongst indirect and direct drivers operating across different scales *(established but incomplete)* {5.3.4}. Integrated scenarios and models are explicit about nature and cover multiple drivers, sectors and scales. This enhances the understanding of complex interdependencies between human and environmental systems to support coordinated decision-making {5.2.2, 5.3.1}.

Figure SPM 11 **Summary of the extent to which goals similar to the Sustainable Development Goals are expected to be achieved under the scenario archetypes up to 2100 and pathways to sustainability up to 2050 for Europe and Central Asia {5.3.4, 5.5.4}.**

Part **A** shows that the scenario archetypes *regional sustainability* and *global sustainable development* project a widespread achievement of goals (see **Box SPM.3** for description of the scenario archetypes). Part **B** introduces pathways that support the achievement of goals albeit to a different extent. This is exemplified in part **C**, where the wedges indicate the extent to which the pathways address each goal (see D3 for description of the pathways).

A: orange = widespread failure in the achievement of goals; green = widespread achievement of goals; grey = mixed achievement of goals. **B**: darker shades of green indicate a greater number of goals are addressed by the pathways. **C**: two examples of pathways with smaller and greater number of goals addressed.



D3 Pathways propose coherent sets of actions towards the sustainable futures envisioned for the region *(established but incomplete)* {5.1.2, 5.4.3, 5.5.2}. The most effective pathways stress longterm societal transformation (behavioural change) through education, knowledge sharing and participatory decision-making. These pathways emphasize nature's regulating contributions to people and the importance of considering diverse values *(established but incomplete)* {5.5.2, 5.5.3, 5.5.4}.

Four types of pathways are specified. Two types of pathways do not challenge the economic growth paradigm *(green economy* and *low carbon transformation* pathways). They include actions related to technological innovation, land sparing or land sharing, and focus on combinations of top-down legal and regulatory instruments and economic and financial instruments. These pathways do not fully mitigate trade-offs and may not be able to achieve sustainable futures *(established but incomplete)* {5.5.2, 5.5.4, 5.6.1}. The third type of pathways focus on radical social innovation to achieve local food and energy selfsufficiency and local supply of nature's contributions to people *(ecotopian solutions).* They emphasize local multifunctionality, green infrastructure, urban design and food production *(established but incomplete)* {5.5.2, 5.5.4, 5.6.1}. The fourth type of pathways emphasize a change towards diverse values, promoting resource-sparing lifestyles, continuous education and innovative forms of agriculture where different knowledge systems combine with technological innovation *(transition movements).* They achieve transformation using social and information-based policy instruments focusing on participatory processes, community actions and voluntary agreements. Rights-based instruments and customary norms, including indigenous and local knowledge, are used in combination with legal, regulatory and economic instruments *(established but incomplete)* {5.5.3, 5.6.1}. Actions proposed in all of the pathways can be combined. For example, short-term, incremental actions in *green economy* and *low carbon transformation* pathways may pave the way for more transformative *transition movements* pathways *(established but incomplete)* {5.5.4}. Despite distinct differences, all pathways stress some of the governance options highlighted in section E, including mainstreaming, integrated approaches that cut across sectoral boundaries, awareness-raising tools, education and participation to facilitate multi-actor governance *(established but incomplete)* {5.5.3}.

Box SPM 4 Evidence from this regional assessment for Europe and Central Asia relevant in the context of the Aichi Biodiversity Targets and the Sustainable Development Goals.

The Strategic Plan for Biodiversity 2011–2020, including its 20 Aichi Biodiversity Targets under five Strategic Goals, provides a framework for the United Nations system, including national Governments and others, for management and policy development on biodiversity. The 2030 Agenda for Sustainable Development, with its 17 Sustainable Development Goals, sets out the broader strategy towards global sustainability for the United Nations. This assessment summarizes the progress that the literature has reported towards these goals, as far as they pertain to the region and as far as there is sufficient evidence.

Evidence relevant in the context of the Aichi Biodiversity Targets

Evidence suggests progress in addressing the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society (Strategic Goal A) *(established but incomplete)*, although subsidies with negative impacts have not yet been reformed *(well established)*. Public awareness about the importance of biodiversity and ecosystem services (Aichi Biodiversity Target 1) appears to be increasing. Progress has also been reported in integrating biodiversity and ecosystem services into planning processes and national accounting in Western and Central Europe (Target 2) *(established but incomplete)* {6.6.2}. Substantial reforms could reduce the negative impacts of subsidies **(Table SPM.4)** {4.4.1}. Increasing positive incentives for conservation could also improve progress towards Target 3 (harmful incentives eliminated, positive incentives developed and applied) **(Table SPM.4)** {6.2, 6.4.1}. Several countries have implemented ecological fiscal reforms, with mixed results *(established but incomplete)* {6.2, 6.4.1, 6.4.2}, but some policy instruments continue to have negative environmental impacts *(well established)* {4.3.1}. Without complementary strategies for reducing the impacts of consumption and production, more efficient resource use alone is unlikely to render current production and consumption patterns sustainable (Target 4 - sustainable consumption and production) **(Table SPM.4)** {6.5.4, 6.6.2, 6.6.3.2}.

Pressure from direct drivers on biodiversity is unlikely to be reduced *(established but incomplete)* and the use of biodiversity is not yet sustainable *(well established)* (Strategic Goal B). The evidence base in Europe and Central Asia related to the global Aichi Biodiversity Target 5 (habitat loss halved or brought close to zero) shows negative trends in biodiversity in agricultural areas {3.3.2.9}, important ecosystems such as seagrass beds {3.3.4}, and many fish stocks {4.4.1}*(established but incomplete).* Target 5 (habitat loss halved or brought close to zero) could, however, be achieved for terrestrial biodiversity in all subregions through, inter alia, effective and representative protected areas (see Target 11), mainstreaming biodiversity considerations into and across all sectors and policies and integrated conservation management *(established but incomplete).* Contributions toward Targets 6 (sustainable management of marine living resources) and 10 (pressures on vulnerable ecosystems reduced) for the deep-sea are hampered by increased habitat degradation, and declines in biodiversity and ecosystem functioning. More effective fisheries management and increasing protected areas could improve this situation *(well established)* {3.3.4, 6.5.3}. Current trends in freshwater and terrestrial biodiversity suggest that it is highly unlikely that Europe and Central Asia will be able to fully contribute to Targets 7 (sustainable agriculture, aquaculture and forestry), 8 (pollution reduced) and 9 (invasive alien species prevented and controlled) *(well established)* {3.4.3}.

Progress has been made toward improving the status of biodiversity by safeguarding ecosystems, species and genetic diversity (Strategic Goal C) through protected areas *(well established).* The extinction risk of domestic breeds is increasing and the genetic diversity of cultivated plants is decreasing, in spite of measures to counter this *(well established)*. Overall trends in biodiversity are still negative, however. Europe and Central Asia appears to achieve protected area coverage of 17 per cent of its terrestrial surface (Target 11) {3.2.9}, notwithstanding great variability in the level of protection. The European Union already protects about 25 per cent of its terrestrial surface. There has been a general increase in the number and extent of marine protected areas in the region. In 2017, 15 countries protected more than 10 per cent of their marine waters, and 12 per cent of the Baltic Sea area is protected *(well established)* {3.3.4.7}. Other marine systems, especially those further from the coast, are less protected *(well established).* The ecological representativeness, connectivity and management of protected areas have improved, but most still lack management measures to protect biodiversity, such as no-take zones *(well established)* {3.3.4}. In spite of some progress, current trends in biodiversity make it highly unlikely that the region will be able to contribute fully to achieving Targets 10, 11 and 12 (extinction prevented) {3.4, 3.5}. Downward trends in the Red List Index (increasing aggregate extinction risk) and Living Planet Index (decreasing population trends) also indicate that Europe and Central Asia will not be able to fully contribute to meeting Target 12. Europe and Central Asia are contributing to Target 13 (genetic diversity maintained) through the development of safeguards for rare domestic breeds and germplasms of cultivated plants. The extinction risk of domestic animal breeds is increasing, however, and there is evidence of the genetic erosion of cultivated plants under modern production systems *(established but incomplete)*.

The Europe and Central Asia region has not advanced in enhancing the benefits to all people from biodiversity and ecosystem services (Strategic Goal D), as a consequence of the deterioration of nature's capacity to provide certain contributions to people *(well established)* {2.2.5} and the unequal distribution of nature's contributions *(established but incomplete)* {2.3.4}. Owing to biodiversity trends in freshwater, marine and terrestrial ecosystems, it is highly unlikely that Europe and Central Asia will fully contribute to achieving Target 14 (ecosystems and essential services safeguarded) {3.3} **(Figure SPM.6)**. Progress is being made towards contributing to Target 16 (Nagoya Protocol in force and operational). By 2014, when the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity entered into force, eight parties to the Protocol (15 per cent) in Europe and Central Asia had ratified the Protocol, while by 2017, the number had grown to 25 (46 per cent), including the European Union {6.4.1}.

Enhanced implementation through participatory planning, knowledge management and capacity-building (Strategic Goal E) has been positive where the Aichi Biodiversity Targets have informed the development of national-level targets. This has not been achieved, however, where indigenous and local knowledge and practices have declined or not been fully respected in relation to traditional land use *(well established)*. The Aichi Biodiversity Targets have been translated into national-level targets in all but 13 countries in the region. This suggests progress towards Target 17 (national biodiversity strategies and action plans adopted as policy instruments) {6.4.1}. The practices and knowledge of indigenous peoples and local communities in Western and Central Europe have continued to decline since the 1960s and have often not been fully respected or even marginalized, in contrast to Target 18 (traditional knowledge respected) *(well established)*. Evidence suggests that the further mobilization of financial resources (Target 20) is key for increasing the success of policy to achieve biodiversity conservation objectives *(well established)* {6.3.2, 6.3.3, 6.4.1, 6.5.4, 6.6.2, 6.6.4}.

Evidence relevant in the context of the Sustainable Development Goals

Progress in contributing towards achieving the Sustainable Development Goals has generally been positive in Europe and Central Asia in terms of environmental protection, human health, food security and water security (particularly in Europe) {2.3.1, 2.3.2} *(well established).* Nature offers various contributions to good quality of life, supporting the achievement of Goal 3 (good health and well-being) *(well established)* {2.3.2}. Conversely, the consumption of natural resources in Western Europe has increased large-scale land acquisition in other parts of the world, including Eastern Europe and Central Asia *(established but incomplete)* {2.2.4, 2.3.1.1}. This may contribute to not achieving Goal 2 (zero hunger), Goal 7 (affordable and clean energy) and Goal 12 (responsible consumption and production). The erosion of indigenous and local knowledge and the associated decline in sustainable traditional land use threatens the region's contribution to accomplishing Goal 2 and Goal 4 (quality education) *(established but incomplete)* {2.2.3.1.2}. Future climate and land-use change will decrease water security (Goal 6 - clean water and sanitation), with the number of water-stressed countries in Europe and Central Asia expected to increase by 2030 *(well established)* {2.3.1.2}. Some advances have been made towards accomplishing environmental protection goals (Goals 14 – life below water and 15 – life on land), but the negative trend of biodiversity especially in agricultural areas currently restricts progress towards contributing to Goal 15 {3.3.2.9}. Despite some recent progress, the conservation of at least 10 per cent of coastal and marine areas by 2020, a target under Goal 14, has not been reached for all marine systems *(well established)*, although it has already been surpassed in some coastal areas of the North and Baltic Seas and by 15 countries *(well established)*.

Beyond the Aichi Biodiversity Targets and Sustainable Development Goals

Looking beyond the 2030 timescale of the Sustainable Development Goals up to 2100, scenario analysis highlights that the continuation of past and current trends in drivers (as represented in *business-as-usual* scenarios) will inhibit the region from contributing to the widespread achievement of goals similar to and including the Sustainable Development Goals. In contrast, scenarios which focus on achieving a balanced supply of nature's contributions to people and incorporate a diversity of values are more likely to contribute to achieving the majority of such goals *(established but incomplete)*. A continuation of the business-as-usual approach in Europe and Central Asia is expected to result in failure to contribute to achieving most of the Sustainable Development Goals (contribution to achieving 4 out of 17), and Aichi Biodiversity Targets (contribution to achieving 8 out of 20) *(established but incomplete)*. Scenarios of *economic optimism* are expected to enable the region to contribute to achieving 8 of the Goals, but only 4 of the 20 Targets. Scenarios of *regional competition* are expected to enable the region to contribute to achieving only two of the Goals and only one of the Targets *(established but incomplete)*. By contrast, scenarios of *sustainability* are expected to enable the region to contribute to achieving the majority of the Goals (14) and Targets (14) *(established but incomplete)* {5.4, 5.6.}. A more comprehensive visual summary is provided in **Figure SPM.11**.

E. Promising governance options for Europe and Central Asia

E1 Mainstreaming the conservation and sustainable use of biodiversity and the sustained provision of nature's contributions to people into policies, plans, programmes, strategies and practices of public and private actors could be achieved with more proactive, focused and goal-oriented environmental action, including quantitative goals *(well established)* {6.1, 6.3, 6.4, 6.5, 6.6; Figure 6.15}.

The conservation and sustainable use of biodiversity in the more than 80 per cent of landscapes and seascapes outside protected areas would benefit from embedding biodiversity considerations into policies, strategies and practices of public and private actors that impact or rely on biodiversity {Table 6.1; Figure 6.2, Figure 6.15}. These considerations are equally important inside protected areas. Although progress has been made towards mainstreaming by setting up, reviewing and updating biodiversity strategies and action plans at multiple levels, existing legislation in all economic sectors could be implemented more effectively {6.3, 6.4.1} **(Table SPM.4)**. Mainstreaming the conservation and sustainable use of biodiversity would benefit environmental policies {6.4.2}, economic sectors and business actors depending on, or influencing, biodiversity {6.4.1, 6.5, 6.6; Table 6.10} **(Table SPM.4)**. Opportunities to successfully mainstream biodiversity and nature's contributions to people, in public and private policy and decision-making **(Table SPM.4)** {6.6, 6.6.1; Figure 6.13}, could be harnessed by: first, raising awareness of the dependence of good quality of life on nature, enhancing capacity-building and strengthening participation of affected actors in decision processes; second, defining policy objectives concerning the ecological, economic and sociocultural needs for achieving sustainable living, taking account of the diverse values of nature for different stakeholder groups; and, third, designing instruments and policy mixes to support the implementation of effective, efficient and equitable policy and decision-making for nature and a good quality of life {6.6, 6.6.1}. Taking the European Union Common Agricultural Policy as an example, a number of factors would increase the effectiveness, efficiency and equity of related policy instruments. These factors include a better definition of clear and coherent objectives for the Common Agricultural Policy, simultaneously addressing multiple ecosystem services; a more defined focus on biodiversity conservation and the delivery of nature's contributions to people at the landscape level; a more explicit disclosure of trade-offs and synergies between different objectives; and more balanced and transparent funding between the production of agricultural commodities and the delivery of public goods {6.5.1.3}.

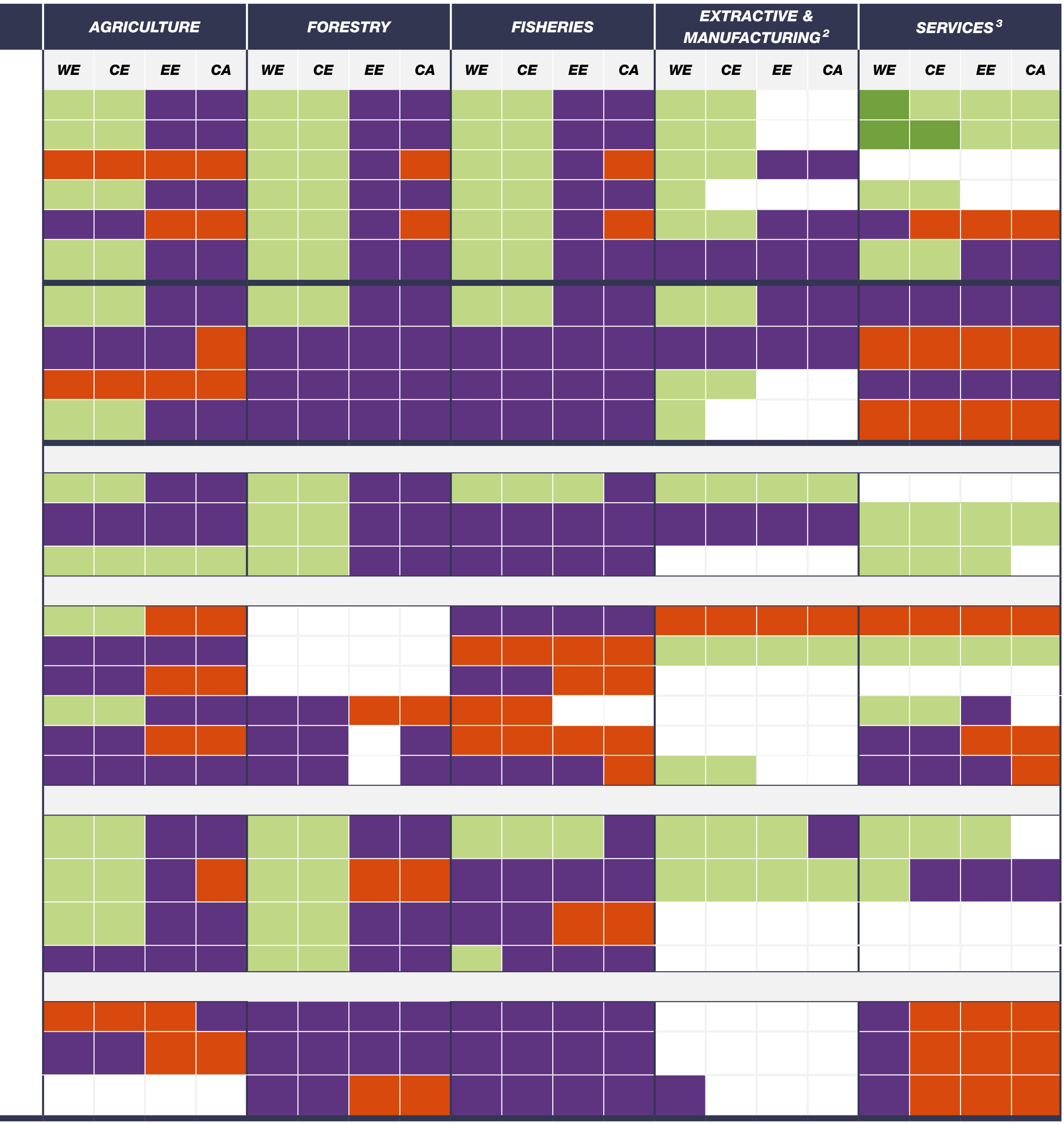
Table SPM 4 **Policy options and opportunities for mainstreaming the conservation and sustainable use of biodiversity and the sustained provision of nature's contributions to people in Europe and Central Asia.**

Building on three key steps of mainstreaming, options and opportunities for mainstreaming are provided for seven policy and economic sectors. The evidence shows that biodiversity and nature conservation will benefit from being mainstreamed in environmental policies and all economic sectors and their policies and that nature's contributions to people will benefit from being mainstreamed in all economic sectors, as well as the conservation sector. The table synthesizes those policy options and opportunities from the sectoral analyses in chapter 6 that are relevant to all sectors. It can be used by

	Sectors	*CONSERVATION*				*ENVIRONMENT*[1]			
STEPS	**OPTIONS AND OPPORTUNITIES** *Subregions*	*WE*	*CE*	*EE*	*CA*	*WE*	*CE*	*EE*	*CA*
STEP 1: Raising awareness	Encourage education, joint learning and common understanding								
	Promote information sharing, transparency, knowledge management and training								
	Make trade-offs and tipping points visible at the relevant spatial scales								
	Encourage participation and dialogue among different actors								
	Make diverse values visible through national and business accounting								
	Mainstream recognition of need for profound societal transformation towards sustainability								
STEP 2: Defining policy objectives	Adopt and translate international and regional targets and standards into national and local strategies and action plans								
	Improve integration and coherence of legislation, sectoral policies and planning processes, to account for trade-offs and synergies								
	Develop context appropriate targets and objectives to stimulate positive change								
	Increase transparency and participation of a wide range of actors including indigenous peoples and local communities in decision making								
STEP 3: Designing instruments and policy mixes	***Legal and regulatory instruments***								
	Define and ensure property and access rights and responsibility								
	Set up, adjust and enforce legal and regulatory standards to sustain biodiversity and nature's contributions to people								
	Set up areas to protect biodiversity and nature's contributions to people								
	Economic and financial instruments								
	Phase out harmful subsidies	NA	NA	NA	NA				
	Tax and charge negative environmental impacts	NA	NA	NA	NA				
	Redistribute public revenues considering ecological objectives								
	Reward socio-economic activities delivering public goods								
	Secure conservation financing					NA	NA	NA	NA
	Foster sustainable technological and social innovation								
	Social and information-based instruments								
	Promote eco-labelling and certification schemes and improve their transparency and accountability								
	Promote voluntary agreements and partnerships for responsible management, which include self-enforcement mechanisms								
	Promote sense of agency and efficacy through the enhancement of public participation								
	Support social norms that promote sustainable lifestyles and practices								
	Rights-based approaches and customary norms								
	Strengthen the use of indigenous and local knowledge and practices								
	Strengthen the consideration of cultural properties and heritage in protecting sites and landscapes					NA	NA	NA	NA
	Strengthen the use of Social License to Operate or similar approaches to recognize the needs of indigenous peoples and local communities								

1. Include the following policy areas: Marine and freshwater quality and quantity, flood management, air and wider environmental pollution (including eutrophication and acidification), waste management, mitigation of and adaptation to climate change, soil management and land degradation. Options and opportunities in rows left blank have been covered by the other sectors, also in relation to their environmental outcomes.
2. Include the following policy areas: Energy, mining, manufacturing.
3. Include the following policy areas: Health, education and research, transport, tourism, finance.

policymakers of the subregions as a checklist to identify potential for improvement and for new policy instruments not yet initiated within the subregion. Although they have scope for improvement, legal and regulatory instruments are the most widely applied policy instrument category in all sectors and subregions, emphasizing their role as the backbone of policy mixes. Social and information-based instruments have been partly implemented in some subregions. There is also considerable scope for new or improved economic and financial instruments. Rights-based approaches and customary norms are the least developed and applied instrument category, indicating knowledge gaps (see **Box SPM.5**) or possibly a lack of attention or even acknowledgement to indigenous and local knowledge and practices.



WE = WESTERN EUROPE **CE** = CENTRAL EUROPE **EE** = EASTERN EUROPE **CA** = CENTRAL ASIA

EFFECTIVELY IMPLEMENTED UNDER DEVELOPMENT OR STARTED NOT ASSESSED

IMPLEMENTED WITH SCOPE FOR IMPROVEMENT NOT YET INITIATED **NA** = NOT APPLICABLE

E2 Developing integrated approaches across sectors would enable more systematic consideration of biodiversity and nature's contributions to people by public and private decision makers *(well established)* {6.1, 6.2, 6.4, 6.5, 6.6, 6.6.4.1; Figure 6.2}. This includes further options to measure national welfare beyond current economic indicators, taking account of the diverse values of nature {6.6.3.1}. Ecological fiscal reforms would provide an integrated set of incentives to support the shift to sustainable development *(established but incomplete)* {4.3–4.8, 6.4.1, 6.4.2, 6.6.2}.

Conventional sectoral approaches are insufficient to tackle interlinked environmental, economic and social challenges. Actions in one sector may affect other sectors, because policy design, instrument choice, or policy implementation rarely consider trade-offs {6.2, 6.4.1, 6.4.2, 6.6, 6.6.4.1, 6.6.4.2; Box 6.1, Box 6.9}. Without coordination between, and sustainable management practices within, sectors, there is evidence that agriculture, forestry, fisheries, mining, energy, manufacturing and the services sector may exert negative impacts on biodiversity, on nature's contributions to people and on the livelihoods of indigenous peoples and local communities {4.2.2, 6.4.2, 6.5.1–6.5.5, 6.6.4.1; Table 6.6}. Taking individual sectors as an example, a mismatch has been detected between the low degree of forest sector integration with other policy sectors on the one hand, and on the other its high potential to contribute to policy integration {6.5.2.3}. While some instruments of the European Union Common Agricultural Policy support extensive management practices, others are less well suited to, or implemented by, particularly, Central European countries of the European Union, to support indigenous and local knowledge and practices of small and semi-subsistence farms in high nature value farmland {6.5.1.2}. With regard to economy-wide policy integration, reflecting the real changes in the diverse values of nature's contributions to people in national income accounts is one option to provide better information and help to mitigate trade-offs {6.6.3.1}. Another option would be complementing national income accounts with satellite accounts containing information on the costs of ecosystem degradation. Ecological fiscal reform that creates an integrated set of incentives by redirecting taxation from labour to environment, including ecological indicators in intergovernmental fiscal relations and by greening public expenditure programmes, could support the shift to sustainable development {6.4.1, 6.4.2, 6.6.2}. Designing, implementing and assessing instruments in relation to their role in the overall policy mix would help to mitigate conflicting policy goals and trade-offs {6.2, 6.4.1, 6.5.5, 6.6.1, 6.6.2, 6.6.4.1, 6.6.5.5; Box 6.1}. The use of proactive strategies, tools and methodologies to account for diverse values and criteria, and of participatory processes can support trade-off analyses and facilitate policy integration {6.4.1, 6.4.2, 6.6.4, 6.6.5}.

E3 Effective governance of biodiversity and nature's contributions to people would benefit from well-designed mixes of policy instruments, suited to the context *(well established)*. Legal and regulatory instruments are the backbone of policy mixes, and economic, financial, social and information-based instruments provide additional incentives for Governments, businesses, non-governmental organizations and citizens. Further efforts would help to develop better rights-based approaches {6.2, 6.3, 6.4, 6.5, 6.6; Figure 6.2; Boxes 6.2, 6.4} (Table SPM.4). A key factor constraining the effectiveness of existing policy mixes is limited enforcement owing, for example, to a lack of human resources, institutional capacity and financial means, or corruption *(well established)* {6.3.1, 6.4.1, 6.4.2}.

Where legal and regulatory instruments are concerned, the ratification and implementation of international treaties and transboundary agreements provide strong impetus for improving national and subnational policies in all sectors {6.3}. Marine protected areas, however, need more attention {4.5.4, 6.4.1}. For freshwater ecosystems, the European Union Water Framework Directive is of particular importance for achieving a good status for surface and groundwater {6.3.2.3, 6.4.2, 6.5.1, 6.5.2, 6.5.3, 6.5.4, 6.6.3, 6.6.5.5}, although integration and implementation of such novel governance approaches often remain incomplete, and ineffective when member States retain existing structures and procedures without transferring responsibilities and power to the river basin authorities {6.4.2}. Similar structures have been developed in non-European Union countries, such as Ukraine, which share river basins with European Union countries {6.4.2}. Targeted spatial and urban planning integrated across sectors and scales can support the conservation of biodiversity and nature's contributions to people, and enhance the quality of life of urban dwellers {6.6.4.2}.

Economic and financial instruments complement regulatory and other policy instruments by balancing conservation benefits and costs between actors and regions *(well established)* {5.5.3, 6.2, 6.3, 6.4, 6.5, 6.6}. Improving existing policies and developing and implementing new policies could help to avoid biodiversity loss and ecosystem degradation *(established but incomplete)* {6.2, 6.4.1, 6.4.2, 6.5, 6.6.2, 6.6.5.2; Tables 6.5, 6.6} **(Table SPM.4)**. Since markets undervalue nature's contributions to people, economic and financial instruments aim to change the behaviour of businesses, land users, citizens and public-sector actors, through incentives and disincentives to correct price signals. Environmental taxes, charges and fees make environmental pollution and habitat degradation more expensive, thereby making the polluter pay, whereas payments for ecosystem services or compensation payments reward conservation-friendly behaviour that is otherwise not profitable or affordable {6.4.1, 6.4.2, 6.6.5.2}. Reforming environmentally harmful subsidies in sectors that negatively affect ecosystems (e.g., agriculture, fisheries, energy) would support more cost-effective use of public funds in reaching conservation objectives. Innovative economic and financial instruments include biodiversity offsets and habitat banking, tax reliefs, ecological fiscal transfers and integrated funding for biodiversity and climate-change adaptation {5.5.3, 6.4.1, 6.4.2, 6.5.1–6.5.5, 6.6.2, 6.6.3.2, 6.6.5.2}. Economic and financial instruments are more effective if customized to relevant scales, from global to national and local conditions in achieving conservation targets, while considering social impacts {6.2, 6.4, 6.6.2, 6.6.5}.

Social and information-based policy instruments have the capacity to integrate environmental concerns and to trigger behavioural change at the local, national and international levels, and to include consumers and producers in policy development *(established but incomplete)* {6.2, 6.3, 6.4, 6.5, 6.6.5.3; Table 6.5, Table 6.6} **(Table SPM.4)**. Enhanced consumer awareness, media coverage, business commitment and sustainable government procurement have increased the market shares of certified products {6.6.5.3}. Progress with certification is more advanced in countries with developed market economies and less so in countries in economic transition **(Table SPM.4)**. Owing to the lack of compliance mechanisms and clearly assigned responsibilities, there is a trade-off between the effectiveness of certification schemes and their accountability and impact. Efforts to change social norms through education and information-based campaigns promoting pro-environment behaviour have also been important {4.5.3, 5.5.3, 6.2, 6.4.1, 6.4.2.3, 6.5.1.2, 6.5.2–6.5.5, 6.6.5.3}.

Rights-based instruments and customary norms are increasingly supported and promoted by a wide range of multilateral environmental agreements, and by human rights *(established but incomplete)* {6.2, 6.3, 6.3.2.5, 6.3.2.6, 6.4, 6.5, 6.6, 6.6.5.4} (Table SPM.4). Those instruments integrate rights, norms, standards, and principles into policy, planning, implementation and evaluation, and offer ways to reconcile biodiversity conservation and human rights standards {6.2; Table 6.2}. While decisions by multilateral environmental agreements are implemented at the national level, the recognition of human rights, and in particular the rights of indigenous peoples, in relation to sustainable use of biodiversity varies considerably between countries in Europe and Central Asia **(Table SPM.4)**. Further efforts would be required for the full integration of the fundamental principles of good governance; equalizing power relations and facilitating capacity building.

For all these instruments and their combination in policy mixes, ecosystem-based approaches, such as successfully implemented in the Norwegian system of fisheries management {Box 6.11}, the concept of nature-based solutions, as promoted by the European Union, or the idea of a circular economy adopt a more systemic perspective to environmental problems rather than addressing single issues {2.2.1.7, 6.4.2.1}.

E4 A wide range of actors and stakeholders is increasingly integrated into governance processes. This can have a positive effect on biodiversity and nature's contributions to people if the effectiveness, efficiency and equity implications of such integration are carefully monitored, evaluated and improved *(well established)* {6.2, 6.4, 6.5, 6.6}. Lack of adequate financing is a major constraint on efforts to achieve biodiversity conservation and ecosystem restoration *(well established)* {6.4.1}.

The role of multi-actor environmental governance is recognized in Western and Central Europe, and increasingly also in Eastern Europe and Central Asia. In parallel to top-down governance, decision-making concerning biodiversity and nature's contributions to people is increasingly devolved to public-private partnerships, co-management arrangements or even private governance, involving many stakeholders {6.2, 6.4, 6.5, 6.6; Tables 6.1, 6.8}. Promising developments include the establishment of new protected areas, and the protection of cultural landscapes through the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Convention, the European Landscape Convention, and the International Union for Conservation of Nature (IUCN) protected landscape approach, where various forms of knowledge are integrated into management. Assessing the effectiveness, efficiency and equity of promising governance arrangements and taking power relationships and asymmetries into consideration require careful evaluation and monitoring {6.2, 6.4.2.2, 6.5.1.2, 6.5.1.5, 6.5.1.6, 6.2.2.2; Table 6.8; Boxes 6.7, 6.11}. This holds especially true for environmental governance in Central Europe, Eastern Europe and Central Asia with their rapid transformation processes since the early 1990s, moving from hierarchical, state-dominated processes to more collaborative governance processes {6.4.2; 6.5.1.4}. Another key challenge for policy success is posed by sufficient mobilization of financial resources. Increased funding from both public and private sources, together with innovative financing mechanisms, such as ecological fiscal transfers, would help to strengthen institutional capacities; to invest in research, training, capacity-building and education; to employ necessary staff; and to secure monitoring activities {6.3.2, 6.3.3, 6.4.1, 6.5.4, 6.6.2, 6.6.4}.

E5 Dealing with change is a matter of societal choice (see D1). The way in which we choose to organize our societies and institutions, in both public and private spheres, is key to the realization of

pathways towards the sustainable future envisioned by a diverse range of actors in Europe and Central Asia *(well established)* {6.6.6}.

The design of promising governance options and smart institutional arrangements supports the effective involvement of different actors in policy and decision-making with the aim of promoting shared responsibility for our common future. Developing pathways and corresponding experiments in a participatory manner, including all relevant stakeholder groups and indigenous peoples and local communities, enables the inclusion of a diversity of perspectives and promotes the necessary deliberation of strategic planning and agenda-setting {5.4.3, 5.5.1, 5.5.2, 5.5.6, 5.6.2}.

Governing direct and indirect drivers in complex adaptive systems, a process which often includes various forms of incomplete knowledge, would benefit from limiting institutional failures and promoting policy processes that stimulate adaptation and learning. Hence, policies, programmes and strategies may be seen as experiments that require governance and management for – rather than against – change, and systematic monitoring and evaluation. This can be achieved incrementally through adaptive governance and management and the systematic improvement of policy implementation, or via transition governance and management, and the organization of evolutionary processes of societal change {6.2, 6.4.2, 6.6, 6.6.6}.

Box SPM 5 **Key knowledge gaps.**

In the course of conducting this assessment, key information and data were not always available. Knowledge gaps are especially acute in the subregions of Central Asia and Eastern Europe, and in the Balkan countries in Central Europe {1.3, 1.6.1, 3.6, 5.6.2}. If future assessments are to provide a more comprehensive account of the status and trends in nature and its contributions to people, the following knowledge gaps would need to be addressed:

- **Gaps in our understanding of nature's contributions to people:** There is a need for better understanding, quantification and integrated monitoring of the diverse values of nature's contributions to people. Moreover, there is limited understanding of how these diverse values are endorsed by different social groups and genders. Indigenous and local knowledge systems and scientific knowledge could co-produce such understanding in the future {2.5}. There is also a lack of understanding about how biodiversity contributes to ecosystem services, especially in marine systems.

- **Gaps in our understanding of the contribution of indigenous and local knowledge:** Little research has been conducted on the integration of indigenous and local knowledge into national and international policy frameworks and initiatives to create synergies across knowledge systems. These knowledge gaps exist not only for biodiversity, but also in sectors of direct relevance to biodiversity, such as agriculture, forestry, fisheries, water and climate change {6.4.1.3, 6.4.2.4, 6.6.2}.

- **Gaps in our understanding of the status and trends of nature:** These gaps include habitat extent and intactness, and species conservation status and trends for the whole region, but critically for Eastern Europe and Central Asia. In addition, systematic and integrated biodiversity monitoring of fungi, non-vascular plants, invertebrates, marine and freshwater species and soil organisms are required to better assess the status and trends for the whole region. Monitoring ecosystem functioning and species interactions is necessary to better understand the cascading effects of biodiversity changes and anticipate ecological tipping points.

- **Gaps in our understanding of drivers of biodiversity change:** A better understanding is needed of ways in which combinations of interacting indirect and direct drivers influence biodiversity and nature's contributions to people in various contexts. Furthermore, it is critical to understand time lags in the effect of drivers on biodiversity and nature's contributions to people to comprehend their real impact. In addition, there is a key gap in the identification, quantification and assessment of trends in drivers over time owing to their high spatial and temporal variability. There are also gaps in understanding the impact of climate change in combination with context-specific drivers on biodiversity and ecosystem services, especially with respect to tipping points and planetary boundaries. Moreover, there are gaps in understanding of the effects of interregional flows, especially the effects of global trade on ecological footprints and invasive alien species {4.7.1, 5.6.2}.

- **Lack of integrated scenario and modelling studies:** Scenarios rarely account for effects of multiple drivers and their interactions on impacts on the different components of biodiversity, nature's contributions to people and a good quality of life {5.6.2}. There is also a significant gap in terms of exploring the full range of synergies and trade-offs between the multiple aspects of biodiversity, ecosystem services and a good quality of life under different scenario archetypes and across different scales. It is also important to develop and couple process-based models of ecosystem functioning with the human dimensions of socioecological systems and to thoroughly evaluate these models, including the assessment of uncertainties {5.6.2}.

- **Gaps in the quantification and timing of pathways towards desired futures:** Pathways and envisioning studies are often not supported by modelling and, so, lack detailed quantification of goals and actions. Detailed description and sequencing of actions within pathways is rare, as is information on combinations of policy instruments to implement specific actions {5.6.2}. The incorporation of combinations of exemplary *transition movements* pathways into large-scale scenario exercises and into participatory scenario development is suggested as a way forward for better resolving trade-offs and for scaling-up local or sectoral solutions {5.6.2}.
- **Inadequate understanding of how to mainstream policy objectives within different sectors and integrate them across sectors and scales:** This requires a better understanding of the interaction between different policy instruments in existing policy mixes, not just the optimization of single instruments. More knowledge is needed about the effectiveness and efficiency of policy instruments that also consider institutional contexts, social impacts and how equity can be improved. There are further knowledge gaps on the effects of policy instruments on behaviour (e.g., of households and of companies) and on the economic and social systems within which these stakeholders operate {6.6.5}.


APPENDICES

APPENDIX 1

Communication of the degree of confidence

Figure SPM A 1 **The four-box model for the qualitative communication of confidence.**

Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Source: IPBES (2016).[11]

In this assessment, the degree of confidence in each main finding is based on the quantity and quality of evidence and the level of agreement regarding that evidence **(Figure SPM.A1)**. The evidence includes data, theory, models and expert judgement. Further details of the approach are documented in the note by the secretariat on the information on work related to the guide on the production of assessments (IPBES/6/INF/17).

The summary terms to describe the evidence are:

- **Well established:** comprehensive meta-analysis or other synthesis or multiple independent studies that agree.
- **Established but incomplete:** general agreement although only a limited number of studies exist; no comprehensive synthesis and/or the studies that exist address the question imprecisely.
- **Unresolved:** multiple independent studies exist but conclusions do not agree.
- **Inconclusive:** limited evidence, recognizing major knowledge gaps.

11. IPBES, Summary for policymakers of the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S.G. Potts, V. L. Imperatriz-Fonseca, H. T. Ngo, J. C. Biesmeijer, T. D. Breeze, L. V. Dicks, L. A. Garibaldi, R. Hill, J. Settele, A. J. Vanbergen, M. A. Aizen, S. A. Cunningham, C. Eardley, B. M. Freitas, N. Gallai, P. G. Kevan, A. Kovács-Hostyánszki, P. K. Kwapong, J. Li, X. Li, D. J. Martins, G. Nates-Parra, J. S. Pettis, R. Rader, and B. F. Viana (eds.)., secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany, 2016. Available from www.ipbes.net/sites/default/files/downloads/pdf/spm_deliverable_3a_pollination_20170222.pdf.

APPENDIX 2

Nature's contributions to people

This appendix describes the evolving concept of nature's contributions to people and its relevance to this IPBES regional assessment.[12]

Nature's contributions to people are all the contributions, both positive and negative, of living nature (i.e., diversity of organisms, ecosystems and their associated ecological and evolutionary processes) to the quality of life of people. Beneficial contributions from nature include such things as food provision, water purification, flood control and artistic inspiration, whereas detrimental contributions include disease transmission and predation that damages people or their assets. Many of nature's contributions to people may be perceived as benefits or detriments depending on the cultural, temporal or spatial context.

The concept of nature's contributions to people is intended to broaden the scope of the widely-used ecosystem services framework by more extensively considering views held by other knowledge systems on human-nature interactions. It is not intended to replace the concept of ecosystem services. The concept of nature's contributions to people is intended to engage a wide range of social sciences and humanities through a more integrated cultural perspective on ecosystem services.

Ecosystem services has always included a cultural component. For example, the Millennium Assessment[13] defined four broad groups of ecosystem services:

- Supporting services (now part of "nature" in the IPBES Conceptual Framework)
- Provisioning services
- Regulating services
- Cultural services

At the same time, there has been a long-standing debate in the ecosystem services science community, and in policy circles, about how to deal with culture. The social science community emphasizes that culture is the lens through which ecosystem services are perceived and valued. In addition, the groups of ecosystem services have tended to be discrete, while nature's contributions to people allow for a more fluid connection across the groups. For example, food production, traditionally considered to be a provisioning service, can now be categorized both as a material and a non-material contribution by nature to people. In many – but not all – societies, people's identities and social cohesion are strongly linked to growing, gathering, preparing and eating food together. It is thus the cultural context that determines whether food is a material contribution by nature to people, or one that is both material and non-material.

The concept of nature's contributions to people was developed to address the need to recognize the cultural and spiritual impacts of biodiversity, in ways that are not restricted to a discrete cultural ecosystem services category, but instead encompass diverse world views of human-nature relations. Nature's contributions to people also make it possible to consider negative impacts or contributions, such as disease.

There are 18 categories of nature's contributions to people, many of which closely map onto classifications of ecosystem services, especially for provisioning and regulating services. These 18 categories of nature's contributions to people are illustrated in **Figure SPM.2**. The 18 categories fall into one or more of three broad groups of nature's contributions to people regulating, material and non-material.

12. Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R., Chan, K.M.A., Baste, I.A., Brauman, K.A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P.W., van Oudenhoven, A.P.E., van der Plaat, F., Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C.A., Hewitt, C.L., Keune, H., Lindley, S., Shirayama, Y., 2018. Assessing nature's contributions to people. Science 359, 270–272. https://doi.org/10.1126/science.aap8826.
13. Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being*. (Island Press, Washington, D.C.).

CHAPTER **1**

SETTING THE SCENE

Coordinating Lead Authors:

Mark Rounsevell (United Kingdom of Great Britain and Northern Ireland/Germany), Markus Fischer (Germany/Switzerland)

Lead Authors:

Sander Jacobs (Belgium), Inge Liekens (Belgium), Alexandra Marques (Portugal), Zsolt Molnár (Hungary), Jana Osuchova (Czech Republic), Anton Shkaruba (Belarus/Hungary), Mark Whittingham (United Kingdom of Great Britain and Northern Ireland), András Zlinszky (Hungary)

Fellow:

Fanny Boeraeve (Belgium)

Contributing Authors:

Sandra Brucet (Spain), Sholpan Davletova (Kazakhstan), Hilde Eggermont (Belgium), Christine Fürst (Germany), Matthew Grainger (United Kingdom of Great Britain and Northern Ireland), Walter Jetz (Germany/United States of America), Boris Leroy (France), Oksana Lipka (Russian Federation), Frances Lucy (Ireland), Martin Schlaepfer (Switzerland), Mark Snethlage (The Netherlands/Switzerland), Isabel Sousa Pinto (Portugal), Frédérique Viard (France), Penelope Whitehorn (United Kingdom of Great Britain and Northern Ireland/Germany), Meriwether Wilson (United Kingdom of Great Britain and Northern Ireland)

Review Editors:

Tuija Hilding-Rydevik (Sweden), László Podmaniczky (Hungary)

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CHAPTER 1

SETTING THE SCENE

EXECUTIVE SUMMARY

The IPBES Regional Assessment for Europe and Central Asia critically evaluates and summarizes the available knowledge on the status and trends of nature and its contributions to people. Nature is protected for its diverse values and because it is essential for sustaining human life. To conserve the planet's variety of life - including the human species - and to ensure that people benefit from nature's contributions now and into the future, effective policies and actions are required, based on a broad understanding of what is happening and why. The Regional Assessment for Europe and Central Asia supports decision-making processes by identifying options, opportunities and trade-offs building upon the best available data and information in compiling policy-relevant knowledge (1.1).

Assessing new knowledge is highly relevant and timely. More than 50 previous international and national assessments demonstrate that biodiversity and ecosystems have intrinsic value and are essential for human life. Since the publication of the Millennium Ecosystem Assessment in 2005, there are now four times as many scientific papers on biodiversity and ecosystem services, their drivers and their consequences for people, and on related options for decision-making. To support decision-making it is necessary to synthesize the most recent scientific literature in combination with the grey literature and indigenous and local knowledge (1.1).

The assessment responds to requests from Governments. In requesting this assessment, Governments have recognized the problems arising from the loss of biodiversity and nature's contributions to people and the potential of relevant information for future decision-making. Governments posed a number of policy-relevant key questions that underpin the Regional Assessment for Europe and Central Asia. Questions in common with the other IPBES regional assessments concern the dynamics of, and interplay between, nature's contributions to people, the underlying biodiversity and ecosystems, the drivers of change in biodiversity and ecosystems, their diverse values and relevance for human well-being. Further policy-relevant questions are specific to the Europe and Central Asia region. How can ecosystems be protected through investments, regulations and management regimes for terrestrial, freshwater, coastal and marine systems? What are the effects of production, consumption and economic development on biodiversity and ecosystem services and their contributions to human well-being? How can sectoral policies and new policy instruments encourage opportunities arising from the contributions of biodiversity and ecosystem services to human well-being? The assessment seeks to inform policy, public and private decisions, to raise public awareness and to initiate new research (1.1, 1.2).

Answering the region-specific key questions offers important knowledge concerning progress toward the Aichi Biodiversity Targets, the Sustainable Development Goals, and national policies. The questions specific to Europe and Central Asia map directly onto the Aichi Biodiversity Targets and are relevant to the Sustainable Development Goals (SDGs). Goals 14 and 15 address biodiversity and ecosystems explicitly and correspond closely with the Aichi Biodiversity Targets. Beyond Goals 14 and 15, several Sustainable Development Goals address the broader importance of biodiversity and ecosystems for human well-being. The European Union Biodiversity Strategy 2020 aims to halt biodiversity loss in the European Union, restoring ecosystems where possible, and stepping up efforts to avert global biodiversity loss. This underpins the European Union's commitment to the Convention on Biological Diversity and the Aichi Biodiversity Targets by integrating policies on the ecosystem services approach into member States' economies and planning. Non-European Union countries contribute to the implementation of the Aichi Biodiversity Targets through national strategies, plans or programmes. Most Europe and Central Asia countries have developed a national biodiversity strategy and a corresponding action plan (1.2, 1.4).

The Regional Assessment for Europe and Central Asia also takes account of the requests and knowledge of actors other than Governments and provides information for them. Identifying the existing and potential links between nature, nature's contributions to people, and human well-being supports the actions of a wide range of stakeholders in addition to Governments. Non-governmental organizations (NGOs), academic organizations and private businesses can protect and enhance biodiversity and ecosystem services through a number of actions, including management practices, education and awareness raising. The assessment provides relevant evidence upon which stakeholders can base such actions, which involved consulting stakeholders throughout the assessment process (1.2, 1.4).

Europe and Central Asia is characterised by strong differences in terms of industrialization and governance that have a high impact on the state of biodiversity and nature's contributions to people. There is large variability between the Europe and Central Asia subregions in governance systems, cultures, economies, ecoregions and sectors, as well as data monitoring and availability. Europe and Central Asia also has a long history of land management with major human intervention arising from high population densities in the west, but less intervention in the east. Europe and Central Asia faces many important transboundary issues, for example for water resources, pollution, and invasive species, which cut across the subregional divisions (1.3).

Processes within Europe and Central Asia have a large influence on the rest of the world, and Europe and Central Asia depends strongly on other world regions. Such influences include teleconnections via global markets that can displace impacts on biodiversity and ecosystems from Europe and Central Asia to other parts of the world, leading to a large ecological footprint elsewhere. Dependencies include the import of food, feed, fibre and other goods. Western and Central Europe's consumption, in particular, has impacts on land, water and biodiversity in other regions of the world (1.3).

The Regional Assessment for Europe and Central Asia addresses the interactions between nature and people through the IPBES conceptual framework, accounting for the different worldviews and values that exist within the region. To guide the assessment process, IPBES has developed and applied a conceptual framework, an integrated valuation approach and a strategy that integrates information from different knowledge systems, including indigenous and local knowledge. A number of actions were implemented to base the assessment on multiple worldviews and value systems, including the knowledge of local practitioners such as farmers and foresters. Thus, the assessment accounts for different worldviews and values, which underpins its credibility, legitimacy and relevance (1.1, 1.5).

The Regional Assessment for Europe and Central Asia communicates confidence in its findings using qualitative self-assessment in line with the standardised IPBES confidence terms. The need for confidence language arises from the differences in the availability of evidence across subregions, across taxa, and over time. Confidence levels for key messages and findings as well as knowledge gaps are used systematically, including a traceable account of their supporting information and data, to facilitate comparison and interpretation towards policy. Data-related and method-related limitations and issues beyond the scope of this assessment are clearly stated (1.5, 1.6).

The evidence base contains inevitable biases in coverage of the different components and values of nature. Only a small proportion of species are studied to any degree. Out of about 8 million species that exist globally, the 2016 Red List of Threatened Species assessed 82,954 of the estimated 1.64 million species that have been described. Within Europe and Central Asia, only 2,493 species were described on the Red List in 2016. Of the studied species some groups have complete coverage (all known bird and mammal species), while other groups have far less known about them (e.g. only 7% of known plants and <1% of fungi). Answering the policy-relevant questions requires knowledge about the three dimensions of values of nature: nature's values (i.e. biodiversity), nature's contributions to people (i.e. ecosystem services) and aspects of good quality of life. While the assessment covers these three dimensions equally, better supporting evidence on nature's contributions to people and good quality of life would improve the assessment's capacity to answer the policy-relevant questions (1.1, 1.6).

1.1 INTRODUCTION

1.1.1 The purpose of the Regional Assessment for Europe and Central Asia

The conservation and sustainable use of nature matter for its intrinsic value (Batavia & Nelson, 2017) and because it provides the basis for livelihoods, economies and the good quality of life of people throughout the world (Decision IPBES-5/1, Annex IV: Scoping report for a thematic assessment on the sustainable use of wild species: deliverable 3 (b) (iii)). Effective and urgent action is required to halt the loss of biodiversity to secure the planet's variety

Box 1 1 **Policy-relevant questions.**

General questions

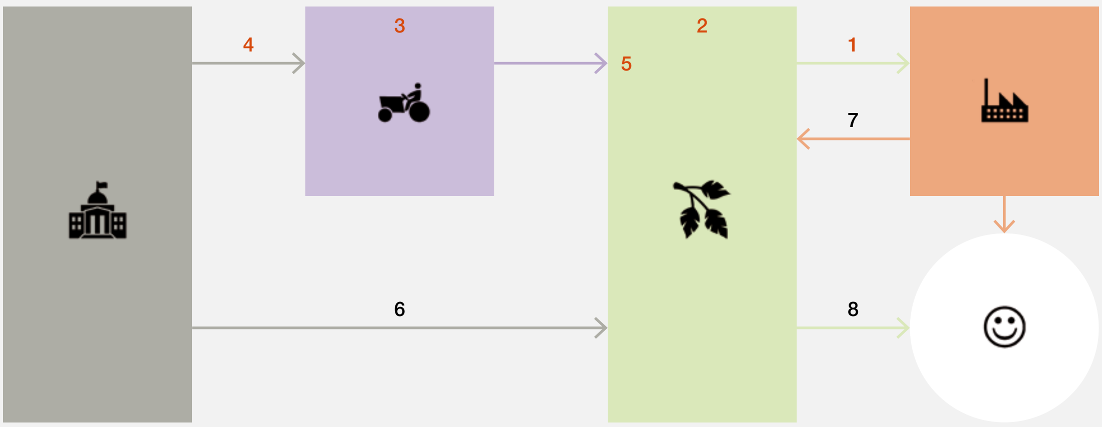
1. How do biodiversity and ecosystem functions and services contribute to the economy, livelihoods, food security, and good quality of life in the regions, and what are the interdependences among them?
2. What are the status, trends and potential future dynamics of biodiversity, ecosystem functions and ecosystem services that affect their contribution to the economy, livelihoods and well-being in the regions?
3. What are the pressures driving the change in the status and trends of biodiversity, ecosystem functions, ecosystem services and good quality of life in the regions?
4. What are the actual and potential impacts of various policies and interventions on the contribution of biodiversity, ecosystem functions and ecosystem services to the sustainability of the economy, livelihoods, food security and good quality of life in the regions?
5. What gaps in knowledge need to be addressed in order to better understand and assess drivers, impacts and responses of biodiversity, ecosystem functions and services at the regional level?

Questions specific to Europe and Central Asia

6. How can ecosystems that provide ecosystem services, such as those underpinning ecosystem-based adaptation to climate change and nature-based solutions to sustainable development, be protected through investments, regulations and management regimes for terrestrial, freshwater, coastal and marine systems?
7. What are the effects of production, consumption and economic development on biodiversity and ecosystem services and their contribution to human well-being? Major links with other regions will be assessed;
8. How can sectoral policies and new policy instruments encourage opportunities arising from the contribution of biodiversity and ecosystem services to human well-being?

Figure 1 1 **Simplified diagram of the sectors and processes addressed by the IPBES Europe and Central Asia policy questions.**

Red numbers: generic IPBES questions; black numbers: Europe and Central Asia-specific questions.
Key to symbols reflecting the IPBES conceptual framework (Díaz *et al.*, 2015) (see Section 1.1.5).



Indirect drivers (which, among others, include policy and management)

Direct drivers (the pressures of human activities)

Status, trends and futures in biodiversity and nature's contributions to people

Indirect drivers (which, among others, include production, consumption & economic development)

Good quality of life

of life, which includes human life (CBD, 2010; Tittensor *et al.*, 2014; United Nations, 2015). These actions require a strong knowledge base, good communication between scientists and decision-makers, and the will to act.

The IPBES Regional Assessment for Europe and Central Asia is based on a request from Governments, multilateral environmental agreements and other stakeholders to investigate the key policy questions outlined in **Box 1.1.** IPBES member States have recognized the dependence of quality of life and the economy on nature, and have requested new knowledge about the importance of nature for the human species. Hence, the assessment critically evaluates and summarizes the available knowledge on the status and trends of nature (including biodiversity) and nature's contributions to people[1] (including ecosystem services) and how they support good quality of life. The assessment also evaluates the underlying causes and consequences of change in the past, present and future in support of governance towards sustainability and good quality of life. Section 1.7.2. describes how the policy-relevant questions structure the Regional Assessment for Europe and Central Asia.

1.1.2 Why is this assessment important?

Nature and its contributions to people are fundamental to the existence of humans as a species and for our societies and their future development. Nature and its contributions to people are, however, continuing to decline, largely because of human actions. Of 2,493 species assessed in Europe and Central Asia, 13% are included on the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN), which constitutes 6.5% of the total number of the species included on the IUCN Red List of Threatened Species, globally (IUCN, 2017). The IPBES Regional Assessment for Europe and Central Asia responded to the need to establish a broader understanding of nature and its contributions to people for the past, present and future through an evidence base in support of effective options for policies and actions to maintain ecosystem integrity. The assessment analyses the relationship between nature and people for the region, based on the latest knowledge and the inclusive IPBES approach. It informs future decisions through a comprehensive analysis of the dynamics of, and interplay between, biodiversity and ecosystems (or nature), their drivers, and their contributions to people. It also identifies opportunities for sustainable development and good quality of life arising from nature.

1. Nature's contributions to people encompass the positive contributions, or benefits, and occasionally negative contributions, losses or detriments, that people obtain from nature. The term resonates with the original use of the term ecosystem services in the Millenium Ecosystem Assessment (MEA, 2005), and goes further by explicitly embracing concepts associated with other worldviews on human–nature relations and knowledge systems.

1.1.3 Review of previous assessments

Previous global assessments on the status of nature and its contributions to people showed that the levels or quality of both are declining (Leadley *et al.*, 2013; MEA, 2005). Over the past 50 years, humans have changed ecosystems more rapidly than ever before; 60% of ecosystems are degraded and often overexploited, and pressures on nature are increasing despite the growing number of responses to tackle biodiversity loss (Butchart *et al.*, 2010; Leadley *et al.*, 2013; MEA, 2005; Tittensor *et al.*, 2014). Effective responses can be achieved by mainstreaming nature, and its importance to good quality of life, at all societal levels, as in the Strategic Plan for Biodiversity 2012-2020 and its Aichi Biodiversity Targets (CBD, 2010).

Overall, the state of nature (biodiversity and ecosystems) is deteriorating in Western, Central and Eastern Europe (see for example: European Commission, 2015b; EEA, 2015b). Approximately, 60% of the European Union-level species assessments and 77% of the European Union-level habitat assessments indicate an unfavourable or deteriorating status (EEA, 2015b; European Commission, 2015b). Nevertheless, some species are returning to Western, Central and Eastern Europe after long periods of absence, for example, the European bison and the Eurasian beaver (Batbold *et al.*, 2016; European Commission, 2015b; Olech, 2008).

The state of nature is also deterioriating in Central Asia (Appleton *et al.*, 2012; Zoi International Network, 2011) **(Figure 1.2)**. Its most distinctive species are, and have been, heavily impacted. For example, the last tigers in the region are thought to have been killed in the 1950s; the snow leopard is extremely rare; and the saiga antelope is critically endangered (Mallon, 2008; Zoi International Network, 2011). Some positive signs are, however, observed in the development of policies for conservation and the expansion of protected areas **(Figure 1.2)**.

Of the 54 countries in Europe and Central Asia, only one has not submitted a fifth national report[2] to the Convention on Biological Diversity. Other national biodiversity or ecosystem assessments are available for the majority of the Europe and Central Asia countries with an updated list of current assessments available through IPBES (see http://catalog.ipbes.net/).

Since the Millenium Ecosystem Assessment (2005), the body of scientific knowledge on nature and its contributions to people has quadrupled by the end of

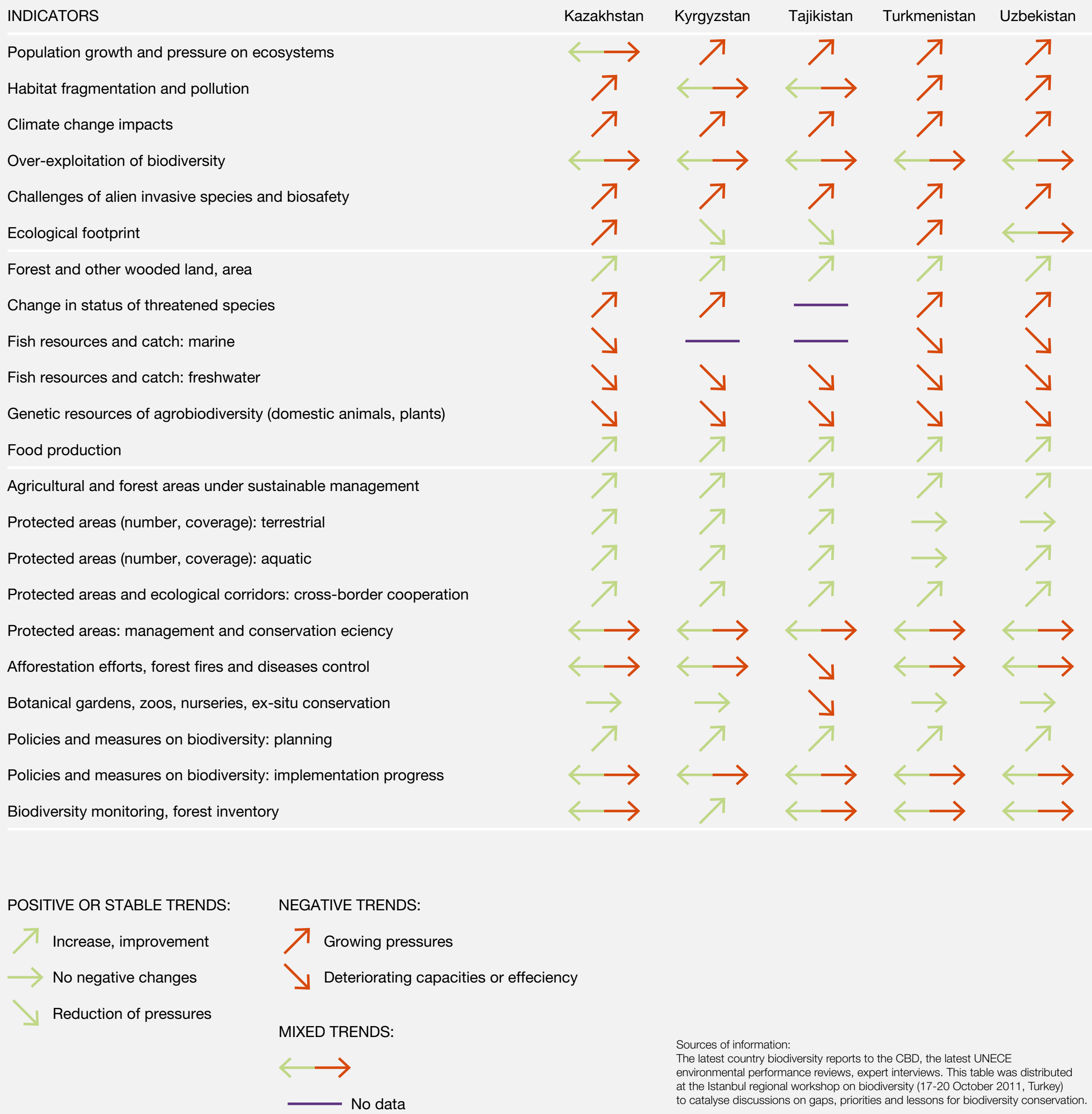
2. The fifth national reports provide, among other aspects, an update on the national status and trends of, and threats to, biodiversity, using national biodiversity indicators and also an assessment of the progress towards the Aichi Biodiverity Targets and the implementation of the Strategic Plan for Biodiversity 2011-2020.

2016 (based on a Scopus search using "biodiversity" and "ecosystem services" as search terms). The Regional Assessment for Europe and Central Asia covers previous and new knowledge in a synthetic assessment of the region. Scientific and societal debate on the valuation of nature and its contributions to people has generated new insights. For example, publications about "human well-being" increased rapidly after the Millennium Ecosystem Assessment concluded in 2005 and continued to rise after the publishing of the initial "The Economics of Ecosystems and Biodiversity" (TEEB) reports in 2010 (see **Figure 1.3**).

1.1.4 Why another assessment? The added value of the Regional Assessment for Europe and Central Asia

The Europe and Central Asia assessment aims to be broad and inclusive, builds on previous assessments and takes into account not only new research, but also evolved insights. Previous assessments covered various aspects of nature, nature's contributions to people and good quality of life. Some of these assessments were more inclusive in terms of world

Figure 1 2 **Summary of the trends on the status of nature (biodiversity and ecosystems) in Central Asia. Source: Zoi International Network (2011).**



Sources of information:
The latest country biodiversity reports to the CBD, the latest UNECE environmental performance reviews, expert interviews. This table was distributed at the Istanbul regional workshop on biodiversity (17-20 October 2011, Turkey) to catalyse discussions on gaps, priorities and lessons for biodiversity conservation.

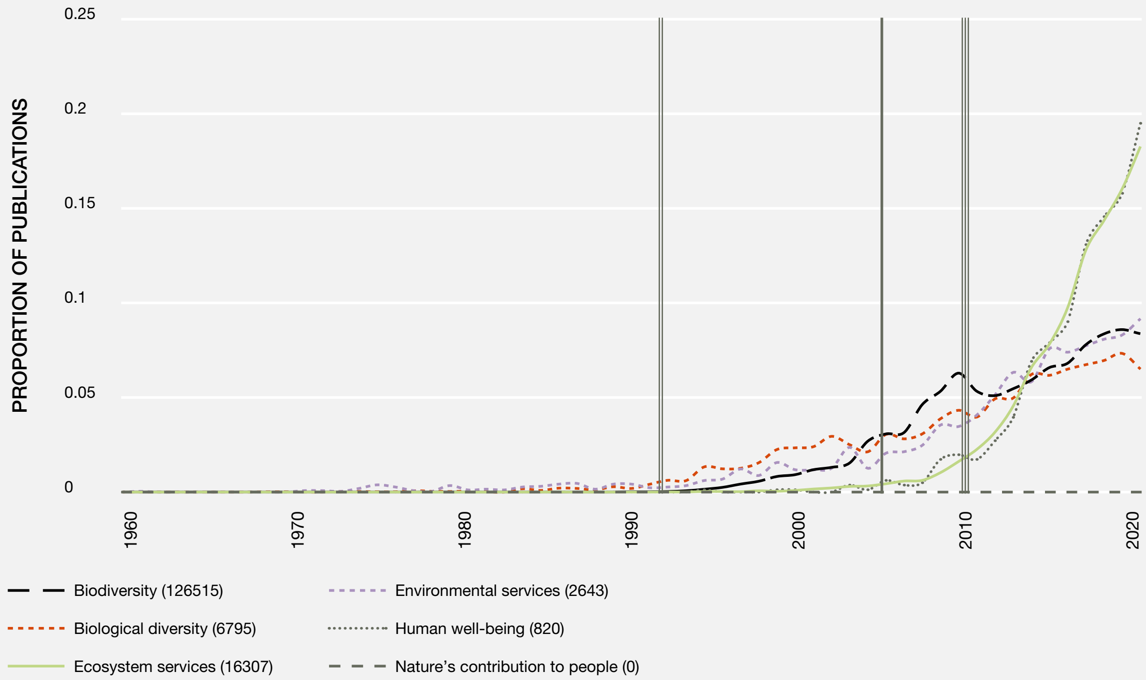
views and diverse values than others, but this was done implicitly (e.g., MEA, 2005). Nature has mainly been linked with a limited set of instrumental values (e.g., TEEB, 2010a). Although the valuation field has been developing rapidly, most assessments have emphasized traditional economic (monetary) valuation approaches (e.g. TEEB, 2010a). More recent regional assessments (e.g., Jacobs *et al.*, 2016) and research projects (e.g., OPERAs, 2017; OpenNESS, 2017) have been more inclusive of stakeholders and diverse values. The Regional Assessment of Europe and Central Asia explicitly covers the diverse values connected to nature, nature's contributions to people, and good quality of life (see **Figure 1.4**) according to the IPBES conceptual framework (see Section 1.1.5) (Díaz *et al.*, 2015; Pascual *et al.*, 2017). These values range from values of nature itself (individual organisms, biophysical assemblages, biophysical processes); regulating, material and non-material contributions of nature to people; new options for nature's contributions to people; and good quality of life from cultural, societal and individual perspectives.

The policy questions summarising Government requests (see Section 1.1.1) require these diverse values to be addressed, with a main focus on nature's contributions to people and to good quality of life **(Figure 1.4)**. Based on the conceptual framework, the Europe and Central Asia assessment aims to have a balanced representation of these different values. This responds more closely to policy demands and is a novelty of IPBES compared with previous assessments.

IPBES assessments are the first assessments on nature and its contributions to people to have been through a formal process to establish political legitimacy and to respond directly to requests from Governments. Of the 54 countries in Europe and Central Asia, 38 are members of IPBES. Moreover, many stakeholders from the region are part of IPBES's stakeholder network, including learned societies, NGOs, and representatives of indigenous and local communities. The assessment also uses a broad variety of knowledge and evidence sources beyond the natural sciences. All chapters consider indigenous and local knowledge (ILK). The assessment is therefore a legitimate and credible analysis relevant to all levels of governance and decision-making, from multinational organizations, through national Governments to the local level, and relevant to a broad audience.

Figure 1 3 **Changing frequency of keywords in the scientific literature to reflect the prevalence of these terms.**

Data generated from the Scopus database for all publications from 1960 to 2016 (using search terms as shown in the legend, except "human well-being" AND each of the other terms). The actual number of publications associated with each search term is shown in parentheses. The vertical axis shows the proportion within each search term published in each year to show the changing use of search terms through time. Each vertical black line represents a key moment relevant for global policy: the Rio Conventions in 1992 (‖) ; Millennium Ecosystem Assessment (|); The Economics of Ecosystems and Biodiversity (|||).

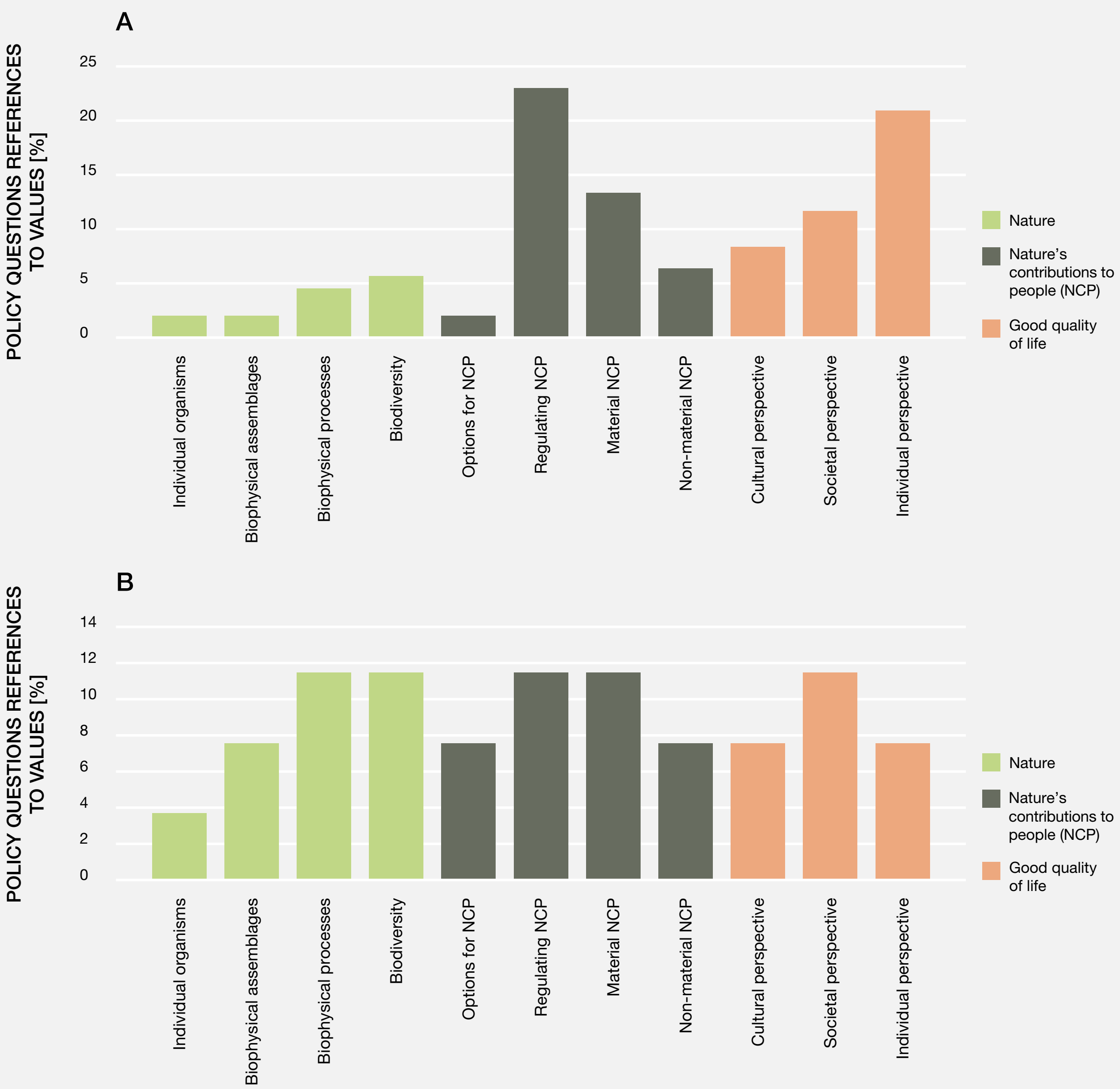


1.1.5 The IPBES conceptual framework

IPBES has developed and approved a conceptual framework to summarize the components of the system comprised of people and nature, and the relationships between them (Díaz *et al.*, 2015; IPBES, 2014). **Figure 1.5** is a simplified version of the conceptual framework as adopted by the second meeting of the IPBES Plenary. It retains all the essential elements, but some of the detailed wording for each of the elements has been removed from the boxes to improve readability.

The IPBES conceptual framework provides structure and comparability to the assessments that IPBES is producing at different spatial scales, on different themes, and in different regions. It was developed through a transparent and participatory process and explicitly considers diverse scientific disciplines, stakeholders, and knowledge systems, including indigenous and local knowledge. It is essential

Figure 1 4 **A Europe and Central Asia policy questions explicitly refer to diverse values. Bars are based on the number of times value targets are mentioned in the eight Europe and Central Asia policy questions. Policy questions are described in Section 1.1.1; B The Regional Assessment for Europe and Central Asia effectively covers diverse values. Bars based on cross-validated coverage estimates per value focus and per chapter. Value foci are introduced in Section 1.5.2.**



for interpreting the finding of the Regional Assessment for Europe and Central Asia and links strongly to the diverse values discussed in Section 1.5.2. The framework also provides common terminology for use across IPBES assessments. The six chapters of the Regional Assessment for Europe and Central Asia map onto the conceptual framework as indicated in **Table 1.1**.

Integrative, but explicit conceptual frameworks are particularly useful tools in fields requiring interdisciplinary collaboration. They help to cope with complexity by clarifying and focusing thinking about relationships, and supporting communication across disciplines and knowledge systems and between knowledge and policy. The main elements of the IPBES conceptual framework are:

- **Nature:** the natural world with an emphasis on the diversity of living organisms and their interactions among each other and with their environment.

- **Anthropogenic assets:** including knowledge, technology, work, financial assets, and built infrastructure that, together with nature, are essential in the co-production of nature's contributions to people.

- **Nature's contributions to people:** all the contributions of nature, both positive and negative, to the quality of life of humans as individuals and societies.

- **Drivers of change:** all external factors that affect nature, and, consequently, the supply of nature's contributions to people. The conceptual framework includes drivers of change as two of its main elements: institutions, governance systems and other indirect drivers on the one hand and direct drivers on the other:

    - Institutions and governance systems are among the root causes of the direct anthropogenic drivers that affect nature. They include systems of access to land, legislative arrangements, international regimes (such as agreements for the protection of endangered species) and economic policies.

    - Direct drivers, both natural and anthropogenic, affect nature directly. Direct *anthropogenic* drivers result from institutions and governance systems and other indirect drivers. They include human-caused habitat conversion and climate change, pollution, exploitation of ecosystems and species, and species introductions. Direct *natural* drivers also directly affect anthropogenic assets and quality of life (e.g. a volcanic eruption can destroy roads and cause human deaths), but these impacts are not the main focus of IPBES.

- **Good quality of life:** the achievement of a fulfilled human life. It is a highly values-based and context-dependent element comprising multiple factors such as access to food, water, health, education, security, and cultural identity, material prosperity, spiritual satisfaction, and freedom of choice. A society's achievement of good quality of life and the vision of what this entails directly influences institutions and governance systems and other indirect drivers and, through them, all other elements in the conceptual framework.

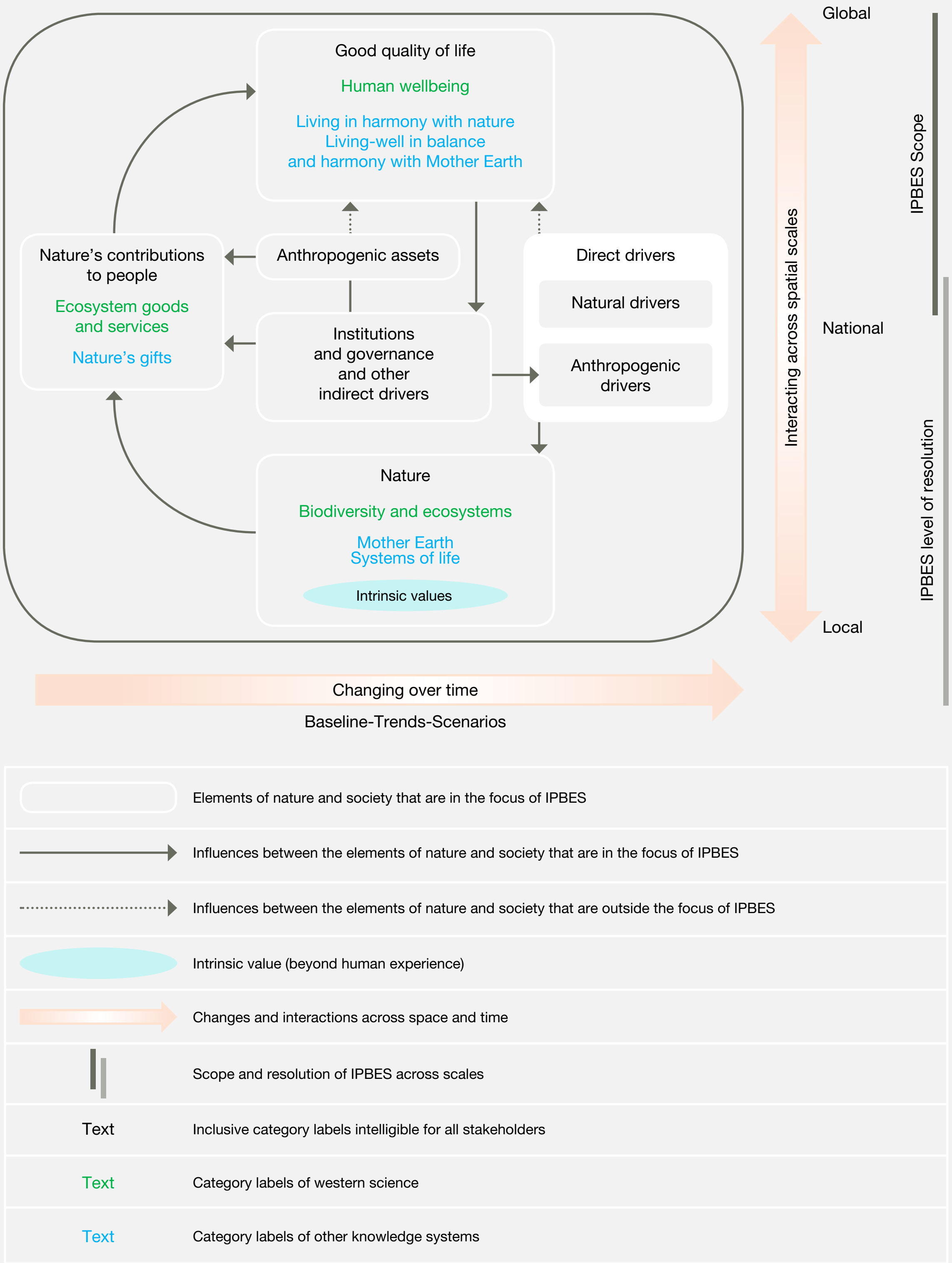
The inclusive nature of the conceptual framework, in terms of contributions, stakeholders, knowledge systems and worldviews, necessarily requires the consideration of diverse value systems. Value systems vary among individuals, within groups, and across groups at various temporal and spatial scales. For example, some nations tend to be more

Table 1 1 **How the IPBES conceptual framework maps onto the chapters of the Europe and Central Asia assessment.**

Chapter	Conceptual framework boxes and fluxes
Chapter 1: Setting the scene	All the boxes and fluxes of the conceptual framework
Chapter 2: Nature's contributions to people and quality of life	"Nature's contributions to people" and their relation to "good quality of life"
Chapter 3: Status, trends and future dynamics of biodiversity and ecosystems underpinning nature's contributions to people	"Nature" and its relation to "Nature's contributions to people"
Chapter 4: Direct and indirect drivers of change in biodiversity and nature's contributions to people	"Institutions and governance and other indirect drivers" and their relation to "direct drivers"
Chapter 5: Current and future interactions between nature and society	All the boxes and fluxes of the conceptual framework
Chapter 6: Options for governance and decision-making across scales and sectors	"Institutions and governance and other indirect drivers" and their effects on all other boxes of the conceptual framework

dominated by value systems that prioritize individual rights and others by value systems that prioritize collective and community-level values (Díaz *et al.*, 2015). The Regional Assessment for Europe and Central Asia covers the diverse values of nature, including non-anthropocentric, instrumental and relational values. This involves a range of different data and information sources that typically are not found within a single assessment, such as biophysical and socio-ecological

Figure 1 5 **The IPBES conceptual framework. Source: Díaz *et al.* (2015).**



models, socio-economic and socio-cultural valuation and qualitative data such as that based on discursive accounts and social elicitation methods. Accounting for the differences in data availability, and their representativeness for, and acceptance by, different disciplines is challenging both in synthesizing findings and in attributing confidence to these findings.

1.2 RELEVANT STAKEHOLDERS

1.2.1 Who does this assessment concern?

Governments and multilateral environmental agreements requested that the Regional Assessment for Europe and Central Asia be conducted. It is therefore directly relevant to Governments, as it answers their specific policy questions (see Section 1.1.1). Nevertheless, nature's contributions to people have effects not only at different ecological scales, but also at different organizational scales, from the individual to the community, and administrative scales from the local to the international. For instance, material contributions may be of interest to indigenous peoples and local communities (e.g. timber), but the same source can also be of interest at higher institutional levels (e.g. carbon sequestration). Furthermore, national or global stakeholders and indigenous and local communities may differ in their emphasis on the conservation of nature and sustainable use, and the enhancement of the aesthetic, cultural heritage, natural and recreational quality of their living environment. In addition, especially for indigenous peoples and local communities, ecosystems may also be a places of rituals and a point of reference in cultural and spiritual narratives (Hein, 2006; Reyers *et al.*, 2013; Raudsepp-Hearne & Peterson, 2016).

Many stakeholder groups were directly or indirectly involved in the production of the Regional Assessment for Europe and Central Asia - directly through data and knowledge sharing and reviewing drafts, and indirectly by encouraging, facilitating and supporting the participation of scientists and knowledge holders within the assessment (see also the preface for the assessment procedure and Section 1.5). The assessment experts obtained stakeholder knowledge, views and values through discussions at IPBES stakeholder days, IPBES Plenary meetings and by stakeholders reviewing drafts. In addition, grey literature was analysed and knowledge holders were consulted as experts. By including different knowledge and data sources and values, and allowing for a transparent process, an assessment gains credibility, legitimacy and relevance (Cash *et al.*, 2003).

1.2.2 Which benefits are available to stakeholders?

Stakeholder incentives and benefits associated with involvement in the assessment include the opportunity to contribute to the IPBES process, the inclusion of stakeholder-derived data and the acquisition of knowledge. Consequently, the capability to develop partnerships and to learn from insights from other disciplines increases as well as the potential for capacity building, identified from an IPBES stakeholder analysis survey (IPBES/5/INF/16: Implementation of the stakeholder engagement strategy). Stakeholder groups have specific information needs, but also derive different benefits from the insights and knowledge contained within the assessment (see discussion below). Stakeholders acknowledge that the IPBES process in general, and the Regional Assessment for Europe and Central Asia in particular, bring together different disciplines and stakeholder groups. In doing so, the participants gain insights into diverse conceptualisations of values and social and political contexts leading to the building of partnerships.

Regional (supra-national) Governments and national Governments. The questions posed by Governments are outlined in Section 1.1.1. The assessment offers insight into the best indicators to assess the status and trends of biodiversity and nature's contributions to people, as well as pinpointing data gaps. It also highlights the necessary responses and the potential opportunities and differences between countries.

Subnational governments: Subnational and local public actors have an interest in opportunities for investment in nature that leads to social and economic benefits. They request independent sources of information about how nature can help society to cope with future challenges such as water scarcity, climate change or air pollution and to enhance the living standards of citizens.

Multilateral environmental agreements and United Nations agencies: United Nations agencies have a range of scientific advisory processes in addition to being responsible for multilateral environmental agreements. Information provided through the assessment can contribute substantially to informing these processes. Multilateral environmental agreements have subsidiary bodies or other mechanisms to consider scientific and technical evidence. The information provided by the assessment contributes to some of these subsidiary bodies and mechanisms as a means of improving their effectiveness.

Intergovernmental organizations: Policy-relevant information provided by the assessment is also an important source of information about nature, its contributions to people, and good quality of life, for broader intergovernmental organizations.

Practitioners and implementers: Many organizations, including NGOs, and individuals involved in the operational management of nature and its contributions to people in practice can access IPBES products, such as policy support tools, and learn how these can be applied to conservation and sustainable use of nature (Decision IPBES-3/4: Communications, stakeholder engagement and strategic partnerships). The assessment provides examples and case studies for the use of such tools.

The scientific community: The assessment supports the scientific community in gathering information from different data sources and regions to highlight knowledge gaps and provide evidence to fill these gaps.

Indigenous peoples and local communities: Indigenous peoples and local communities are the main users and caretakers of nature and its contributions to people over large areas of Europe and Central Asia. Their understanding of nature, drivers, futures and policies can help to develop subregional or local actions and policies that are more relevant and acknowledge indigenous rights. The assessment serves as an important forum for discussion and knowledge co-production, which is urgently needed to improve the livelihoods of indigenous peoples and local communities.

Private sector: Business is often based on the use of natural resources and frequently has an impact on ecosystems, but the private sector can also find opportunities by aligning business activities with benefits to nature. To achieve this, the private sector requires insight into how to align their actions with goals of conservation and sustainable use by better recognizing and responding to interdependencies and impacts on nature (TEEB, 2010b). Businesses are also decision-makers and have an important role to play in the conservation, use and management of biodiversity and ecosystems upon which they depend. The information within the assessment supports the implementation of sustainable solutions that avoid, minimize or offset impacts on ecosystems and identifies the interdependencies between business and ecosystems.

The general public: "The people who are affected and those who provide resources are increasingly asking for evidence that interventions improve ecosystem services and human well-being." (Carpenter *et al.*, 2009). The assessment provides the general public with an independent source of knowledge.

1.2.3 Policy instruments for different stakeholders

An important function of the IPBES process is to support policy formulation and implementation by identifying policy relevant tools and methodologies. Stakeholders have a number of options and instruments available to protect and enhance biodiversity and ecosystem services. Policy instruments may take many different forms including environmental standards and regulation, economic incentives, education, capacity building and awareness raising (a non-exhaustive list is found in IPBES/4/INF/14: Information on work related to policy support tools and methodologies (deliverable 4 (c))). Policy instruments are often referred to as being designed by public authorities, but IPBES embraces design by all stakeholders including citizen organizations and indigenous peoples and local communities (IPBES/4/INF/14).

Four different categories of policy instruments for different actors have been identified in Chapter 6 (adapted from IPBES/4/INF/14):

1. Legal and regulatory instruments, for example implementing and articulating laws and regulations, planning instruments;

2. Economic and financial instruments or price-based instruments, for example fiscal instruments, and quantity-based instruments such as tradeable permits;

3. Social and information-based instruments with an emphasis on the intertwined relationship between ecosystems and socio-cultural dynamics, including: (i) information related instruments such as eco-labelling, and environmental education; (ii) self-regulation and corporate social responsibility; and (iii) enhancement of the collective actions of local communities;

4. Rights-based instruments and customary norms, that integrate rights, norms, standards and principles into policy, planning and implementation, for example by reconciling conservation and human rights standards, e.g. the rights and institutions of indigenous peoples, and heritage sites.

Various public and private actors can choose from a wide range of policy instruments to achieve their objectives. Traditionally, centralised and decentralised Governments have shaped environmental and biodiversity conservation policies, largely building on legal and regulatory instruments. Such hierarchical decision-making has increasingly been complemented by other governance modes addressing and involving private actors through economic, financial, social and information-based instruments. Furthermore, rights-based instruments and customary norms offer ways to reconcile human rights standards, and to foster complementarity with human well-being (IPBES/4/INF/14). The latter category is especially important to help develop regionally and locally relevant actions and policies for indigenous peoples and local communities. In practice, policy instruments are usually applied in combination in policy mixes (see Chapter 6).

Capacity building is another important function of the IPBES process. As **Figure 1.6** illustrates, capacity building typically represents the development and strengthening of human and institutional resources through the ability to perform functions, to solve problems, and to achieve objectives at individual, societal and institutional levels (United Nations, 2006). Addressing both public and private sectors plays a key role in successful capacity building processes. The Regional Assessment for Europe and Central Asia supports capacity building through new knowledge generation, particularly in the identification and quantification of nature's contributions to people and to good quality of life (Díaz *et al.* 2015). New knowledge can result, for example from long-term biomonitoring on permanent plots, from comparative studies or from experiments. Such records have the potential to contribute to more informed assessments of future changes in biodiversity patterns. By raising awareness at the individual level, such information facilitates appropriate strategies, plans and programmes developed at higher institutional levels.

Education also plays an important role in supporting societal choices that affect biodiversity and ecosystem services. Stakeholders can promote the work done in the assessment through local and region-wide networks and help by disseminating information to relevant communities. In this way, the assessment will raise awareness for important biodiversity and ecosystem issues across stakeholder groups, and across geographic locations.

1.3 DESCRIPTION OF THE REGION

This section introduces the basic characteristics of the Europe and Central Asia region, including the geographic area, the subregional structure, the geographical characteristics including the region's main ecosystem types (units of analysis), together with their most important societal trends in recent history. The basic facts necessary for interpreting the findings of later chapters are introduced.

1.3.1 Overview of the region

Europe and Central Asia encompasses four subregions (see **Figure 1.7**) and 54 countries (see **Table 1.2**). These countries vary greatly in size, including the largest and smallest on Earth, have diverse geography and history, but also common properties in terms of geography and climate, history and social systems. The region shares many cultural norms and historical features reflected in some similarities in land use, environmental history, and nature and its contributions to people. Nevertheless, the region encompasses high heterogeneity in natural and socio-cultural aspects. The seas that surround the region are also very heterogeneous in terms of temperatures, currents, nutrient availability, depths and mixing regimes.

In the assessment, we refer to the IPBES subregions where the data fully covers one or more of them. However, the data shown often represents other divisions, mainly the European Union or "Continental Europe" (sensu European Environment Agency). This includes Western and Central

Figure 1 6 **Potential contribution of the Regional Assessment for Europe and Central Asia to capacity building. Source: Own representation.**

LEVEL	Functions Performance	Problems Solutions	Objective Achievements
Individual	Skill development	Understanding of environmental/natural capital potentials and limits	Change in individual behaviour
Societal	Organizational development*		Social responsibility, corporate social responsibility
Institutional	Policy development	Recognition of value of biodiversity and nature's contributions to people	Appropriate policy and legal frameworks

* Organizational development: a body of knowledge and practice that enhances organizational performance and individual development.

Europe, excluding Anatolia and Israel, and Eastern Europe to a eastern border following the Ural mountains, the river Ural to the Caspian Sea, and a southern board to the Manych valley to the Sea of Azov and the Black Sea, and the Bosporus. When referring to Europe we therefore refer to the geography just illustrated, recognizing that not all data sources will perfectly match this geography. Otherwise we refer to IPBES subregions (**Figure 1.7**).

Europe and Central Asia's climatic zones range from polar through temperate to subtropical (Peel *et al.*, 2007). In terms of area, large parts of the region lie in the subarctic and humid continental climate zones, but most of the human population lives in temperate (oceanic, Mediterranean or continental) climates (European Commission, 2017a). Large-scale climate zonation is influenced by many factors from cold and warm ocean currents at the continental scale, to elevation, slope or urban climate islands at the local scale. A large portion of Europe and Central Asia is highly fragmented in terms of geomorphology by mountain ranges and lake and sea coasts and major river systems. Most of Eastern Europe and Central Asia are lowlands or plateaus; while highly variable local conditions create a fine mosaic of land use and habitat types for most of Western and Central Europe (van Asselen & Verburg, 2012), including diverse cultural landscapes. Across large areas of sparsely-inhabited

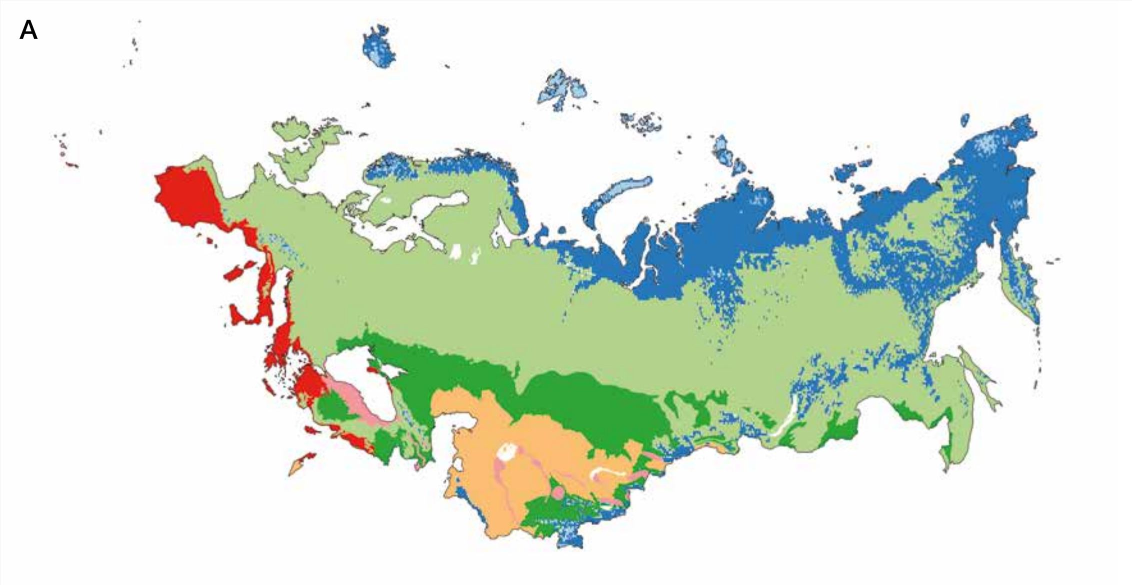
Figure 1 7 **Map showing the Europe and Central Asia region with the four subregions recognized by IPBES, and the surrounding seas.**

ECA SUBREGIONS AND SEAS

Table 1 2 **The subregions and countries covered by the Europe and Central Asia assessment.**

Subregion	Countries
Western Europe	Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland
Central Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, the former Yugoslav Republic of Macedonia, Turkey
Eastern Europe	Armenia, Azerbaijan, Belarus, Georgia, Moldova (Republic of), Russian Federation, Ukraine
Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan

Figure 1 8 **Maps of the main units of analysis used in the Regional Assessment for Europe and Central Asia. Source: Own representation.**



Deserts

Temperate grasslands

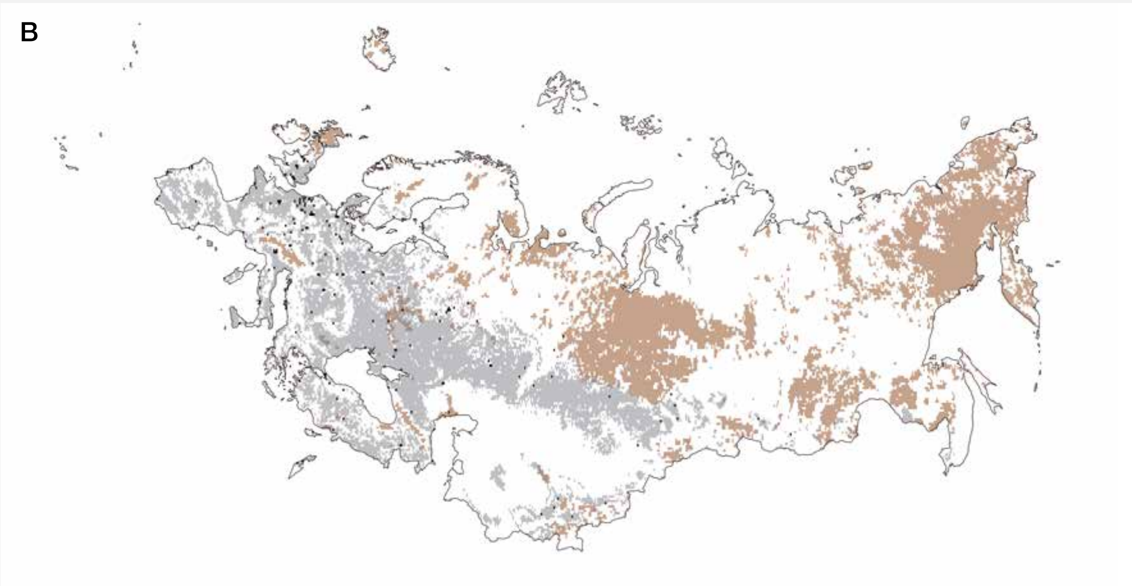
Tropical and subtropical dry and humid forests

Mediterranean forests, woodland and scrub

Broad-leaved, mixed and coniferous forests

Tundra and mountain grasslands (only high-elevation grasslands)

Snow and ice-dominated systems



Urban ecosystems

Agroecosystems

Peatlands and mires

land in Eastern Europe and in Central Asia, ecosystems are less modified by local human activity, but nevertheless affected by global change and natural resource extraction (Hansen *et al.*, 2013). The main ecosystems and land use types (known as units of analysis) are described in **Table 1.3** and shown in **Figure 1.8**. These units of analysis are used throughout the assessment as a means of simplifying, through classification, the complexity of nature.

Europe and Central Asia is characterised by major human intervention arising from continuous high population densities and a long history of unbroken land management (Ellis *et al.*, 2013). This has led to the most populated parts of the region being strongly modified by people, including the creation of cultural landscapes based on traditional management approaches (Plieninger *et al.*, 2014). Within the subregions there is a large variability in human population density, with a broad trend of less intensive human impact in the eastern parts of the region (**Figure 1.9**, **Table 1.4**). Moreover, the subregions have different time lines of human intervention arising from very different histories (Jepsen *et al.*, 2015). This also reflects heterogeneity in cultures, natural heritage, governance structures, politics, and the implementation of environmental legislation. Small-scale

Table 1 3 **Main units of analysis for the purpose of the IPBES assessments and comments specific to the Europe and Central Asia region.**

Main type	Name	Description
Snow and ice dominated ecosystems	Glaciers	Areas where the terrain surface is constantly covered in ice
	Nival belt	Areas in mountains with an extremely short growing season (<10 days) and low average annual temperature (<3.5°C)
	Polar deserts	Vegetation covers less than half of the soil surface, dominated by mosses, lichens, algae and rarely vascular plants
Tundra and mountain grasslands	Tundra	Areas with permafrost, with conditions too adverse for forest growth. Dominated by mosses, grasses or dwarf shrubs
	Alpine belt	Not permanently snow or ice covered, low vegetation dominated by grasses, sedges and forbs
	Subalpine belt	Transition between alpine zone and forests or grasslands. High grass meadows, dwarf shrubs, heathlands or short grasslands, subalpine thinned/crooked forests
Temperate and boreal forests and woodlands	Broad-leaved, mixed and coniferous forest	Vegetation dominated by tall trees
Mediterranean forests and scrubs		Highly seasonal vegetation with water stress during part of the year, dominated by needle-leaved or sclerophyllous trees and/or shrubs
Tropical and subtropical dry or humid forest		Subtropical climate, dominated by deciduous, evergreen or mixed trees
Temperate grasslands		Dry or seasonally wet, non-coastal areas with more than 30% vegetation cover, mainly grasses and herbs. Self-sustaining due to fire, aridity or grazing; or secondary, sustained by mowing or grazing
Deserts		Precipitation less than 250 mm/year. Can be cold (with snow cover) or warm (very dry and hot in summer, no snow)
Peatlands		Organic matter accumilation in soil due to limited decomposition, water abundant, specific soil
Urban habitats		Natural and artificial habitats within or close to human settlement. Suburban (with abundant green space), or urban (dominated by built structures and sealed soil surfaces)
Agricultural areas		Human management of vegetation and soil. High, medium or low intensity
Special systems	Heathlands	Dwarf shrub dominated areas in Atlantic, Subboreal or Continental climate. Developed due to human land use in historic times
	Caves and other subterranean habitats	Lack of light, trophic dependence on aboveground systems, stable temperature, high humidity, limited supply of organic material. Terrestrial or aquatic, epikarst and endokarst
Marine and freshwater habitats	Deep seas benthic habitats	Deep sea benthic habitats and species inside the exclusive economic zones and deeper than 200 m
	Shelf and water column	All non-enclosed seas with benthic habitats shallower than 200 m and pelagic habitats
	Enclosed seas and saline lakes	Brackish to hypersaline enclosed water bodies, both temporary and permanent
	Freshwater lakes and streams	Water bodies with salt content below 0.1 g/l

heterogeneity and a high level of fragmentation both in a geographical and a cultural sense is probably the most important difference between most of Europe and Central Asia and some other continental regions. Partial coordination of governance across parts of this region is the role of the European Union and also of the various international treaties.

1.3.2 Marine areas of Europe and Central Asia

In terms of marine areas, this assessment focuses on the Exclusive Economic Zones (EEZ) of the countries in the region, therefore mainly marine areas within 200 nautical miles from the shores (unless interrupted by

Figure 1 9 **Population density across Europe and Central Asia. Source: SEDAC (2017).**

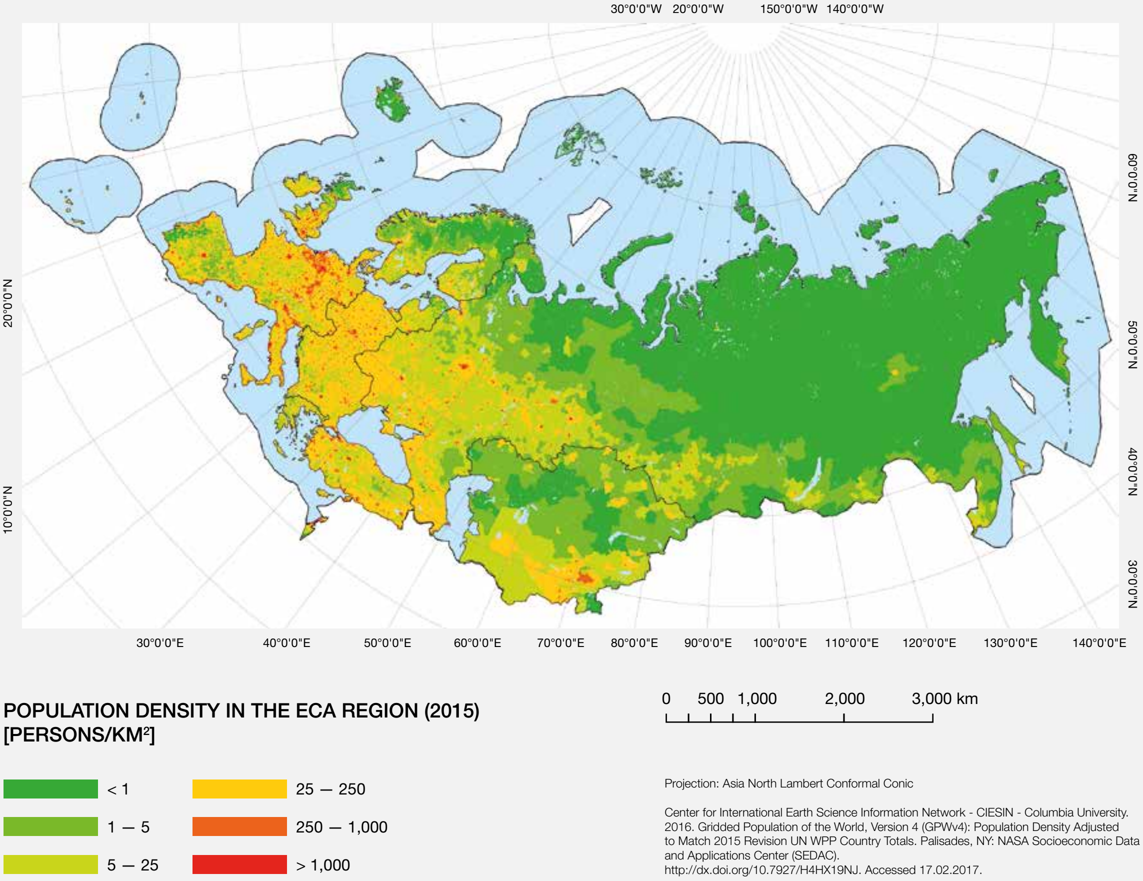


Table 1 4 **Indicators of land use in Europe and Central Asia. Source: data.worldbank.org.**

Indicator	Western Europe	Central Europe	Eastern Europe	Central Asia
Area (km²)	3,837,700	2,238,000	20,785,800	4,008,000
Population	421,446,000	200,486,000	217,576,000	69,052,000
Average population density (people/km²)	110	90	10	17
Urban population %	78	66	71	40
Agricultural land %	37	48	21	75
Forested land %	39	27	43	3

land) are discussed. Since marine units typically bridge several subregions, here they are presented followed by a description of their main habitat types (units of analysis) in an order that is independent of the subregions (see **Figure 1.7**).

North East Atlantic. The European part of the Atlantic Ocean (*sensu lato*, i.e. including North Sea, Irish Sea, English Channel, Iberian coast and Macaronesean Islands) encompasses large latitudinal gradients, extending from the sub-tropics (e.g. Gibraltar at approximately 36°N) to the upper latitudes of Svalbard in the Arctic (e.g. 77°N) and bridging several biogeographic provinces from Arctic to warm temperate systems (Spalding *et al.*, 2007). It includes highly diverse and complex benthic habitats such as hyderothermal vents, seagrass meadows, kelp forests and biogenic reefs (Prather *et al.*, 2013; Smale *et al.*, 2013; Worm *et al.*, 2006). The North East Atlantic is influenced by transcontinental ship traffic in addition to climate change, pollution, fisheries and aquaculture. Shore areas have also been widely altered by human activities in the past, including the building of shorewalls, drainage and infilling of coastal wetlands and pollution via inflowing rivers. Coastal areas are hotspots of urbanization, with about 40% of the Western European population living in coastal areas.

Baltic Sea. The Baltic sea is relatively shallow and brackish, has almost no tide, and experiences intense seasonality in temperature and inflow. It holds both marine and freshwater species, with relatively low species diversity, also influenced by industrialization mainly in its southern part. Human influence is similar or even more intensive than in the North East Atlantic.

Mediterranean Sea. The Mediterranean Sea is one of the largest of the marine units in the Europe and Central Asia region. It is microtidal, oligotrophic, homothermic and highly saline. The Mediterranean is composed of four sub-units, and has its own zonation predominantly influenced by vast watersheds and rivers that flow into them, resulting in a wide diversity of conditions and high biodiversity (Lejeusne *et al.*, 2010).

Black Sea (including Azov sea). The Black sea is a medium-sized tideless inland sea with an outlet to the Mediterranean. It is extremely stratified, resulting in a lack of oxygen in the deeper strata. The depth of the thermocline and the anoxic layer depends on seasonality, with changes resulting in major losses of biota. It is a highly sensitive ecosystem dominated by mediterranean species (although less diverse than the mediterranean itself).

Arctic Ocean. The Arctic Ocean has a large area, and is characterized by ice-associated ecosystems. Climate change (especially changes in sea ice) is rapidly changing the situation in the Arctic Ocean, and opening up new opportunities for natural resource exploration and shipping, which are however expected to strongly affect local biodiversity and ecosystem functioning. Species diversity is largely unexplored (Belikov *et al.*, 2011).

North West Pacific. The seas linked to the Russian Far East include a continental shelf, but also very deep basins which have their own circulation, partially connected to the Pacifc Ocean. As one of the most highly productive regions of the global ocean (Antonov *et al.*, 2016), these are important fishing areas with high biodiversity, threatened by recent hydrocarbon exploration. Marine mammal diversity is especially important (Artyukhin & Burkanov, 1999; Burdin *et al.*, 2009; Geptner *et al.*, 1976; Hunt *et al.*, 2000; Sokolov, 1986; Yablokov *et al.*, 1972).

1.3.3 Marine and inland surface water units of analysis of the Europe and Central Asia region

Shelf and water column. This unit of analysis includes all the benthic habitats down to 200 m depth and all the water column within the exclusive economic zone of the Europe and Central Asia region. This unit was sub-divided geographically into the different seas and ocean areas described above. Many of the policies regarding the marine environment, e.g. the European Union Marine Strategy Framework Directive (European Union, 2008) as well as regional cooperation agreements (e.g. HELCOM, 2017; OSPAR, 2017) consider the seas and oceans separately.

Deep Sea benthic habitats. All benthic habitats inside the Exclusive Economic Zones of Europe and Central Asia countries that are deeper than 200 m fall into this category. This is the most widespread habitat type on Earth with rich diversity, but it is not well known or understood. Deep sea habitats and biodiversity contribute important regulating functions and services on a global scale.

Enclosed seas and saline lakes. Saline lakes range from several thousand square kilometers (Caspian Sea) to small ephemeral habitats. Based on their salt content, saline lakes are classified as brackish (salt content in the range 0.1-3.5 g/l), saline (above 3.5 g/l) or hypersaline (above 50 g/l) lakes. The Caspian is large and brackish with high biodiversity and many endemisms. The Aral Sea is now extremely saline and mostly dried up. Smaller saline lakes are typical in endorheic basins and lowland areas mainly in the Mediterranean (Čížková *et al.*, 2013) and continental regions (Comin & Alonso, 1988; EEA, 2002; Izmailova, n.d.; Kazanci *et al.*, 2004; Kortekaas & Vayá, 2009; Kotova *et al.*, 2016; Kulagin *et al.*, 1990; Montes & Martino, 1987; Orlov *et al.*, 2011; Örmeci & Ekercin, 2005; Government of Turkey, 2014; Stenger-Kovács *et al.*, 2014; Williams, 1981; Zektser, 2000).

They are fed by rain and groundwater, with highly variable salinity conditions depending on inflow and evaporation. Brackish lakes can be highly diverse while very saline lakes usually hold only a less diverse flora and fauna, including unique and highly valuable extremophile bacterial diversity (Oren, 2006). Both salinity and ionic composition control species richness and biodiversity, but this is also influenced by ionic composition (Balushkina *et al.*, 2009; Boros *et al.*, 2013; Brucet *et al.*, 2012; Oren, 2006; Ventosa & Arahal, 2009). Both large permanent and small ephemeral saline lakes are important habitats for migratory birds.

Freshwater lakes and streams. Freshwater habitats include both standing and running water, with the Europe and Central Asia region holding almost 60% of the global freshwater volume (Messager *et al.*, 2016). Many lakes are found in the sub-boreal and boreal zone as relicts of glacial activity. Central and Eastern Europe hold vast drainage basins that feed a system of large rivers (compared with Western Europe, where watersheds are more fragmented, and Central Asia, where the climate is more arid). The overall diversity of freshwater species in Europe and Central Asia was routinely reported to increase towards lower latitudes (Hof *et al.*, 2008). River and lake systems often sustain coastal wetlands which are hotspots of biological production and diversity in the landsape mosaic. Therefore, freshwater habitats contribute importantly to green corridors and networks.

1.3.4 Subregion descriptions of Europe and Central Asia

Western Europe

Western Europe has highly fragmented and diverse landscapes of peninsulas, islands, mountain ranges and riverbasins. The subregion includes a wide range of climatic zones from from polar deserts on Svalbard and Iceland to the most extreme desert, the Negev Desert in Israel, and to subtropical island forests. The climate is typically favourable for agricultural production, except at northern latitudes and in some parts of the Mediterranean, where water is limiting. Hence, agro-ecosystems and forests dominate the landscape. Agro-ecosystems are maintained by human activity, and include croplands, orchards, horticultural systems and managed grasslands. Except for extensive grasslands, these habitats have low species diversity. Agriculture includes intensive cropland production and livestock production on grassland that ranges from intensive pasture to extensive rangelands and mountain meadows. Soils are often over-used in intensive agricultural areas and degraded due to erosion and salinization (Montgomery, 2007; Pimentel, 2006). Forests mainly dominate the high latitudes and altitudes, and can be both managed and semi-natural. Boreal forests have high diversity and provide important services (e.g. carbon sequestration), but are also very sensitive to climate change and management. Temperate forests have a long history of human influence in the region and maintain high biodiversity. Mediterranean forests grow in areas of cool wet winters and hot summers, and are typically evergreen or hard-leaved. These range from forests through shrublands to semi-open heaths depending on climate and disturbance. Mediterranean forests and scrubs have extremely high species richness (ca. 25,000 vascular plant species) with high endemism in spite of being heavily modified in historic times. Alpine and sub-alpine meadows, heaths and shrublands occur in the upland areas, with the actual treeline heavily modified by human activity. These habitats are very diverse with a high level of endemism. Urban and semi-urban areas with sealed surfaces also occupy large areas in the densely populated countries of Western Europe, which also contain two (the London and Paris metropolitan areas) of the four megacities - with more than 10 million inhabitants - in Europe and Central Asia. These ecosystems have high levels of disturbance and pollution, but especially residual habitats such as parks can conserve relics of local natural vegetation and may be relatively diverse. In peat bogs, water-saturated soils result in incomplete decomposition of organic matter, leading to an accumulation of organic-rich soils. These habitats have many specialist species, and are common in the oceanic, sub-boreal and boreal zone, but more rare towards the continental and mediterranean regions. Wetlands connected to lakes and rivers are often significantly diminished and modified by water regime regulations. Subterranean habitats are dark systems, which depend trophically on above-ground systems. They have many endemic species that are not well studied, but are extremely sensitive to environmental change.

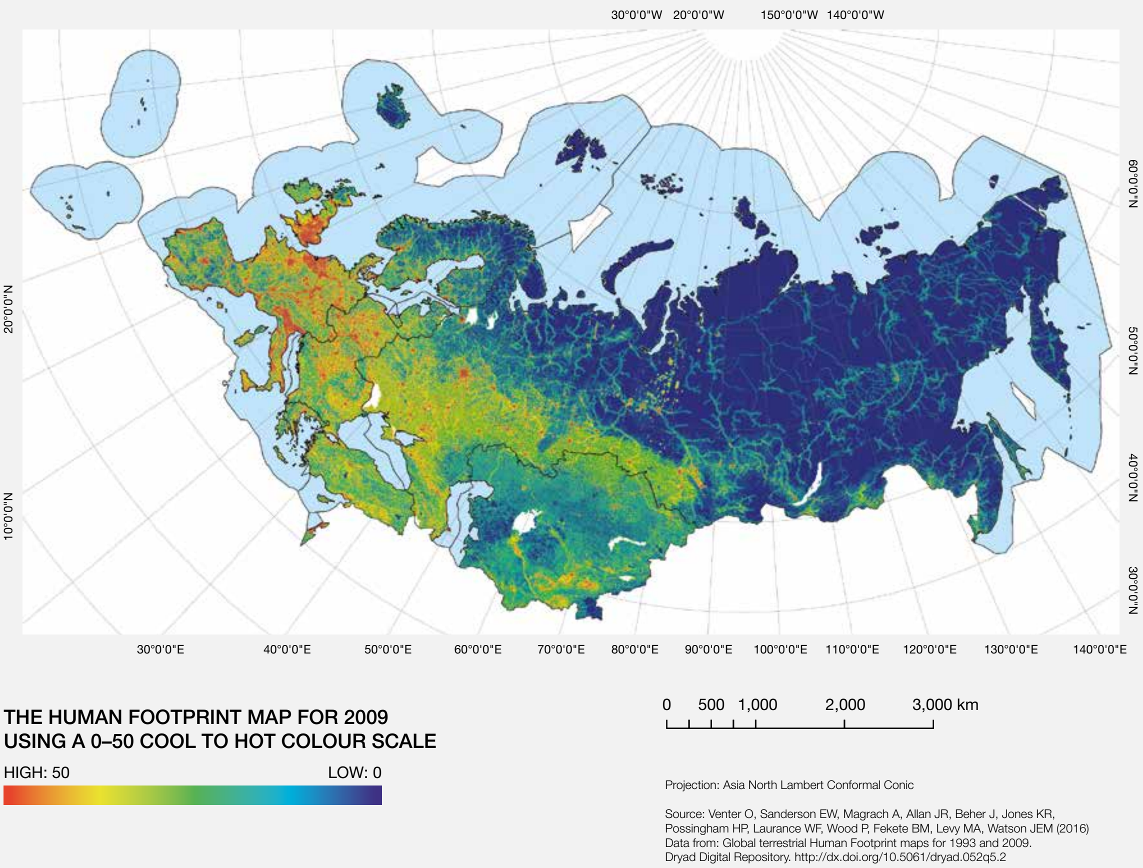
The historic transition from self-sustaining agricultural systems to industrialized monocultures with high inputs (chemical and mineral inputs, energy and machinery) has led to the transformation of mosaic landscapes into homogeneous agricultural areas where nature and its contributions to people have relatively low value (Mazoyer & Roudart, 2006). The industrial revolution starting in the 18th century, and associated rapid urbanization, have also had a profound impact on the landscapes of much of Western Europe (Jepsen *et al.*, 2015). More recent land use trends have seen a reduction in agricultural area, especially for cropland, and increases in forest areas. This has happened because of the productivity gains of the green revolution, but also because of increasing imports of food and other commodities causing land use change in other parts of the world (Meyfroidt *et al.*, 2010).

Western Europe is the most densely populated subregion of Europe and Central Asia, with half of the total population of the subregion living on approximately 10% of its terrestrial surface. Worldviews and value systems are highly diverse. Many countries in the subregion are deeply rooted in democracy where individual human rights are at the centre of those worldviews and values. During the 20th century relatively multi-cultural societies developed with diverse, often contrasting worldviews among citizens. Very large ecological footprints led to a strong increase in environmental awareness. Lifestyles and consumption are rapidly globalizing, but local products and local cultural keystone places are gaining increasing recognition. Traditional lifestyles have almost disappeared, but there are movements toward a new generation of farmers who are more conscious of sustainability.

Fifteen of the 24 countries within Western Europe are members of the European Union; the others retain strong cultural and trade links to the European Union. Hence, environmental policy in this subregion is dominated by European Union legislation, although European Union member States determine how European Union directives are implemented at the national scale, and non-member States define their own environmental policies, albeit influenced by the European Union approach. There is a strong political will within the European Union to use policy to conserve natural and cultural heritage. This is demonstrated by the large number of ecologically-oriented European Union policies, including the Biodiversity Strategy, the Habitats Directive, the Marine Strategy Framework Directive and the Water Framework Directive, amongst others. However, some other European Union sectoral policies have had negative impacts on biodiversity and ecosystem functioning in the past, such as the Common Agricultural Policy's subsidising of intensive agriculture. In addition to the strong political will, there is strong public support for, and interest in, biological conservation across Western European societies.

The Western European region supports a wide range of conservation measures and marine protected areas driven largely by the European Union Habitats Directive. The European Environment Agency 2015 State of the Seas report (EEA, 2015c), estimates that, as of 2012, about 4%

Figure 1 10 **Human footprint in the Europe and Central Asia region derived from the following indicators: 1) built environments, 2) population density, 3) electric infrastructure, 4) crop lands, 5) pasture lands, 6) roads, 7) railways, and 8) navigable waterways. Source: Venter *et al.* (2016).**



of European Union marine areas were part of the Natura 2000 Network. However, given the vast biogeographic and geopolitical scope of Western Europe, there is a range of long-standing cumulative environmental pressures (e.g. centuries of coastal habitat alteration and fishing), to more emerging challenges, in particular those associated with climate change. Key examples, within Western Europe include: changes in sea-surface temperature (Philippart *et al.*, 2011) and poleward species migrations, as well as declining polar sea-ice and the opening of Arctic shipping areas (Wassmann & Reigstad, 2011). Various countries provide ongoing regional management plans for respective seas, e.g. Norway for the Norwegian Sea and Barents Sea (Government of Norway, 2012).

Western Europe has many countries with high levels of development that is commensurate with high levels of consumption, in terms of both the amount of consumption, e.g. Alexander *et al.* (2016a), and the variety of products consumed. This has had a profound effect on the ecosystems of Western Europe, which are all under strong human influence (see **Figure 1.10**). The general trend of habitat loss and deterioration (Birdlife Europe and Central Asia, 2015; European Commission, 2015b) has also reached Alpine and sparsely-populated Arctic areas, but even these are under pressure from tourism, natural resource exploitation and global change. Meanwhile, there is an increasing trend towards restoring natural habitats, with many successful examples. Western Europe is a net "ecological debtor" (with the exception of Sweden, Norway and Finland) being dependent on the import of external resources, therefore causing environmental impacts elsewhere. The human appropriation of net primary productivity (HANPP) embodied in the European Union's consumption is strongly dependent on the appropriation of biological productivity outside of Western Europe (Kastner *et al.*, 2015), with increasing reliance on Latin America as a main supplier. Moreover, deforestation embodied in European Union consumption is almost entirely due to imports, as deforestation within the European Union is negligible (EEA, 2015b).

Central Europe

Central Europe is mostly a continental biogeographical region with segments of Alpine, Boreal, Pannonian, and Steppic landscapes, and also comprises Mediterranean and, in Turkey, subtropical ecosystems, and many subterranean cave habitats, especially in the Balkans. It includes a wide variety of landforms and geographical conditions. Low elevation moraine landscapes prevail around the Baltic coast (Estonia, Latvia, Lithuania, central and northern Poland), and are dissected by rivers, lakes and wetland systems following glacial landforms (Metzger, *et al.*, 2012). Geographically, these areas belong to the eastern periphery of the Eastern European Plain. Farming dominates these landscapes, but one of Central Europe's largest primeval forests, Białowieza forest, is also located here, as well as large wetland areas in north-eastern Poland and Estonia. At the westernmost edge of the steppe zone, both semi-natural and natural grasslands occur, maintained by soil conditions, fire, aridity, and nowadays to a lesser extent herbivore pressure. These are some of the most diverse habitats of the region. Further south, lowland basins dominate the landscape separated by sub-alpine mountain ranges, including the Carpathian basin (with its sub-basins, the small and large Hungarian Plain and the Transsylvanian Plain), the Czech basin (drained by the Elbe, Vltava and Morava rivers) and the Wallachian Plain of the lower Danube. Mountain ranges and hills dissect the Balkan area (the main watercourses being the Danube and Sava rivers) which lacks extensive lowlands. The Anatolian Peninsula is surrounded by mountain ranges around the semi-arid Anatolian plateau. Although highly variable within small areas, climatic and edaphic conditions in Central Europe are favourable for agriculture, except in some water-deficient areas in the Anatolian plateau, and agriculture and forestry are the most widespread land use types. Relatively large, but fragmented, forests exist mainly in boreal areas, while unmanaged forests are rare. Except for Białowieza forest in Poland, Romanian old-growth forests are unique in continental Europe. To safeguard the remnants of primeval forests, the world heritage list of the United Nations Educational, Scientific and Cultural Organization has recently been expanded (in July 2017), to include the Primeval Beech forests of the Carpathians, which stretch over Albania, Bulgaria, Croatia, Romania, Slovakia and Ukraine.

The political borders within Central Europe have been highly dynamic throughout history. This was caused by changes in political regimes from self-sustaining kingdoms to empires (Austria-Hungary, Prussia, the Ottoman Empire), two world wars in the 20th century, and finally by the dissolution of the Soviet Union in the late 1980s. Since the 1990s, most of Central Europe has been through important political and socio-economic transformations. This determined the nature of governance structures, affecting environmental protection and the management of natural resources, which currently remain of secondary importance to economic growth. Traditional practices and indigenous and local knowledge that are important for local nature conservation often survive in marginal cultural landscapes.

Although geopolitical transformations had different effects in different countries, the basic economic processes were similar as a consequence of the preparation of accession to the European Union (Bański, 2008). The semi-enclosed seas of the subregion have been influenced by eutrophication due to urbanization and fertilizer use, and the shore areas are increasingly under pressure from tourism. Invasive species are particularly a problem in the Black Sea and the mediterranean sea (Blenckner *et al.*, 2015). Large patches of wetlands exist attached to floodplain river deltas and freshwater lake systems, but are influenced by water level regulation, infilling, pollution and drainage (Hein *et al.*, 2016).

Central Europe is home to about 20% of the population of Europe and Central Asia on 6% of its land area, with population densities comparable to Western Europe. Many people live in rural areas in Central Europe, and there is only one megacity - Istanbul (out of 4 megacities located in Europe and Central Asia). However, with the exception of Albania, the added value of agriculture to the GDP of Central Europe is minor and economies are built on services and industry (The World Bank Group, 2016). Worldviews and value systems are highly diverse, partly as a consequence of this diverse history. Top-down determination of worldviews and values became stronger during the 20th century causing considerable change. During the Soviet era many community-level structures and informal regulations were deliberately dismantled. After 1989, a strong cultural revival was typical in many countries, together with an increase in national identity. Traditional values and lifestyles survive and are being adapted to the new socio-economic environment in thousands of semi-subsistence villages in marginal areas throughout Central Europe.

Central Europe is characterised by rapid economic and social development and urbanization in recent decades that increasingly resembles Western Europe together with relatively large areas of more intact nature in the form of cultural landscapes. The green corridors throughout such areas are of critical importance. These networks of landscape features dominated by near-natural vegetation enhance landscape connectivity, facilitating migration and dispersal of species. These existing resources raise the challenge of an alternative economic development pathway that can conserve natural capital while consumption patterns appear to continue to adjust to Western European norms. While local value systems are close to Western Europe, due to a similar long-term history, the ecological, economic and cultural heritage is different in many ways, influenced by divergent historical pathways in the 20th century. Environmental policy in Central Europe is strongly influenced by the European Union since all Central European countries are either members of, or closely associated with, the European Union.

During the 20th century, many ecosystems were impaired by water and air pollution, such as acid rain, industrial waste, and production intensification. In Western Europe, protected areas cover on average 25% of the land surface, while in Central Europe the equivalent area is only 21% and in Eastern Europe 7% (The World Bank Group, 2016). However, biodiversity is often on average richer than in most parts of Western Europe. For example, some of the most species-rich grasslands in the world are found in Estonia and Romania (Wilson *et al.*, 2012). There is increasing public support for, and interest in, nature conservation across Central European societies. Natural areas are seen as resources providing ecosystem services, supporting environmental resilence and facilitating adaptation to, and mitigation of, climate change (EEA, 2012). Climate change observations and projections indicate that Central Europe faces increasing risk of droughts and warm temperature extremes (EEA, 2015b) and, especially in the Mediterranean Sea, increasing sea temperatures and ocean acidification (Gambaiani *et al.*, 2009).

Eastern Europe

Most of the IPBES subregion of Eastern Europe is geographically located in Asia: only Belarus, Moldova, Ukraine and the western part of Russia are completely within what is commonly known as Europe, while most of Russia is beyond the Urals, and Azerbaijan, Armenia and Georgia are beyond the Greater Caucasus, which are traditionally set as the geographic divides between Europe and Asia.

Most of this “European” part of Eastern Europe is occupied by the Eastern European Plain, spanning from the Black Sea and Caucasus to the Arctic Ocean, and from the easternmost European Union borders to the Urals. The Plain contains the basins of some of Europe’s longest rivers, such as the Volga, Dnepr and Pechora. Being a vast mountain-free space with an average elevation of only 170 m, the Plain shows a uniquely gradual and continuous change of climatic zones and biogeographic regions, from Arctic deserts and tundra to boreal taiga, and then to mixed and deciduous continental forests and forested steppes, steppes and semi-deserts of the steppic zone. Arctic deserts have negligible vegetation productivity due to the extreme cold and the short growing season, and are dominated by algae, mosses, lichens and only a few vascular plants (ca. 100 species), covering about half of the ground surface altogether. Tundra habitats also have permanently frozen subsoils and environmental conditions that do not allow for forest growth (temperature, wind, precipitation). Vegetation is composed of a grass and a moss layer with sparse bushes, inter-laced with open soil, including lichen and moss or alternatively shrub tundra. Such habitats have relatively low species diversity (totalling ca. 500 vascular plants). Only continental, and northern and middle steppic regions are dominated by croplands (with steppe soils often heavily overused and degraded), while the boreal taiga region is mostly forested, except the areas around major cities. The forests are mostly natural and semi-natural, and managed only towards the southern part of the taiga region and further to the south. The south-eastern segment of the steppic and semi-desert and desert strip (especially within the Caspian Depression) contains vast arid rangelands (Isachenko, 1985). Several old industrial areas (notably Donbass in Ukraine) are densely populated, while elsewhere, except the south-western part of the plain, population density drops to less than 10-15 people/km^2. The region contains the Moscow metropolitan area, one of the four in the region with more than 10 million inhabitants. Many areas in western Russia have been rapidly losing their rural population over several decades (Alekseev & Safronov, 2015). In addition, the Chernobyl nuclear accident of 1986 led to the relocation of hundreds of thousands of people in Belarus, Ukraine and Russia (Hostert *et al.*, 2011).

There are several mountain systems on the edge of the Eastern European Plain: the eastern (Ukrainian) Carpathians, Urals, Crimean Mountains, the Greater Caucasus and Khibiny. All of these, especially the Greater Caucasus can be regarded as very important for biodiversity and, in general, their ecosystems are better preserved than the surrounding areas, except for some mining and industrial areas in the central and southern Urals, and the edges (especially in the south) of the Crimean Mountains and the Greater Caucasus, which are densely populated. The Greater Caucasus features a broad range of ecosystems, from dry steppes, semi-boreal forests, alpine meadows and glaciers to humid subtropical forests (Isachenko, 1985). Some of its peaks, including seven peaks over 5,000 m, are Europe's highest.

The geographically Asian part of Russia (Siberia and the Far East) stretches for over 5,000 km from the Urals to the Pacific coast, and for over 3,000 km from the Arctic Ocean to Mongolia and China. It consists of the flat and swampy (except the southern steppic part) Western Siberian Lowland, the hilly and sometimes low mountainous Central Siberian Plateau, the Southern Siberian (Altai, Sayany) and Transbaikalian Mountains limiting the lowlands and the plateau in the south, and the extremely complex topography of the almost entirely mountainous Russian Far East. Most of the area is covered by boreal taiga, except for tundra and Arctic deserts in the extreme north and in Arctic archipelagos, while in the south, the taiga changes to semi-steppes and steppes. There is an area of semi-deserts between the Sayany mountains and Mongolia. The mountains (except those located in high latitudes) are mostly forested and recognised as important global and regional biodiversity hotspots. Taiga forests are not managed sustainably. There, control and protection cannot prevent forest fires and illegal logging and the area of burnt forests is larger than the area of logging reported by the Russian Forest Agency (Minprirody of Russia, 2016). Most of the steppe and semi-steppe landscapes have been converted to croplands and pastures, except saline areas and some broken terrains. The Russian Far East is richer in biodiversity than Siberia, especially its south-eastern part, which is covered with deciduous and mixed monsoon forests (this also includes the southern part of the Kuril Islands) (Gvozdeckii & Mikhailov, 1978). Siberia and the Far East are drained by some of Asia's largest rivers, such as Lena, Yenisei, Ob' and Amur; Lake Baikal located at the south-eastern edge of the Central Siberian Plateau is the world's largest (in terms of volume of water) and deepest (up to 1,642 m) freshwater body and a unique habitat to many endemic species. Human population density is extremely low in most of Siberia and the Far East, and everywhere except the southern steppic edge and some industrial and mining areas, is below 1 person/km^2. In the areas north of the relatively inhabited strip, most settlements are in river valleys. The industrial areas are often heavily polluted. Climate change is an important threat to the nature of Siberia and the Far East, especially given that most of the region has permafrost, while the ecosystems in the Arctic Ocean are sensitive to sea ice dynamics.

The Transcaucasia region contains the flat and wet Kolkhida Depression open to the Black Sea, the dry Kura-Aras Depression open to the Caspian Sea, the Lesser Caucasus Highlands between and to the south of the Lowlands, and the Greater Caucasus in the north. The coastal lowland areas are home to the only humid and semi-humid subtropical forests of the subregion, with high levels of endemism and quite high diversity (several thousand vascular plant species). The Kolkhida Depression is densely populated (mostly by over 100 people per km^2) and dominated by croplands, with only very small fragments of subtropical wetlands remaining by the seashore. The Kura-Aras Depression is located in the zones of subtropical steppes, subtropical forests and semi-deserts, and most of it is converted to croplands and pastures, except some saline and broken lands; the population density is sparser in general (50-100 people per km^2) than in Kolkhida, although next to major cities it can be as high. The Lesser Caucasus is a system of relatively low mountain ridges, mostly deforested and heavily eroded, occupied by pastures and with high-density populations in the valleys. It is an important regional biodiversity hotspot.

The common historical legacy of Eastern Europe is closely tied to the history of the Soviet Union, which has led to a gradual and challenging political and socio-economic transition. During the Soviet era, many social and economic institutions, especially those related to self-organization, enterpreneurship and religion, were destroyed or severely damaged. This also had a strong and clearly visible impact on patterns of rural settlements. In Belarus and Ukraine, whose western parts only became Soviet in 1939, the pre-war border of the USSR can be traced even on topographic maps, where dense networks of small villages and farms suddenly change to patterns dominated by large villages with vast empty spaces surrounding them. This divider can also be found in many behavioural patterns and cultural preferences including attitudes towards nature and livelihoods. It is generally noted that more traditional ways have been preserved in the Caucasus, some other mountain systems (e.g. Carpathians) and the northern parts of Eastern Europe. The trend in recent decades has been a growing interest in traditional values combined with rapidly globalizing lifestyles and consumption. Environmental awareness is generally growing, but is still a somewhat low priority.

The core of the system of protected areas was established by the USSR, although it has significantly expanded since then, inspite of conservation programmes being underfunded in most countries. The countries of Eastern Europe maintain hierarchical political systems, limiting public participation in the development of nature conservation mechanisms and with different degrees of involvement of the public and of non-govermental organizations in the establishment and management of proteced areas; corruption is also considered to be a serious concern in some countries, and can result in illegal deforestation, land-grabbing, soil degradation and environmental pollution (Newell & Simeone, 2014; Richardson, 2015). All Eastern European countries, except Belarus, are involved in local armed conflicts that have led to substantial biodiversity losses (Burns *et al.* 2017). Eastern European countries have well-integrated environmental legislation, initially based on common USSR legislation. More recently, some countries have started to harmonize their environmental legislation with European Union directives and best practices, but compliance standards are rather low in most instances (Ermolin & Svolkinas, 2016; Malets, 2015). All Eastern European countries report to the Convention on Biological Diversity.

Nevertheless, the emerging multilevel biodiversity governance arrangements, such as the European Diploma for Protected Areas or forest certification schemes, work towards more transparent and accountable nature conservation regimes (Otto *et al.*, 2011).

Central Asia

The five countries constituting Central Asia were all former Soviet republics, located between the Caspian Sea and China. The subregion has a harsh continental climate, and is dominated by steppic landscapes in the north changing to deserts in central and southern parts. Its deserts have warm or cold climates with precipitation less than 250 mm/year (according to the Köppen-Geiger classification, or 150 mm according to the IPBES land degradation assessment), with specific soil types and vegetation (Asian Development Bank, 2010). They have moderate species richness, for example comprising a total of 1,000-1,500 recorded vascular plant species. Most of Central Asia consists of plains or hilly uplands, which are delimited by mountain systems on the eastern and southern peripheries. The main geographical subdivisions of Central Asia are central Kazakhstan (subdivided into the Turgay Plateau and Kazakh Uplands) and the vast desert plain to the south that contains numerous plateaus, uplands and lowlands. In the geographic literature, this plain is often divided into two: the region of northern deserts and the region of southern deserts (Gvozdeckii & Mikhailov, 1978). Central Asia is limited in the east and south by large mountain systems with extensive glacier and nival ecosystems. Such habitats have low temperatures and a short growing season (< 10 days) (Körner *et al.*, 2011). Central Asia also includes the southernmost parts of the Eastern Siberian Lowlands, the Urals (Mugodzhar Hills), Altai and the Eastern European Plain. Croplands in Central Asia are irrigated everywhere except at their northern edge and in some mountainous areas and, therefore, most settlements and the highest density of rural population are found in river valleys and similar irrigated areas. The vast areas between these settlements are almost uninhabited and mostly used for animal husbandry (usually nomadic), often based on indigenous and local knowledge. All the rivers in the central and southern parts of the subregion belong to endorheic basins (closed basins or internal drainage systems), and water overuse due to irrigation has led to severe downstream water quantity and quality issues, the most famous being the dessication of the Aral Sea, which was one of the largest inland lakes of the world in terms of surface area.

The Caspian Depression geographically belongs to the Eastern European Plain and is a flat lowland (Gvozdeckii & Mikhailov, 1978). Its southern part is dominated by rangelands with sandy and salty deserts, salt marshes and salty lakes, while in the central part and further towards the north the landscapes change to desert and then to dry steppes. Croplands are found only on the northern edge of the depression, while the rest is used for sheep husbandry, mostly nomadic. The south-east of the depression is an old oil production area with soil and water pollution widespread. The Eastern Siberian Lowland within Central Asia is a steppic landscape that changes to dry steppes in the south, often with salty soils, marshlands and numerous salty lakes towards the south-east (Isachenko, 1985). It is dominated by croplands, with rangelands mostly occurring in salty landscapes.

The Mugodzhar Hills and Central Kazakhstan are dominated by dry steppes in the north and semi-deserts towards the south. The steppes are mostly cultivated, while the semi-deserts are used for sheep husbandry. The Mugodzhar Hills reach 657 m; the Turgay Plateau is a system of plateaus slightly elevated over surrounding areas (up to 310 m); while the Kazakh Uplands is a hilly area with strongly eroded residual mountain ridges (the highest peak is 1,565 m), thousands of small lakes, and relict pine forests on northern slopes (Gvozdeckii & Mikhailov, 1978). A large area in the north-eastern segment of the Uplands (over 18,500 km^2) was used from 1949 to 1991 as a test site for nuclear weapons, and is still heavily contaminated. Central Kazakhstan is limited in the east by the westernmost ranges of the Altai and the Saur and Tarbagatai Mountains. The core of Altai is in Russia, while peripheral parts are also found in China and Mongolia. The Altai Mountains are dominated by coniferous forests. Alpine and subalpine meadows are less common. The Kazakh part of Altai is an important mining area with large-scale non-ferrous metal production that causes heavy environmental pollution.

The region of the northern deserts is located in southern Kazakhstan, northern and western Uzbekistan, and northern Turkmenistan, and includes a small portion of Kyrgyzstan in the valley of the Chu River. It is characterised by low winter temperatures, with January averages from -4°C in the south to -16°C towards the north (Asian Development Bank, 2010). The most prominent landforms of the region of northern deserts are the Plateaus of Ustyurt (raising from 150 to 365 m) and Mangyshlak (555 m); the rest is a rather extensive plain with a few residual mountain ridges, gradually raising from about 5 m under the cliff of Plateaus of Ustyurt to 300-500 m in the east, next to the Dzungarian Gate, connecting the plain with the Dzungarian Depression in China. This plain is dominated by sandy deserts in the western (Kyzylkum, Aralian Karakum, Barsuki) and eastern parts (Saryesik-Atyrau), while the central part is mostly stony and clay desert (Betpak-Dala). The plain contains several large lakes, including the remnants of the Aral Sea, and the Lake of Balkhash (half of which is salty, while the other half is fresh water), and is crossed by a few major rivers with large deltas, such as the rivers of Syr Darya and Amu Darya that used to be tributaries of the Aral Sea, the Ili that is a tributary of the Balkhash, and the Chu disappearing into the desert. Due to intensive irrigation, the rivers' discharge is continuously dropping which, in addition to the loss of the Aral Sea, threatens the existence of the Lake of Balkhash. Surface irrigation also leads to soil salinisation, especially in clay deserts, such as Betpak-Dala. Most of the area is rangeland, used for animal husbandry. Croplands such as cereal and cotton are found in river valleys and irrigated areas fed by the rivers. Remnants of riparian forests (also known as "tugai") can be found in the deltas of the Amu Darya and the Ili, and along the along the Syr Darya. These have high productivity and moderate species diversity (ca. 600 vascular plants) with many endemics, and serve as habitats for many iconic mammal species (Milkov, 1977) (Sokolov & Syroyechkovskiy, 1990).

The region of southern deserts includes most of Turkmenistan (except the extreme north and the south-western mountain part), central Uzbekistan, and the southernmost part of Kazakhstan. January average temperatures are 0°C or higher, while July averages are the highest in the Europe and Central Asia region exceeding +32°C in southern Turkmenistan (Asian Development Bank, 2010). Most of the region is a rather monotonous plain gently raising from -28 m at the shore of the Caspian Sea to 200-300 m in the east. The prevailing landscape is sandy deserts (Karakum, southern Kyzylkum) with salty marshes and clay deserts occurring by the Caspian Sea (especially by the Bay of Garabogazköl) and in local depressions. The most important rivers are the Syr Darya, the Amu Darya, the Zeravshan and the Murghab (the latter two with deltas disappearing into deserts); all heavily utilised in large-scale irrigation projects. The most important project was the Karakum Canal, constructed in 1954-1988 to promote cotton production in Turkmenistan. It is 1,375 km-long, and carries over 13 km^3 of water annually from the Amu Darya, which arguably led to the disappearance of the Aral Sea. Due to its high water losses the canal also causes soil salinization along its route. Deserted rangelands dominate the region of southern deserts and are mostly used for sheep and camel husbandry, often nomadic.

The mountain peripheries of Central Asia are often divided into three areas, which are distinctively different in terms of geomorphology and climatic characteristics (Gvozdeckii & Mikhailov, 1978): (1) the Central Asian Mountains (Saur, Tarbagatai, Dzungarian Alatau, northern Tian Shan), (2) south-eastern Tian-Shan and Pamir, and (3) Kopet Dag. All of these areas are important for biodiversity. The Central Asian Mountains consist of high ranges (Dzungarian Alatau reaches 4,464 m, and northern Tian Shan reaches 7,439 m), which usually stretch latitudinally. The mountains are dominated by steppes, shrubs and dry meadows, while lower ranges are covered by shrubs and arid woodlands. The foothils and intermountain depressions are mountain deserts, which are often irrigated and densely populated; the most important depressions (also known as "valleys"), such as Fergana and Gissar, and contain a large proportion of Central Asia's population. The Central Asian Mountains include several large lakes, notably Issyk-Kul, which is a habitat for many endemic species. Primary wild walnut-fruit forests are a specific feature of the Central Asian Mountains, occuring on mountain slopes around 1,000 m above sea level wherever precipitation is sufficient (Shukurov, 2016; Shukurov *et al.*, 2005). They are dominated by walnut (*Juglans regia*), maple, juniper and wild variants of many cultivated fruit trees, thus representing an extremely important genetic reserve. With about 300 species of vascular plants, these forests are not particularly diverse, but have a large number of tree and shrub species, with many endemics and rare species (Ashimov, 2014; Government of Tajikistan., 2014; Shukurov, 2016). South-eastern Tian-Shan and Pamir is a complex junction of the Central Asian mountain ranges. Its highest peak in Central Asia is 7,495 m. The prevailing landscapes are high-mountain plateaus, valleys and ridges covered with dry meadows and mountain steppes. There are many glaciers, including the Fedchenko Glacier that is the world's longest outside of the polar regions. Most of Pamir is sparsely populated; the valleys are used for seasonal pastures. Kopet Dag is recognised as the northern extension of the Iranian Uplands. It is a relatively low mountain range reaching 2,940 m and covered with shrubs and low woodlands, which are mostly used for sheep husbandry.

Central Asia experienced attempts at rapid industrialisation and socio-economic change during the Soviet era, followed by massive migration from the western parts of the USSR, while local ethnic communities maintained many traditional ways and practices, especially in the countryside, and remained almost unchanged in remote areas, such as the mountain periphery. The exceptions include northern Kazakhstan dominated by migrants from western parts of the USSR, and some large cities. After the dissolution of the Soviet Union in 1991, the significance of traditional cultural and religious views and practices grew considerably, although to varying extents across the region. Environmental disasters, such as the drying out of the Aral Sea and large scale soil salinisation, as well as conflicts over water resources, keep environmental awareness relatively high and well represented in policy agendas, although much oriented towards resource availability and quality of life.

When Central Asia was part of the Soviet Union, many large-scale irrigation and hydropower projects were launched that led to water management problems. With the end of the Soviet era these issues became transboundary in nature, but with Central Asian countries rebuilding their economies, the preservation of natural resources was often assigned a low priority. In the 21st century, the transition to a green economy and more resource-conscious agriculture was initiated in several Central Asian countries. Programmes for conserving agro-biodiversity, wetland habitats and CO_2 sequestration have been put in place, and indigenous and local knowledge continues to contribute to land management, especially in areas where semi-nomadic and transhumance livelihoods prevail. The natural contributions provided by these large steppe areas are important at the global level, especially for climate regulation, water regulation and soil formation. Many Central Asian States are interested in the transition to a green economy and have the natural capital to support this, but the prospect of rapid economic development based on the export of resources also has strong potential.

1.3.5 Relationships between Europe and Central Asia subregions

Transboundary connections within and beyond Europe and Central Asia are briefly introduced here, and are dealt with more extensively in Chapter 2. Europe and Central Asia has a number of transboundary issues that broadly fall into 3 categories: 1) transboundary governance systems, 2) transboundary nature and its contributions to people, and 3) links to other regions of the world. The European Union is economically the largest of the transboundary governance structures, and a major player in ecological protection in the region. However, other important transboundary governance structures exist, such as the European Free Trade Association (EFTA) of Iceland, Liechtenstein, Norway, and Switzerland, the Commonwealth of Independent States (CIS) of Russia, Ukraine, Belarus, Kazakhstan, Kyrgyzstan, Tajikistan, Armenia, Azerbaijan, Uzbekistan, Turkmenistan and Moldova, and the Eurasian Economic Union (EEU) of Belarus, Kazakhstan, Russia, Armenia and Kyrgyzstan. Although these associations are broadly based on economic criteria, they provide opportunities for cultural exchange and shared interests across a range of topics, potentially including the protection of natural capital.

A major transboundary issue for nature and its contributions to people concerns water as a resource and as a habitat, especially along major rivers, with the impact of dams, hydroelectric plants and water abstraction for irrigation from lakes, rivers and inland seas. Effects can be far-reaching from source to sea inlet and often bridge several subregions. Furthermore, air pollution can have widespread geographic impacts on habitat quality, especially nitrogenous compounds. Resources, products, pollution and waste are also transported across the boundaries within Europe and Central Asia, which impacts on ecosystems in multiple ways, including eutrophication and invasive species. However, green corridors (mountain ranges, river floodplains, the former Iron Curtain) provide a more positive benefit of transboundary interactions across Europe and Central Asia.

1.3.6 Global connections and issues

Europe and Central Asia has many links and teleconnections with the rest of the world, notably through global trade and the transport of goods (Kastner *et al.*, 2015). Transport supports the movement of invasive species that impact directly on ecosystem quality within the region (Hulme, 2009). The import of food and other goods has the effect of displacing the environmental pressures exerted by Europe and Central Asia's regional consumption to other parts of the world (Cuypers *et al.*, 2013), while Europe and Central Asia is dependent on these imported goods. Moreover, there is some evidence to suggest that Western Europe has been responsible for overfishing in waters beyond its jurisdiction (e.g. Akiba, 1997). Cultural links with regions outside of Europe and Central Asia are important in transforming human livelihoods, consumption patterns, value systems and attitudes towards nature, which also affect local nature and its contributions to people. China is an important emerging power that has an influence from outside the Europe and Central Asia region (Tracy *et al.*, 2017). China-led political, security and economic initiatives, such as the Silk Road Economic Belt or the

Shanghai Cooperation Organization are increasingly visible in the region, in particular in Eastern Europe, and even more so in Central Asia. The implications for nature are not entirely clear yet, but impacts may arise from the further growth of international trade, and possibly with large-scale infrastructural developments in regions bordering China (Tracy *et al.*, 2017).

1.4 THE GLOBAL AND REGIONAL POLICY CONTEXT

1.4.1 The Aichi Biodiversity Targets and the Sustainable Development Goals

Aichi Biodiversity Targets. In 2010, the Parties to the Convention on Biological Diversity adopted the Strategic Plan for Biodiversity 2011-2020, encompassing a long-term vision and a shorter-term mission (see **Box 1.2**). The 20 Aichi Biodiversity Targets, divided among five Strategic Goals, are part of the Strategic Plan and an essential tool for its implementation (CBD, 2010). To determine whether progress is being made toward halting biodiversity loss and ensuring that ecosystems are resilient and provide essential services for good quality of life, requires an assessment of current states, and an understanding of past and future trends. Tracking progress towards the Aichi Biodiversity Targets allows an evaluation of the progress towards the accomplishment of both the vision and mission of the Strategic Plan.

Sustainable Development Goals. The Sustainable Development Goals (SDGs) (United Nations, 2015) form the key component of the United Nations' 2030 Agenda for Sustainable Development, and are a re-affirmation of the world's commitment to move towards sustainable development. There are 17 Sustainable Development Goals with 169 targets covering a wide-range of areas, from ending poverty to empowering women and protecting the environment. The Sustainable Development Goals (together with the Aichi Biodiversity Targets) provide a global framework within which to tackle the biodiversity crisis. Goals 14 and 15 address biodiversity and ecosystems (nature) explicitly. However, the broader importance of nature to quality of life makes the Europe and Central Asia assessment relevant for several Sustainable Development Goals. **Table 1.5** maps the Europe and Central Asia questions onto the Goals.

The fifth national reports to the Convention on Biological Diversity provided an important source of information for the mid-term review of progress towards the implementation of the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets. The fifth national reports have also contributed to the development of the fourth edition of the Global Biodiversity Outlook (CBD, 2014).

1.4.2 The relationship between the Europe and Central Asia policy questions, the Aichi Biodiversity Targets, the Sustainable Development Goals, and other biodiversity policies

Since the formulation of the general questions, and those specific to Europe and Central Asia, responded to requests by Governments, multilateral environmental agreements and other stakeholders, they are relevant to policy agendas encapsulated within the Strategic Plan for Biodiversity 2011-2020 and the 2030 Sustainable Development

Box 1 2 The vision and mission of the Strategic Plan for Biodiversity 2011-2020.

"Living in harmony with nature"- The vision of the Strategic Plan

"By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people."

The mission of the Strategic Plan

"take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication. To ensure this, pressures on biodiversity are reduced, ecosystems are restored, biological resources are sustainably used and benefits arising out of utilization of genetic resources are shared in a fair and equitable manner; adequate financial resources are provided, capacities are enhanced, biodiversity issues and values mainstreamed, appropriate policies are effectively implemented, and decision-making is based on sound science and the precautionary approach."
(Convention on Biological Diversity 2010)

Agenda. **Table 1.5** maps the Europe and Central Asia policy questions onto the Aichi Biodiversity Targets and the Sustainable Development Goals. The following sections describe how different parts of the Europe and Central Asia region contribute to achieving these policy goals.

European Union Countries. The European Union Biodiversity Strategy 2020 emerged from the Birds and Habitats Directive, as the cornerstone of European Union biodiversity protection policy (adopted in May 2011). The aim of the Biodiversity Strategy 2020 is to halt biodiversity loss in the European Union, restoring ecosystems where possible, and stepping up efforts to avert global biodiversity loss. The European Union Biodiversity Strategy to 2020 sets six targets addressing the main pressures on nature and ecosystem services in the European Union and beyond (Birdlife Europe and Central Asia, 2015; European Commission, 2011). As such, the European Union has laid down a commitment to various biodiversity-related conventions and the Aichi Biodiversity Targets. **Table 1.6** shows the links between the European Union Strategy targets and the Aichi Biodiversity Targets, which integrate the concept of ecosystem services as an approach to ecosystem conservation and restoration. For example, at the European Union level, policies already integrate the ecosystem services approach into member States' economy and planning, for example in the new rural development policy for 2014-2020, the European Union's regional and cohesion policy, and the blueprint to safeguard the future of its waters by 2015 (Maes *et al.*, 2012).

Table 1 5 **How the Europe and Central Asia policy questions relate to the Aichi Biodiversity Targets and Sustainable Development Goals (see Section 1.1.1 for an overview of the Europe and Central Asia questions).**

Policy-relevant questions	Aichi Biodiversity Targets	Sustainable Development Goals
1. Importance of nature to humans	1, 2, 3, 4, 14, 15, 16	1, 2, 3, 6, 7, 8, 9, 11, 13, 14, 15
2. Current change of nature (ecosystems and biodiversity) and its consequences	5, 6, 7, 11, 12, 13, 14, 15, 18, 19	3, 6, 13, 14, 15
3. Causes of this change	3, 4, 8, 9, 10	12, 13, 14, 15
4. Opportunities for policies and interventions	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17	1, 2, 3, 6, 7, 8, 12, 13, 14, 15, 16, 17
5. Identification of knowledge gaps	18, 19	6, 12, 13, 14, 15
6. Opportunities to apply investment, regulation and management instruments for protection of important ecosystems and management of their contribution to people and good quality of life	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	1, 2, 3, 6, 7, 8, 9, 11, 12, 14, 15, 17
7. Impacts of production, consumption and economic development on nature and nature's contributions, including effects in other regions	2, 4, 6, 7, 8, 9, 10	10, 12, 13, 14, 15
8. How policy sectors and instruments can encourage opportunities for good quality of life related to biodiversity and ecosystems (nature)	3, 4, 6, 8, 9, 10, 13, 14	2, 3, 6, 7, 8, 9, 11, 12, 13, 14, 15

Table 1 6 **Comparison of the targets of the European Union Biodiversity Strategy to 2020 and the Aichi Biodiversity Targets. Source: Based on BISE (2015); CBD (2015).**

European Union Biodiversity Targets	Aichi Biodiversity Targets*
Target 1: Fully implement the Birds and Habitats Directives	1, 11, 12
Target 2: Maintain and restore ecosystems and their services	15, 14, 8, 10
Target 3: Increase the contribution of agriculture and forestry to maintaining and enhancing biodiversity	7, 5, 13
Target 4: Ensure the sustainable use of fisheries resources	6, 7, 10
Target 5: Help combat invasive alien species	9
Target 6: Help avert global biodiversity loss	2, 3, 16, 17, 20

* The three missing Aichi Biodiversity Targets, particularly Target 4 (partnership for biodiversity), and Targets 18 and 19 (building on the biodiversity knowledge base) are cross-cutting issues.

Table 1 7 **Status of the development of national biodiversity strategies and action plans (NBSAPs) of countries in Europe and Central Asia as at July 2017. Source: www.cbd.int/doc/nbsap/nbsap-status.doc.**

	Status of NBSAPs development	Pre-COP-10	Post COP-10
Western Europe	Andorra		X
	Austria		X
	Belgium		X
	Denmark		X
	Finland		X
	France		X
	Germany		X
	Greece		X
	Iceland	Partial revision planned	
	Ireland		X
	Israel	X	
	Italy		X
	Liechtenstein		X
	Luxembourg		X
	Malta		X
	Monaco	NBSAP not submitted yet	
	Netherlands		X
	Norway		X
	Portugal	X	
	San Marino	NBSAP not submitted yet	
	Spain		X
	Sweden		X
	Switzerland		X
	UK		X

	Status of NBSAPs development	Pre-COP-10	Post COP-10
Central Europe	Albania		X
	Bosnia and Herzegovina		X
	Bulgaria	X	
	Croatia		X
	Cyprus	NBSAP not submitted yet	
	Czech Republic		X
	Estonia		X
	Hungary		X
	Latvia		X
	Lithuania		X
	Montenegro		X
	Poland		X
	Romania		X
	Serbia		X
	Slovakia		X
	Slovenia	Strategy only	
	TFYR Macedonia	X	
	Turkey	X	
Eastern Europe	Armenia		X
	Azerbaijan		X
	Belarus		X
	Georgia		X
	Moldova		X
	Russian Federation		X
	Ukraine		X
Central Asia	Kazakhstan	X	
	Kyrgyzstan		X
	Tajikistan		X
	Turkmenistan	X	
	Uzbekistan	X	

Non-European Union countries. Countries outside the European Union contribute to the implementation of the Aichi Biodiversity Targets through national strategies, plans or programmes (in line with Article 6 of the Convention on Biological Diversity). Currently, almost all Parties to the Convention (189 out of 196) and all countries in Europe and Central Asia with the exception of Cyprus, Monaco and San Marino, have developed national biodiversity strategies and action plans (NBSAPs). NBSAPs are instruments for the effective implementation of the Convention at the national level, with the expectation of leading to the successful fulfilment of the Convention. Parties have different levels of NBSAP completion. Only 10 Europe and Central Asia countries completed a revision of the NBSAPs prior to the 10th Conference of the Parties to the Convention on Biological Diversity, when the Aichi Biodiversity Targets were adopted. By August 2017, most of the Europe and Central Asia countries had a revised version of the NBSAP, but for the others, revisions are still underway (**Table 1.7**).

Countries of Europe and Central Asia are signatory to the Convention on Biological Diversity and so, have committed to change their biodiversity strategy to meet the Aichi Biodiversity Targets. The Europe and Central Asia key questions reflect this engagement in responding to current needs and requests by diverse stakeholders from governments to local communities.

1.4.3 Other environmental and non-environmental policies and governance

European Union countries. In addition to the European Union Biodiversity Strategy 2020, there are a number of other sectoral polices within the European Union that affect biodiversity and ecosystems. The Water Framework Directive aims to ensure the "good ecological status" of European water bodies (European Union, 2000). The Common Agricultural Policy (CAP) has been expanded from its food production focus to consider the broader implications of farm management for the environment, through a range of agri-environmental schemes targeting ecological infrastructure (e.g. Batáry *et al.*, 2015). The Common Agricultural Policy also supports rural development and the continuation of traditional agricultural practices of high nature value (EEA, 2015a). At the national and local level, European Union countries have implemented a number of land use planning policies to support green space (Kabisch *et al.*, 2016), and to use the ecosystem services concept for improved nature conservation. There are also many listed conservation areas, implemented through national policy or as part of the European Union Natura 2000 network of protected areas (European Commission, 2008).

The Common Fisheries Policy has become increasingly concerned with the management of fish stocks, although more action is needed to ensure the sustainability of all European Union fisheries. The European Union has developed Sea Basin Management Plans for the Mediterranean (Adriatic and Ionian Seas), the Black Sea, the North Sea, the Atlantic Ocean and the Arctic Ocean (European Commission, 2017b). It also implemented the Marine Strategy Framework Directive (MSFD) in 2008 (European Union, 2008), a Directive for maritime spatial planning (European Union, 2014), and set out a Blue Growth Agenda (European Commission, 2015a).

Non-European Union countries. Most of the non-European Union countries of Europe and Central Asia are either involved in European Union- led initiatives, such as the European Environment Agency (EEA, n.d.), or European Union association agreements (all the non-European Union Western and Central European countries except for Switzerland, Georgia, Moldova and Ukraine), non-European Union organizations such as The European Free Trade Association (EFTA) (EFTA, n.d.), or in post-USSR, organizations led by Russia, such as the Commonwealth of Independent States (CIS) (CIS, n.d.) or the Eurasian Economic Union (EEU, n.d.). The countries involved in European Union-related initiatives are converging their biodiversity governance frameworks with that of the European Union. Post-USSR initiatives do not promote policies or institutions with direct implications for nature. Essentially, they are trade and customs agreements, although with ambitions of expanding to other sectors. The indirect impacts include, for example, the orientation of the agricultural sectors of the Commonwealth of Independent States and Eurasian Economic Union countries towards exports to the Russian market.

Most of the countries in the region have signed and ratified all the major multilateral environmental agreements dealing with nature and related trade and production issues. Private governance arrangements play an increasing role in national and international biodiversity governance regimes. A prime example is forest and fisheries certification, such as those by the Forest Stewardship Council and the Marine Stewardship Council. Although their fit to purpose and role in protecting species and habitats is heavily criticised, there is a consensus that the overall impact is positive (Elbakidze *et al.* 2011). In the case of the Forest Stewardship Council, this is often observed in countries with top-down governance systems (Niedziałkowski & Shkaruba, in press).

1.5 METHODS AND APPROACHES USED IN THE ASSESSMENT

1.5.1 The assessment procedure

The Regional Assessment for Europe and Central Asia synthesizes knowledge from the scientific literature and grey literature and captures indigenous and local knowledge. The assessment operates at the border of scientific *terra incognita*, dealing with large knowledge gaps, potential scientific disagreement and multiple evidence types. Interactions between humans and the natural environment are complex. To allow decision-makers to make informed decisions, experts need to communicate not only the findings in which they have a high level of confidence, but also those requiring further investigation. Confidence refers to the extent to which experts are assured of their findings. Low confidence describes incomplete knowledge and preventing a full explanation of an outcome or a reliable prediction of a future outcome; whereas high confidence conveys extensive knowledge and he ability to explain an outcome or predict a future outcome with much greater certainty. The Regional Assessment for Europe and Central Asia communicates confidence through the use of uncertainty statements (Seppelt *et al.*, 2012), qualitative self-assessment (Crossman *et al.*, 2013) and standardized confidence reporting (Jacobs *et al.*, 2015). By following a common approach to applying confidence langauge within an assessment, authors are able to increase consistency and transparency.

For every key finding in the assessment report, the supporting evidence and the level of scientific agreement was evaluated and qualified with confidence statements, including validation and evaluation by holders of indigenous and local knowledge (see 1.5.4). Confidence statements for qualitative evidence were applied using a four-box model (see **Figure 1.11**). For any of these statements, a reference is included from the key finding to the section in the main assessment report, where the the expert team treated the corresponding issue.

1.5.2 The approach to values used in the Regional Assessment for Europe and Central Asia

Valuation is central to assessments of nature. In this section, we explain how IPBES, and specifically the Regional Assessment for Europe and Central Asia, deals with valuation, which is essential to fully understand its findings. The design of governance, institutions and policies rarely takes account of the diverse values of nature. Valuation, if carried out in a way that is open to diverse perspectives, is a significant resource for a range of decision-makers, including governments, civil society organizations, and indigenous people and local communities. Therefore, value diversity is fully embodied within the IPBES conceptual framework. The Regional Assessment for Europe and Central Asia recognises culturally different worldviews, visions and approaches to achieving good quality of life, following the assessment guidelines on valuation (IPBES/4/INF/13: Preliminary guide regarding diverse conceptualization of multiple values of nature and its benefits, including biodiversity and ecosystem functions and services (deliverable 3 (d))).

IPBES considers three main value dimensions: (1) values directly linked to nature itself (including biodiversity and ecosystem structure and functioning); (2) values derived from nature's contributions to people (including ecosystem services); and (3) values more directly linked to good quality of life (see **Table 1.8**). For each value dimension, the Europe and Central Asia assessment applied specific assessment methods. Basic understanding of the valuation methods used is important since these strongly influence the outcomes of each valuation (IPBES/4/INF/13: Preliminary guide regarding diverse conceptualization of multiple values of nature and its benefits, including biodiversity and ecosystem functions and services (deliverable 3 (d))).

In each of the three main value dimensions, different foci and targets of valuation were distinguished as they relate to different policy arenas and societal decision-making. For example, concern for *individual living beings* is expressed by animal welfare movements and policies, whereas concerns for *genetic diversity* are expressed in the Cartagena Protocol to the Convention on Biological Diversity. As there is overlap

Figure 1 11 **The four-box model for the qualitative communication of confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Source: Modified from Moss & Schneider (2000) in IPBES (2016a).**

between different foci and their significance varies in different contexts, **Table 1.8** - rather than being a rigid classification - is a tool to structure research and the analysis of diverse values across different worldviews. In the detailed value targets, differences may occur between chapters, but these are mostly minor and do not affect findings concerning the value foci or dimensions.

The following provides definitions applied in the Regional Assessment for Europe and Central Asia for the main value components. The definitions are based on the IPBES valuation guidance documents that are slightly adapted to the Europe and Central Asia context where needed.

Nature: In this assessment, the concept of "nature" refers to nature at large, encompassing a continuum from nature as an autonomous functioning and evolving system to nature involving domesticated plants and animals. Within the context of science, it includes categories such as biodiversity[3], ecosystems, ecosystem functioning, evolution, the biosphere, humankind's shared evolutionary heritage, and biocultural diversity. Within the context of other knowledge systems, nature also includes different beliefs and concepts held around the world by indigenous peoples and local communities, such as "Mother Earth" and "systems of life" (Díaz *et al.*, 2015).

Non-anthropocentric values. These include the values that people attribute to living beings, species, ecosystems or regions that are not centred exclusively on humans and contributions to good quality of human life. Some of these values can be assessed using quantitative measures of biological diversity and ecological integrity that involve studies on biodiversity, individual organisms, biophysical assemblages and ecological processes at different levels.

- **Intrinsic values** are independent of any human experience or evaluation. Since intrinsic value can be recognized, but not quantified, by humans it is not the target of any valuation process (Pascual *et al.*, 2017) (see also Batavia & Nelson, 2017). However, intrinsic values are one of the main motivations for nature conservation and for conducting this assessment.

Anthropocentric values. These are values centred on humans. An assessment of anthropocentric values must consider how they relate to the current state and potential changes in nature, nature's contributions to people, and good quality of life. The two main types of anthropocentric values considered in IPBES are instrumental and relational values:

- **Instrumental values** refer to the value attributed to something as a means to achieve a particular end for humans, and in IPBES these are referred to as nature´s contributions to people (see below).

- **Relational values** are the positive values assigned to "desirable relationships", such as those among people and between people and nature (Díaz *et al.*, 2015). Relational values refer to both desirable human-human interactions and human-nature interactions. "Living in harmony with nature", "living-well in balance and harmony with Mother Earth" and "human well-being" are examples of different perspectives on what in the IPBES context is referred to as good quality of life.

Nature's contributions to people. Defined by Pascual *et al.* (2017) as "all the positive contributions, or benefits, and occasionally negative contributions, losses or detriments, that people obtain from nature. It resonates with the original use of the term ecosystem services[4] in the Millenium Ecosystem Assessment (MEA, 2005), and goes further by explicitly embracing concepts associated with other worldviews on human–nature relations and knowledge systems (e.g. "nature's gifts" in many indigenous cultures) (Díaz *et al.*, 2015)". They can be assessed in many different ways, including economic, social and biophysical valuation methods. Each of these methods elicits different values and, so, requires a broad set of approaches (Boeraeve *et al.*, 2014; Jacobs *et al.*, 2016).

Good quality of life. The achievement of a fulfilled human life, the criteria for which may vary greatly across different societies and groups within societies. It is a context-dependent state of individuals and human groups, comprising aspects such as access to food, water, energy and livelihood security, and also health, good social relationships and equity, security, cultural identity, and freedom of choice and action (Díaz *et al.*, 2015). These values are assessed using various methods. A valuation that looks at the social-ecological system as a whole is essential for fully understanding relational values. Such valuation combines data from, for example, narratives, preference assessments, participatory geographical analyses, historical studies and biophysical models. First-hand information from individuals holding relational values is essential.

Integrated valuation. Some valuation methods are appropriate at eliciting a wide range of values (e.g. cultural and social methods) while others are limited to specific value types (e.g. monetary valuation) (Jacobs *et al.*, 2016). Values are not necessarily independent of one another and can

3. In the Regional Assessment for Europe and Central Asia, the term "biodiversity" is used in different senses, from its scientific sense of biological diversity to its more encompassing sense of the natural environment in general and the concept of intrinsic value (see also Mace *et al.*, 2012).

4. The Regional Assessment for Europe and Central Asia uses both the terms "nature's contributions to people" and "ecosystem services". The latter is used when refering to literature dealing with specific ecosystem services, while "nature's contributions to people" is applied to convey statements refering to the broader category of anthropocentric values (which include ecosystem services).

Table 1 8 **The diverse values addressed in the Europe and Central Asia assessment, based on document IPBES/4/INF/13: Preliminary guide regarding diverse conceptualization of multiple values of nature and its benefits, including biodiversity and ecosystem functions and services (deliverable 3 (d))**

Value Dimension	Value Type	Value Focus*		IPBES-Valuation Targets
NATURE	Non-anthropocentric	N1	Individual organisms	Individual organisms
		N2	Biophysical assemblages	Biophysical assemblages
		N3	Biophysical processes	Biophysical processes
		N4	Biodiversity**	Biodiversity
NATURE'S CONTRIBUTIONS TO PEOPLE***	Anthropocentric-Instrumental	C1	Options for NCP	18 Maintenance of options
		C2	Regulating NCP	1 Habitat creation and maintenance
				2 Pollination and dispersal of seeds and other propagules
				3 Regulation of air quality
				4 Regulation of climate
				5 Regulation of ocean acidification
				6 Regulation of freshwater quantity, flow and timing
				7 Regulation of freshwater and coastal water quality
				8 Formation, protection and decontamination of soils and sediments
				9 Regulation of hazards and extreme events
				10 Regulation of organisms detrimental to humans
		C3	Material NCP	11 Energy
				12 Food and feed
				13 Materials and assistance
				14 Medicinal, biochemical and genetic resources
		C4	Non-material NCP	15 Learning and inspiration
				16 Physical and psychological experiences
				17 Supporting identities
GOOD QUALITY OF LIFE	Anthropocentric - Relational	Q1	Cultural	Living well in harmony with nature
				Identity and Autonomy
				Spirituality and Religions
				Art and Cultural heritage
		Q2	Societal	Sustainability and Resilience
				Diversity and Options
				Governance and Justice
		Q3	Individual	Health and Wellbeing
				Education and Knowledge
				Good social relations
				Security and Livelihoods

*: The categorisation in the "value focus" collumn strictly serves as an aid for balanced aggregation and depiction of the diverse value dimensions, rather than mutually exclusive categories

: In the ECA assessment, the term **"biodiversity" is used in different senses, from its scientific sense of biological diversity up till its more encompassing sense of the natural environment in general (see also Mace *et al.,* 2012)

co-exist. Human decisions are ideally made by weighing and summarizing different values that are highly dependent on socio-economic, biophysical and governance contexts (Gómez-Baggethun *et al.* 2014). Most policy decisions *de facto* include diverse values implicitly and are rarely based on economic, ecological or social impacts alone. Integrated valuation has been increasingly developed as a methodology or practice to achieve a more transparent approach in combining diverse values (Dendoncker *et al.*, 2014; Jacobs *et al.*, 2016). Integrated valuation was therefore put forward in the IPBES guidelines to achieve fair, reliable and policy relevant valuation (IPBES/4/INF/13: Preliminary guide

and accommodated following the wording of "nature's contributions to people" (NCP) for the purposes of Europe and Central Asia.

Further examples and clarifications
Living beings (biocentrism), sentient beings (animal welfare/rights)...
Populations, communities, ecosystems, biomes, the biosphere, Gaia, Pachamama, Mother Earth...
Evolution, ecosystem functions and processes, ecological resilience...
Genetic, functional, taxonomic and phylogenetic diversity, uniqueness, vulnerability...
Stewardship, relationships and interactions between people and nature inherently entwined as systems of life, as also indicated by time spent for managing ecosystems, conservation activities, contemplation of nature...
Sense of place, sense of community, historical values, agency, self-determination...
Sacred sites, totemic beings, spiritual well-being…
Inspiration, artistic creation...
Social-ecological resilience, social, economic and ecological sustainability...
Biocultural diversity, diversity of current and future options…
Environmental justice, intra-generational equity, inter-generational equity...
Physical, mental, holistic health, biophilia...
Inspiration, education, experience, learning space...
Community cohesion, social resilience, conviviality...
Physical security, political stability, food and water security, energy security, livelihood security...

***: In the ECA assessment, both terms **"nature contributions to people"** and **"ecosystem services"** are used. The latter is used where refering to literature dealing with specific ecosystem services, while "nature contributions to people" is applied to convey statements refering to the broader category of anthropocentric values (which includes ecosystem services).

regarding diverse conceptualization of multiple values of nature and its benefits, including biodiversity and ecosystem functions and services (deliverable 3 (d))).

IPBES includes integrated valuation directly within the assessment process. In the Europe and Central Asia assessment, integrated valuation was realized through several initiatives supported by a technical support unit established to address these issues. A workshop of valuation experts, the values liaison group for the Regional Assesment for Europe and Central Asia, provided feedback, concrete suggestions and support to the assessment authors, facilitated by the technical support unit for the assessment and the technical support unit on values.

1.5.3 Overview of methods and approaches used in the Regional Assessment for Europe and Central Asia

Each chapter of the Regional Assessment for Europe and Central Asia implemented a comprehensive literature review for a wide range of information sources, from primary information (map archives, databases) to peer-reviewed, academic literature as well as grey literature and knowledge from stakeholders, and indigenous peoples and local communities. The literature reviews adopted a systematic approach to evaluate the large body of information using specific key word searches in English, Russian and Ukrainian. The analysis also used supplementary sources of information, including indicators of relevance to the Convention on Biological Diversity, to the Aichi Biodiversity Targets, to the Sustainable Development Goals, and to regional biodiversity targets (e.g. the IUCN Red List species[5], UNstats[6], Sustainable Development Goal indicators[7], European Environment Agency indicators[8]). The literature reviews formed the basis of expert judgements by the author team including the attribution of confidence statements. Chapter 5 developed scenario archetypes to summarise plausible and consistent future developments for Europe and Central Asia. The archetypes synthesize impacts and identify the key sustainability issues facing policy and society across a wide range of scenarios found in the literature.

The assessment followed common guidelines to ensure consistency across chapters. This included the conceptual framework (see Section 1.1.5) introduced in the IPBES guide to assessments (IPBES/4/INF/9: Guide on the production and integration of assessments from and across all scales (deliverable 2 (a))), a glossary specific to the Europe and Central Asia assessment, a list of indicators (IPBES, 2017), a classification of the units of analysis (see **Table 1.3**), a typology of nature's contributions to people (Pascual *et al.*, 2017) and the confidence statements (see Section 1.5.1).

1.5.4 Consideration of indigenous and local knowledge (ILK)

Indigenous and local knowledge (ILK) systems in IPBES are dynamic bodies of integrated, holistic, social-ecological knowledge, and practices and beliefs about the relationships between living beings, including humans, and their environment. Indigenous and local knowledge is highly diverse, and produced in a collective manner at the interface between the diversity of ecosystems and human cultural systems. It is continuously evolving through the interaction of experiences and different types of knowledge (written, oral, tacit, practical, and scientific) among indigenous peoples and local communities.

Taking indigenous and local knowledge into account in nature-related assessments improves both the social robustness and the accuracy of the outcomes, i.e. outcomes are closer to the studied context (Cowling *et al.* 2008; Donovan *et al.* 2009; Flint *et al.* 2013). This follows from the recognition that many of the remaining biodiversity-rich regions of the world are also homelands to indigenous peoples and local communities (cf. Convention on Biological Diversity). Indigenous and local knowledge holders can represent complementary sources of knowledge, often working at different scales of time and space, addressing different kinds of issues, and informing areas that science has not investigated see e.g. Kalkanbekov & Samakov (2016). As indigenous peoples retain within their knowledge systems an inter-generational memory of fluctuations, trends and exceptional events in relation to the local environment, they can contribute importantly to understanding processes of change, whether these are long-term, global transformation processes or circumscribed local events.

Indigenous and local knowledge is partly available in the published scientific literature, which reports observations from indigenous peoples and local communities about ecosystem characteristics and trends, and drivers of change. However, the integration of indigenous and local knowledge into mainstream science often implies the application of a validation process, which may not be an appropriate way of treating knowledge holders (Agrawal, 2002; Danielsen *et al.*, 2014; Huntington *et al.*, 2002; Kalkanbekov & Samakov, 2016; Nadasdy, 1999). An increasing amount of scientific literature now seeks to produce and co-produce knowledge relevant to local conditions and actors by integrating the complex contextual and socio-ecological knowledge of indigenous peoples and local communities (e.g. Fagerholm *et al.* 2012; Fontaine *et al.* 2014; Sillitoe 2006). IPBES seeks to progress this approach by bringing indigenous and local knowledge into IPBES assessments from the outset. IPBES developed guidance for the integration of indigenous and local knowledge into its assessments that respects not only the diversity and value of this knowledge, but also the rights of indigenous and local communities to share the benefits of knowledge gained from the assessments. IPBES integrates indigenous and local knowledge into its assessments through the appointment of experts with expertise in the subject. In the Regional Assessment for Europe and Central Asia, indigenous and local knowledge was integrated

5. http://www.iucnredlist.org/
6. https://unstats.un.org/unsd/default.htm
7. https://unstats.un.org/sdgs/indicators/indicators-list/
8. http://www.eea.europa.eu/data-and-maps/indicators#c5=&c0=10&b_start=0

through several initiatives supported by a task force on indigenous and local knowledge. A workshop of indigenous and local knowledge holders and experts provided releant case studies and white and grey literature to the assessment authors. It also introduced the assessment to indigenous and local knowledge holders at an early stage. Subsequently, these knowledge holders and experts co-produced the workshop proceedings (Roué & Molnár, 2017) to provide indigenous and local knowledge-relevant information to the assessment. Authors of the assessment, represented by a liaison group on indigenous and local knowledge, reviewed relevant literature, supported by the task force. Furthermore, the assessment report drafts were made available to indigenous peoples and local communities through the external review process.

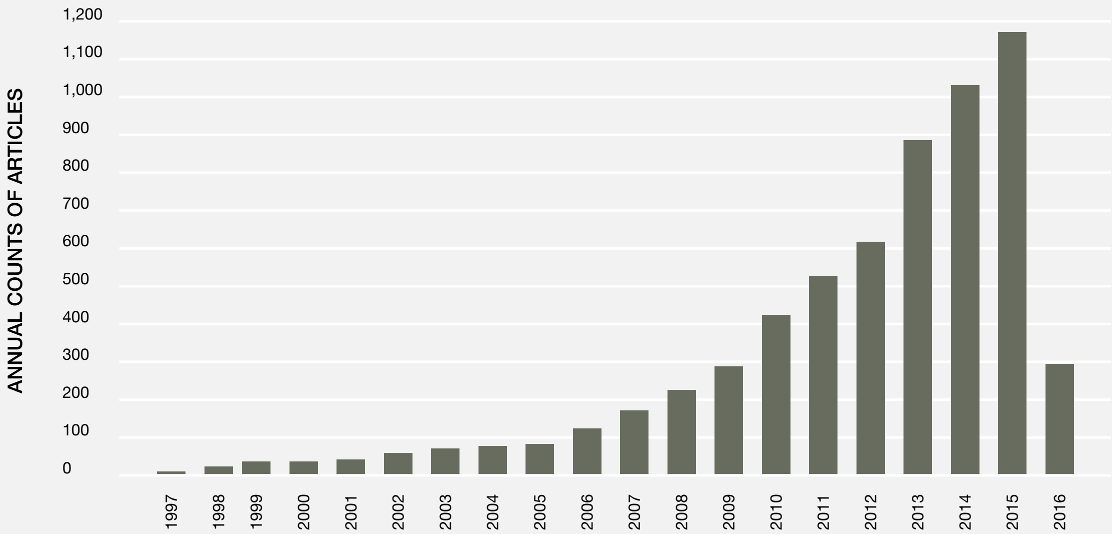
1.5.5 Data and indicators

Current knowledge on nature and its contributions to people is expanding rapidly (see **Figure 1.12** for a bibliographic search on biodiversity and ecosystem services), but is far from complete (see Section 1.6.1 which outlines differences in temporal, taxonomic and spatial coverage across Europe and Central Asia) (Cardinale *et al.*, 2012). Regional and global publically available datasets present opportunities to expand this knowledge (e.g. the IUCN Red List of Threatened Species, Key Biodiversity Areas (specifically Important Bird and Biodiversity Areas (IBAs), and Alliance for Zero Extinction (AZE) sites), Protected Planet, the Global Biodiversity Information Facility). Many efforts have been made to combine data into metrics or indicators that provide aggregate information about status and trends of nature and of pressures. For instance, data such as observations and measurements are used as the basis for deriving indicators, or several measurements can be combined to derive an index.

IPBES uses indicators in conducting its assessments. Indicators are defined here as data aggregated in a manner – quantitative or qualitative - that reflect the status, cause or outcome of an object or process, especially towards targets such as the Aichi Biodiversity Targets or those included under the Sustainable Development Goals. Meaningful indicators require long-term monitoring data. Indicators can help to simplify the enormous complexity of datasets, variables, frameworks and approaches available to IPBES assessments. Complementing other forms of information and knowledge, standardized indicators have the potential to provide a common thread and quantitative point of comparison among assessments. They facilitate the synthesis envisioned for the IPBES global assessment, and ensure comparability and coherence across the regional assessments and between the regional or land degradation and restoration assessments on the one hand, and the

Figure 1 12 **The exponential rise in numbers of scientific articles on the Web of Science produced from the search term [biodiversity AND ecosystem services] (accessed on 26 April 2016).**

The vertical axis shows the annual counts of articles, the horizontal axis the year. In total 7,145 papers were located. Although not a perfect index of the geographical spread of knowledge, the mention of a country (either by the location of authors, e.g. host institution, or the location of the study) gives a reasonable measure of expertise and focus of study on this topic. The countries associated with the most articles were, in descending order: USA, England, Germany, Australia, France, Canada, Netherlands, Spain, Sweden, Italy. Of these, 3,483 papers were associated with European countries, but none were associated with the five countries of Central Asia (limitations ensuing from this biased representation is discussed in 1.7).



global assessment on the other hand. They are useful tools for communicating the results of assessments and are a popular policy support tool used at multiple scales in tracking performance, exploring progress towards policy targets, and understanding the consequences of particular decisions, interventions or even future scenarios (Layke *et al.*, 2012).

Following the IPBES conceptual framework, the Regional Assessment for Europe and Central Asia distinguishes indicators of nature (e.g. biomass), of nature's contributions to people (e.g. production of commercial crops), of contributions to good quality of life (e.g. amount of calories) and of values (e.g. market or cultural values). The assessment has devoted efforts to fully referencing and documenting data sources to allow independent recalculation of indicators and indices and to allow tracing back to their component measures (Ash *et al.*, 2010). It is, however, important to recognize the limitations of a given set of indicators in capturing the complexities of the "real world", since indicators are restricted to what can be measured and for which there are available data. Notably, these limitations are especially significant when it comes to assessing the non-material contributions of nature to people and in quality of life. Moreover, the choice of indicators relates to diverse cultural perspectives. Hence, in IPBES assessments, indicators are subject to critical analysis and review from a diversity of experts. IPBES has consulted widely in arriving at a comprehensive list of biophysical and socio-ecological indicators that cover the conceptual framework (IPBES, 2017).

1.5.6 The role of scenarios and models in the assessment

As other environmental studies have shown (e.g. IPCC 2014; UK NEA 2011; UNEP 2012; MEA 2005), models and scenarios represent effective means of addressing relationships between nature, its contributions to people, and good quality of life for the past, present and future. "Models" are qualitative or quantitative descriptions of key components of a system and of the relationships between those components. "Scenarios" are representations of possible futures for one or more components of a system, especially for the drivers of change in nature and its contributions, including alternative policy or management options (Rounsevell & Metzger, 2010). A scenario archetype describes a group of futures that are deemed "similar" according to the purpose of a specific analysis (Boschetti *et al.*, 2016).

One of the key objectives in using scenarios and models is to move away from a reactive mode of decision-making, in which society responds to the degradation of nature and its contributions to people in an uncoordinated, piecemeal fashion. A proactive mode allows society to anticipate change and thereby to minimize adverse impacts and capitalize on important opportunities through thoughtful adaptation and mitigation strategies. The goals of using scenarios and models in assessments of nature and its contributions to people, are to better understand and synthesize a broad range of data (i) to assess future impacts of global changes, and (ii) to explore the implications of alternative social-ecological development pathways and policy options in support of decision-making (IPBES, 2016b) (see **Figure 1.13**).

Scenarios and models allow research questions to be addressed for which observational evidence is lacking (e.g. model applications across geographic space) or unavailable (e.g. scenarios of the future) (IPBES, 2016b). They allow "what if?" studies to be conducted that cannot be undertaken in empirical experiments, and to explore alternative pathways toward visions or goals for the future (Rounsevell & Metzger, 2010). Thus, scenarios can be exploratory by projecting different pathways from the present situation, or normative by analysing the pathways required to achieve future desired states or goals. The Europe and Central Asia assessment reports on both of these approaches. However, the importance of scenarios extends beyond the scientific or policy arenas. These tools can help to focus investments and technology development, induce societal change, and support engagement with key stakeholders (UNEP, 2012). For example, the Regional Assessment for Europe and Central Asia has access to a large literature base derived from social surveys and participatory scenario development exercises that provide insight into local knowledge (Gramberger *et al.*, 2015; Kok *et al.*, 2015). This involves engagement with a broad range of stakeholders, including primary producers (e.g. farmers, foresters, fishermen) and individuals supporting decision processes (e.g. civil servants, government officials).

Scenarios and models support an understanding of the connections between all aspects of the IPBES conceptual framework. Scenarios and models can be used independently or in combination. An example of a combined use of both are integrated assessment models. Integrated assessment models allow linkages between system components to be explored in interconnected, social-ecological systems (Harrison *et al.* 2016; van Vuuren *et al.* 2012). An economic dimension to biodiversity loss enhances social and ecological considerations and the consequent impacts on the availability of ecosystem services. Thus, integrated assessment models allow experimentation and analysis of co-evolving processes within the social-ecological system across spatial and temporal scales. Particularly, by synthetizing various pieces of disciplinary scientific knowledge and indigenous and local knowledge, models help to qualitatively or quantitatively analyse the cause-effect relationships of, for example, biodiversity loss, and provide outputs for policy-oriented applications (MEA, 2005).

1.6 CHALLENGES IN CONDUCTING THE REGIONAL ASSESSMENT FOR EUROPE AND CENTRAL ASIA

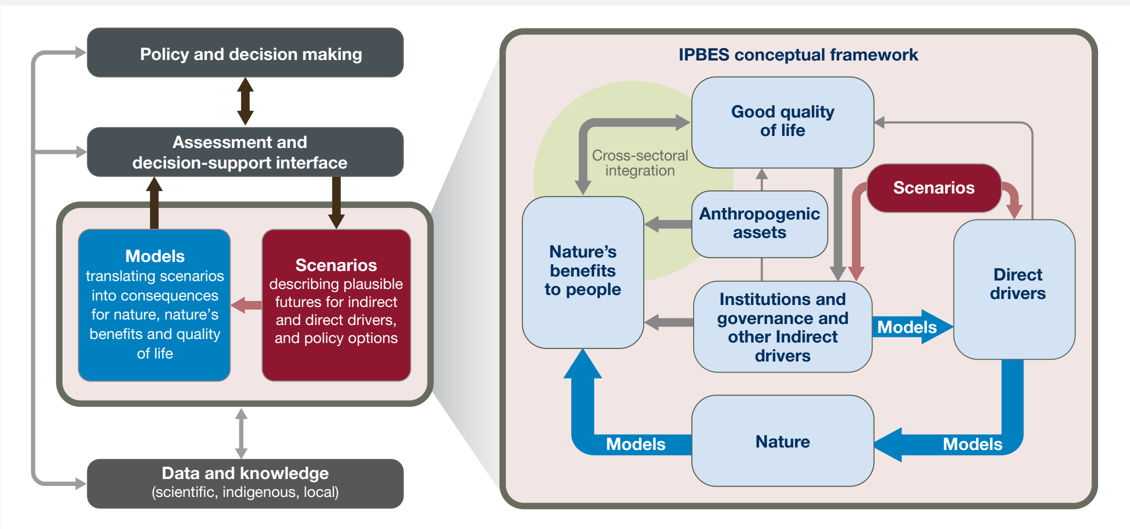
1.6.1 State of knowledge

Data gaps and uncertainties. The Regional Assessment for Europe and Central Asia draws on many different types of data and expert knowledge. Examples include large-scale quantitative data derived from remote sensing, data collected from field sampling of taxa at a range of scales and qualitative data collected by interviewing people. The challenge has been to combine such data into meaningful syntheses while acknowledging the differences in accuracy both within similar methods (in terms of sampling effort) and between methods. Complicating factors include: (i) the fact that the definition of biodiversity is often unclear (Cardinale *et al.*, 2012) and there is a bias towards easily studied taxa (Maier & Feest, 2015); (ii) difficulty in quantifying the different types of anthropogenic and non-anthropogenic values (Pearson, 2016); and (iii) capturing knowledge from regions with little underlying scientific information (although this can be offset in part by the integration of indigenous and local knowledge).

Data collection as an ongoing process. Long-term and widespread data collection both for nature and its contributions to people can be expensive. Although citizen science offers exciting opportunities, it requires the potentially unjustified assumption that volunteers will engage in such projects and that data is of sufficient quality. That said, Europe and Central Asia has a number of ongoing data gathering exercises that can support the improvement of databases in the near term. These include the European Union's project Mapping and Assessment of Ecosystems and their Services, which encourages European Union member States to collect and map spatial data for a number of ecosystem service indicators (biodiversity.europa.eu/maes). The European Environment Agency has created the Biodiversity Information System for Europe (BISE) (http://biodiversity.europa.eu) and Water Information System for Europe (WISE) (http://water.europa.eu/) databases that are continually updated. The European Commission has also funded the development of the Oppla web platform (www.oppla.eu) that is engaging with communities of practice across the science-policy-practice nexus to provide tested methods, data and case study examples of the operationalisation of natural capital and ecosystem services. Oppla is supporting the IPBES process by contributing

Figure 1 13 **An overview of the roles that scenarios and models play in informing policy and decision-making. Source: IPBES (2016b).**

The left-hand panel illustrates how scenarios and models contribute to policy and decision-making through assessments, formal decision-support tools and informal processes. The right-hand panel provides a detailed view of the relationships between scenarios (burgundy arrows), models (blue arrows) and the key elements of the IPBES conceptual framework (light blue boxes; Díaz et al., 2015). Grey arrows indicate relationships between the different elements of the framework. The "cross-sectoral integration" element signifies that a comprehensive assessment of good quality of life will often involve the integration of modelling from multiple sectors (e.g., health, education and energy) addressing a broader range of values and objectives than those associated directly with nature and nature's contributions.



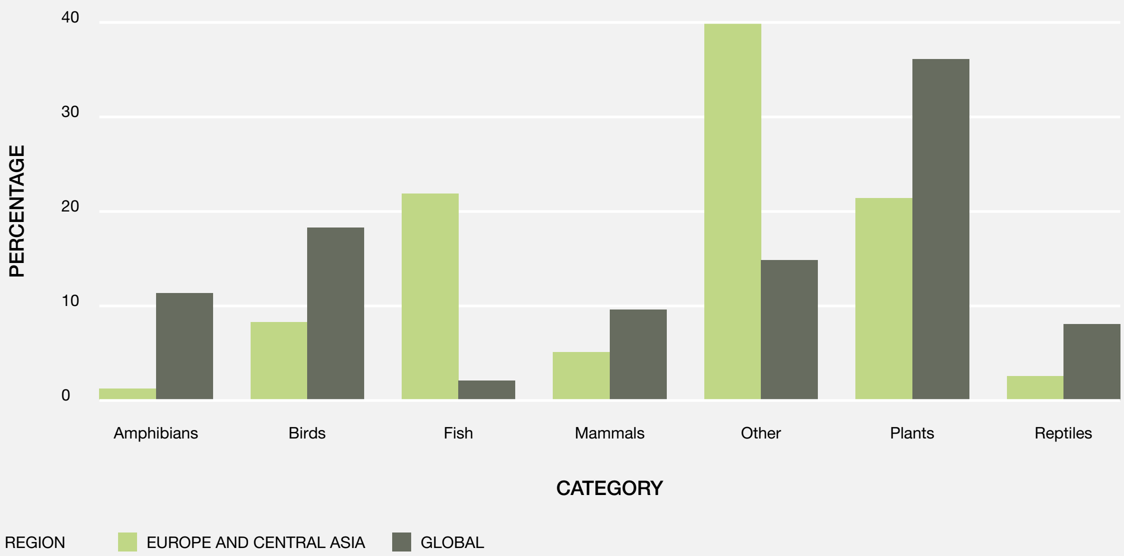
towards the development of the catalogue of policy support tools on the IPBES website (www.ipbes.net). There is also a range of global data collection exercises for biodiversity that can generate data relevant to Europe and Central Asia (e.g. IUCN Red List of Threatened Species) and which, in some cases, already have explicit derivatives (e.g. http://ec.europa.eu/environment/nature/conservation/species/redlist/).

Outside of the European Union, the most consistent peer-reviewed activity for making inventories of the conservation status of endangered species is the development and maintenance of national red lists, while the current trends are usually reported in annual assessments of the state of environment and natural resources (e.g. see Government of Belarus, n.d.; Minprirody of Russia, 2016). Such assessments are based on the outcomes of national programmes of biodiversity monitoring, which are typically run by research institutes of national academies of science or national ministries of environments (or their equivalents). National red lists are based on national lists of endangered species and published as Red Books. The Red Book of Belarus is published about every 10 years (in 1981, 1993, 2006 and the new edition is pending as of 2017) (Government of Belarus, n.d.). Others are one-off publications, such as the Red Book of Russia, published in 2001, while the actual red lists can be available as online databases. In Russia, red lists are kept (and subsequently published as a Red Book) by most of the members of the Federation (FSBI AARI, n.d.-b). In addition, national academies of science or botanical and zoological NGOs or agencies of ministries of environment, maintain national inventories of plant or animal species (e.g. Herbarium of CBG NASB MSKH, n.d.) or of the biodiversity of protected areas (e.g. FSBI AARI, n.d.-a). The initiatives driven by the non-governmental sector are usually less comprehensive, although some ambitious projects should not be overlooked, e.g. BIODAT in Russia (Biodat, 2017) or biodiversity monitoring in the Ukraine (Biodiversity Monitoring in Ukraine, n.d.).

Heterogeneity of data and knowledge across the region. Knowledge of biodiversity is not spread evenly across taxa and there is considerable bias in the coverage of different broad-level taxonomic groups both globally and within Europe and Central Asia (see **Figure 1.14** and **Figure 1.15**). Whilst over 1.64 million species have been described on Earth (Catalogue of Life, 2016) out of a global total of about 8 million (Mora *et al.*, 2011), only 82,954 have been assessed by 31 October 2016 on the IUCN Red List of Threatened Species. At more detailed scales, full assessments have been made of smaller subsets of species within some groups including the following taxonomic groups: amphibians, reef-building corals, chameleons, seasnakes, sharks and rays, tarpons and ladyfishes, parrotfishes and surgeonfishes, groupers, tunas and billfishes, hagfishes, angelfishes, blennies, butterflyfishes, picarels, porgies, pufferfishes, seabreams, sturgeon, wrasses, freshwater caridean shrimps, cone snails, freshwater crabs, freshwater crayfish, lobsters, cacti, conifers, cycads, seagrasses and plant species occurring in mangrove ecosystems (Brooks *et*

Figure 1 14 **Percentage of classified taxa among different broad taxonomic groups classified in Europe and Central Asia compared with the global proportion (note that all categories combined sum to 100%).**

The IUCN Red List has classified proportionally more of some groups of taxa (such as fish) than have been classified globally. Source: Data derived from the IUCN Red List of Threatened Species.



al., 2016). However, some groups have far less coverage, for example plants (7.1%), fungi and protists (<0.001%) and invertebrates (1.4%) (IUCN, 2017).

Europe and Central Asia supports 2,493 species that have been assessed on the IUCN Red List of Threatened Species. Of this group 13% are classified as threatened (Brooks *et al.*, 2016). Of the taxa classified on the global-scale IUCN Red List of Threatened Species the Europe and Central Asia region holds 6.5% (see **Figure 1.16**). There are fewer data available in Central Asia than in the other three subregions. Although there is background knowledge of the role of many taxa in ecosystem functioning, there is far less known about their individual roles in systems; about what would happen if they were removed from food webs; and about the services they provide as individual species. While there is some literature in this area, most is focused on plant studies, e.g. see Cardinale *et al.* (2012); Schwartz *et al.* (2000).

1.6.2 Methodological limitations

Model and scenario uncertainty. Models as tools for quantitative or qualitative descriptions of nature, its contributions to people, and the intra and interrelationships therein, are simplifications of a complex reality. Hence, the limitations of representing complex realities and interactions are embedded within model uncertainty. A number of model inter-comparison exercises have sought to quantify model uncertainty for some components of the natural world (e.g. Alexander *et al.*, 2016b; Prestele *et al.*, 2016). Scenarios, as descriptions of possible futures, contain the inherent uncertainties associated with socio-political, economic, technological and cultural drivers of change that affect nature. Dealing with scenario uncertainties is often done by creating different storylines that cover a range of possible futures, based on different sets of assumptions about future trajectories of key factors (e.g. population, income, technology development or consumption patterns (Rounsevell & Metzger, 2010). Both models and scenarios also share the uncertainty associated with the input data upon which they are based, although the use of confidence intervals can help to make uncertainty more transparent.

Uncertainties in model and input data can often be greater than the differences between the scenarios themselves (Alexander *et al.* 2016b; Dendoncker *et al.* 2008; Prestele *et al.* 2016) leading to conclusions about the need to run multiple ecosystem impact models to capture the full range of model uncertainties. Specific types of models such as integrated assessment models, have additional uncertainties associated with the propagation of errors through coupled sub-modules (e.g. Brown *et al.*, 2015; Dunford *et al.*, 2014). There has been increased interest in moving from scenarios to probabilistic futures of natural and socio-ecological system change, but these methods are in their infancy. Moreover, ascribing probabilities to future events is extremely difficult in practice, in spite of being desirable within a risk management framework. An approach that combines scenarios with likelihoods is based on conditional probabilistic futures (Engström *et al.*, 2016), in which future estimations of the likelihood of different future drivers are conditional on a scenario storyline (Rounsevell & Metzger, 2010).

Figure 1 15 **Percentage of taxa within each taxonomic category that have been classified globally. For example 100% of birds and mammals have been classified, but less than 1% of the known species of fungi.**

Source: Data derived from the IUCN Red List of Threatened Species. Note the "other" category includes all of the remaining taxonomic groups (e.g. fungi).

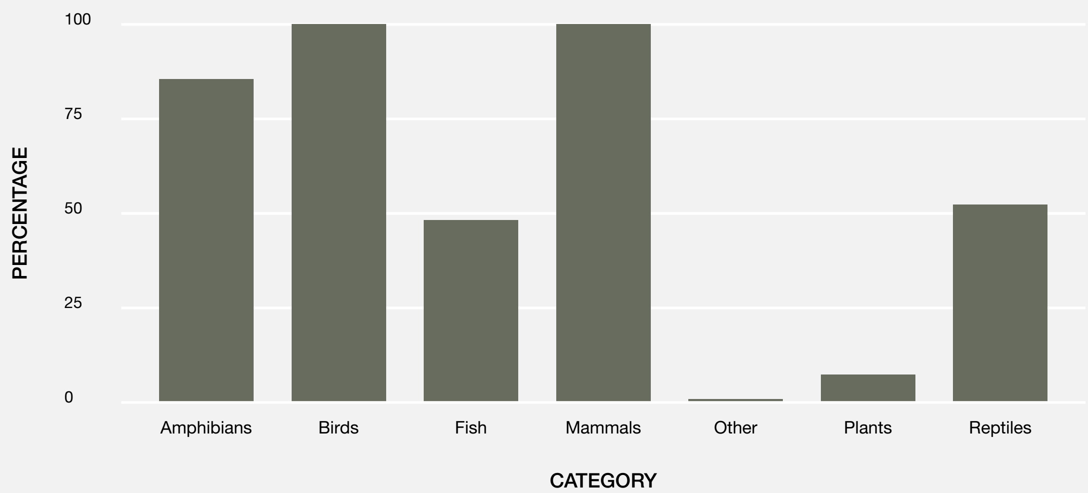
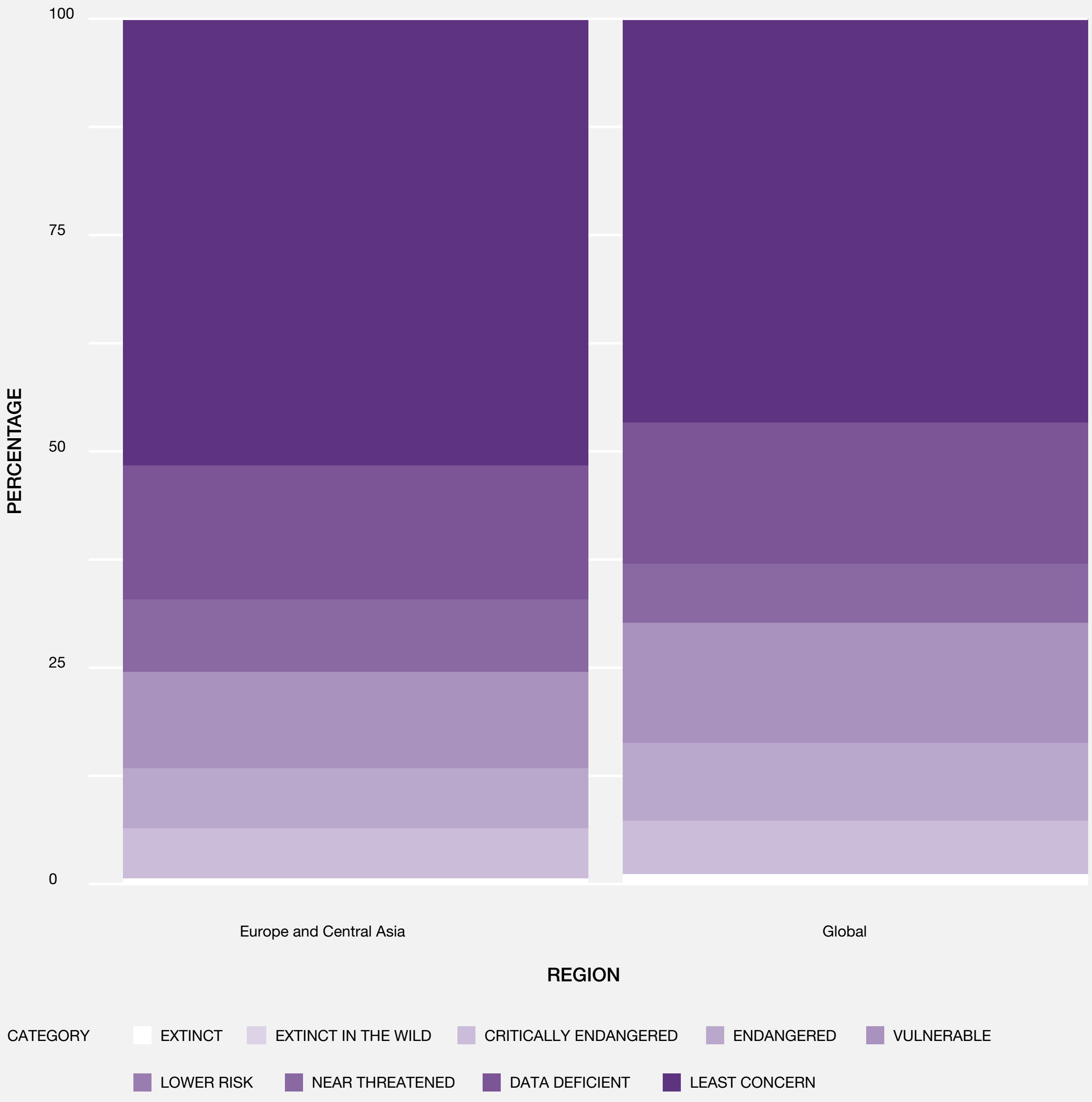


Figure 1 16 **The percentage of species in different extinction categories in Europe and Central Asia compared with the global situation (EX: extinct, EW: extinct in the wild, CR: critically endangered, EN: endangered, VU: vulnerable, LR: lower risk, NT: near threatened, DD: data deficient, LC: least concern).**

Proportionally there are fewer species classified as being at more severe threat from extinction in Europe and Central Asia than globally. Source: Data derived from the IUCN Red List of Threatened Species.



Scale (temporal/spatial/institutional). Assessing diverse values of nature over spatial, temporal and institutional scales is challenging, since these three scale types are interconnected. Spatial scales range from the interactions between the entire Europe and Central Asia region with other global regions, over aggregated large patterns and gradients within Europe and Central Asia down to local communities or smaller. Different organisms operate at different spatial scales, which makes the potential management of different taxa a challenge. Temporal scales involved in the Regional Assessment for Europe and Central Asia also vary: from the overarching sustainability principle spanning across generations, over the assessment of temporal data range (1950-2050, see 1.6.1), down to the varying ranges of data collected over multiple-year sampling campaigns or seasonal variations. A similar trade-off appears between aggregating comparable data for longer periods to capture broad and longer-term trends and the higher precision and specificity of short-term variations.

Institutional scales are a key issue in IPBES. Values will vary greatly between the perspectives of the general public, subnational governments, national Governments, supra-national institutions, NGO's, and businesses (see 1.3.1). Depending on the institutional scale, an assessment may find conflicting or contradicting valuations, with one not necessarily more valid than another. Whether nature, contributions of nature, or good quality of life are considered, different values between scales persist, as do interactions across scales. This suggests caution when synthesizing and interpreting findings of the assessment from a specific spatial, temporal and institutional context.

Difficulties in harmonizing data and indices, limitations of indices, knowledge types, and data types. Given the logistical and resource challenges in monitoring biodiversity or nature and its contributions to people (see Section 1.6) it is not surprising that indicators are commonly used to represent a wider suite of organisms or contributions. Such approaches are common in the Regional Assesment for Europe and Central Asia and, hence, it is important to mention general issues when interpreting such data. There are limitations in the use of ecological, economic and social indicators (e.g. Selomane *et al.*, 2015; Stephens *et al.* 2015; Uuemaa *et al.*, 2013), which are important to recognise. Moreover, as the assessment draws upon a very diverse range of sources from many different places, harmonizing them across the whole of the region was a major challenge.

Gathering indigenous and local knowledge and integrating this knowledge within the assessment. A major challenge is the difference in scale between the regional scope of the assessment and the nature of indigenous and local knowledge, which is grounded in local territories. Hence, seeking representativeness of the highly heterogeneous and complex indigenous and local knowledge covered by the scale of the assessment was a substantial challenge. The Regional Assessment for Europe and Central Asia sought to resolve this scale issue by collating messages from individual publications on indigenous and local knowledge and by utilising available reviews (e.g. Hernández-Morcillo *et al.*, 2014) in highlighting common aspects of the interlinkages between nature, its contributions to people and good quality of life. The indigenous and local knowledge produced from a specific IPBES dialogue workshop (Roué & Molnár, 2017) aimed to illustrate, not represent, the complexity of understanding, values and worldviews held by indigenous and local knowledge holders in the Europe and Central Asia region. For these reasons, the indigenous and local knowledge available for the Europe and Central Asia assessment remained at an early stage of methodological development.

Epistemology and expert judgement (by authors) in the assessment process. IPBES assessments use a four-box model of confidence attributed to their key findings (see Section 1.5.1) based on evidence and agreement and summarised in four main confidence terms. This ensures consistency in the communication of confidence across chapters and assessments. However, the use of confidence terms depends strongly on the author team's expert judgement as to the quantity and quality of supporting evidence and on the level of scientific agreement. This is why a reference to the chapter section is also provided with each key finding.

1.6.3 Issues beyond the scope of this assessment

Emerging questions beyond the scope of the assessment. While the assessment presents the best available information on nature and its contributions to people, it does not analyse available datasets to test new hypotheses or to validate existing ones. During the development of the assessment, new natural or human impacts on nature may have emerged. As the assessment process involves the use of current information, however, any new aspects cannot form part of this regional assessment.

Time cut-off for evidence/published literature. The literature and evidence sourced for this assessment has a standard timeframe, extending from 1950 to the end of April 2017.

Intrinsic values. The IPBES conceptual framework, unlike the ecosystem services concept, includes intrinsic values. The term intrinsic value has many different meanings (Batavia & Nelson, 2017). For this assessment, we follow the definition provided by Jacobs *et al.* (2016) and Pascual *et al.* (2017), which refers to inherent value, i.e. *the value something has independent of any human experience or evaluation*. Since intrinsic value can be recognized, but not quantified, by humans it is not the target of any valuation process or assessment.

Disclaimer and liability - drawing inferences from general patterns. It is important to recognise that, while broad patterns exist, their exact nature in specific contexts may differ. For example, while general patterns of increased ecosystem functioning with increased biodiversity have been widely reported, mostly from experimental botanical and zoological studies, exceptions to this general rule also need to be considered (Hector & Bagchi, 2007; Cardinale *et al.*, 2012; Schwartz *et al.*, 2000). Moreover, many of the relationships reported between drivers, nature (biodiversity) and nature's contributions to people (including ecosystem services) in the literature are associative (e.g. correlative) and thus, in contrast to experimental evidence, not necessarily causal. Particular caution is needed when applying existing knowledge to novel situations, because extrapolating outside of the bounds of where data were collected, might be misleading. It is worth noting, however, that methods that formally acknowledge uncertainty (e.g. scenario testing and modelling) are useful in this respect.

1.7 ROADMAP TO THE ASSESSMENT

1.7.1 What each of the six chapters covers

Chapter 1 sets the scene. Chapter 1 offers a roadmap to all chapters of the Europe and Central Asia assessment. It explains how the assessment has been developed and introduces both the purpose of the assessment and the geographical characteristics of the region. The chapter also provides an overview of the content, and introduces the most important concepts and methods used in the following chapters.

Chapter 2 shows how nature contributes to people's quality of life. Chapter 2 addresses trends in nature's contributions to people and the interactions between natures contributions to people and their quality of life. It assesses the status, trends and future dynamics of nature's contributions to people including material, regulating and non-material contributions. It also assesses the different impacts of changes in these contributions to the quality of life of people in terms of instrumental and relational values.

Chapter 3 provides insight into the relationship between biodiversity and ecosystem functioning and sevices, and into the dynamics of the major ecosystems of Europe and Central Asia. Chapter 3 assesses the existing knowledge on the relationship between biodiversity and ecosystem functioning and ecosystem services, and on the status, trends and future dynamics of nature and the processes underpinning nature's contributions to people. It deals with the entire scope of biodiversity including varying functional characteristics of taxa as well as interactions among living organisms in terrestrial and marine systems and trends in important ecosystem functions. It provides a synthetic analysis of the impact of drivers on the major ecosystems (units of analysis) and taxa.

Chapter 4 documents the drivers of change. Chapter 4 documents the status and trends in both direct and underlying indirect drivers of change that affect nature and its contributions to people across subregions and units of analysis.

Chapter 5 explores possible futures. Chapter 5 provides an integrated and cross-scale analysis of interactions of the natural world and human society. It explores plausible futures that take account of different values through scenario archetypes. It also assesses visions for the future and provides an analysis of the pathways that could lead to realising these visions.

Chapter 6 indicates opportunities in governance and policy. Chapter 6 explores governance options and institutional arrangements for better consideration of nature and nature's contributions to people in public and private decision-making. It also considers the opportunities for a wide range of actors and sectors for the conservation and sustainable use of nature, and the sustained provision of nature's contributions to people in Europe and Central Asia. It highlights areas for successful integration and assesses major categories of policy instruments.

1.7.2 How do the chapters address the policy-relevant questions?

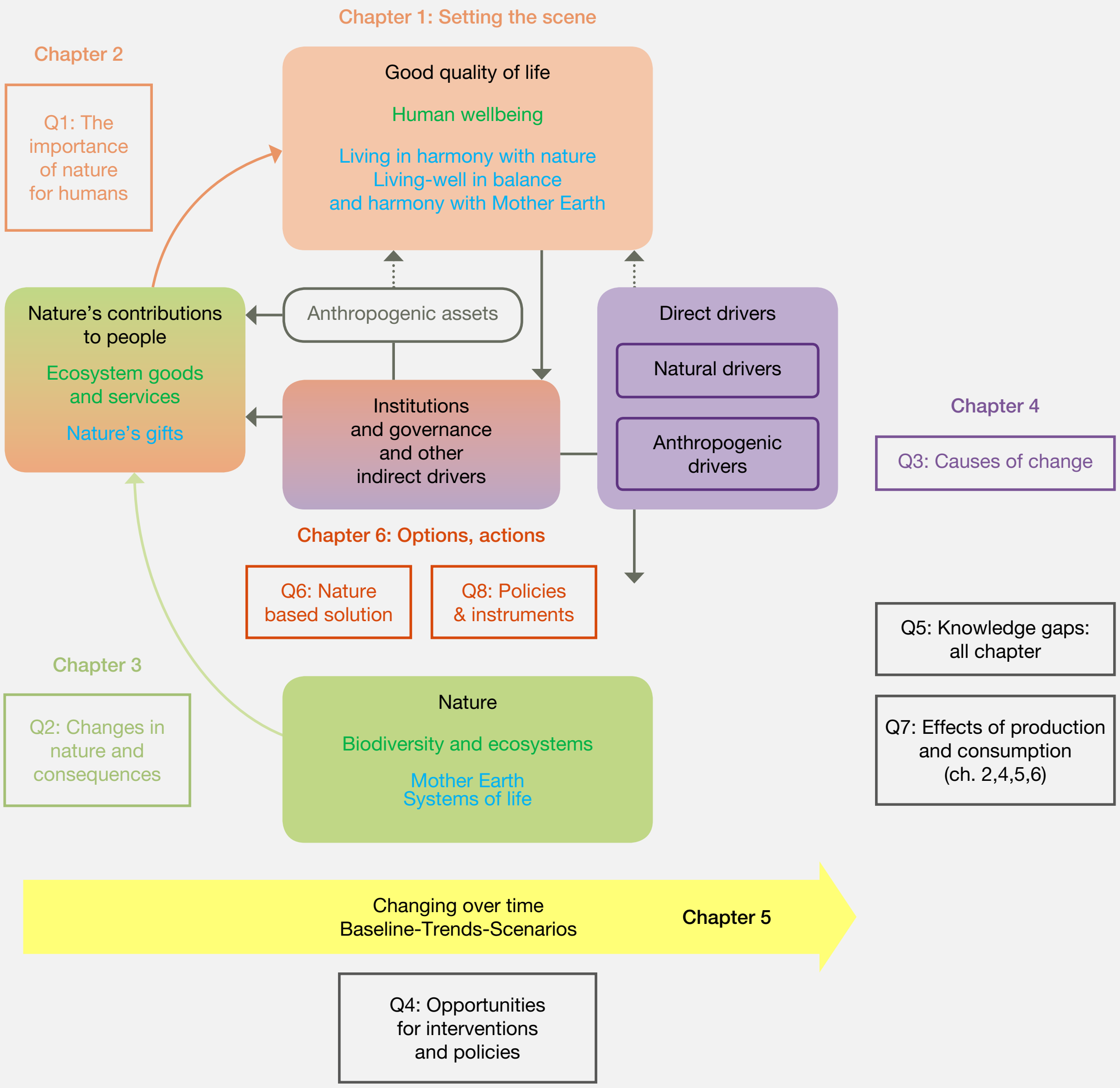
The five general IPBES policy questions on: urgent worldwide knowledge demands on the importance of nature for the human species (Question 1); the current change of nature and its consequences (Question 2); the causes of this change (Question 3); opportunities for policies and interventions (Question 4); and the identification of related knowledge gaps (Question 5) are addressed in Chapters 2 to 5 of this assessment. Questions 1 to 4 guide Chapters 2 to 5, and question 5 on knowledge gaps is addressed as a sub-section in each of Chapters 2-5. Chapter 6 provides governance options for private and public actors based on the findings of Chapters 2 to 5, and it addresses the Europe and Central Asia specific questions on nature-based solutions (Question 6), and how sectoral policies and innovative policy instruments encourage opportunities arising from the contributions of nature to good quality of life (Question 8). Question 7 on the effects of production and consumption and cross-regional linkages is covered by Chapters 2 (see e.g. 2.2.4), 4 (indirect drivers), 5 (scenarios) and 6 (governance options) (see **Figure 1.17**).

The responses to these questions, reflecting the requests of different stakeholders, are highlighted within each section in the key findings. Chapter 1 sets the scene for the different chapters by introducing the important issues discussed in the other chapters, which lead to the assessment's main messages. Transparently presenting the broad evidence base for these main messages and key findings is considered essential for not only the credibility, but also the legitimacy and reliability, of the Regional Assessment for Europe and Central Asia.

1.7.3 What will the Regional Assessment for Europe and Central Asia lead to?

Scientifically sound assessment reports review, summarize and evaluate the evidence related to a specific problem, and provide conclusions that are accessible not only across different disciplines of science, but also for decision-makers and the general public. Previous examples have shown the importance of such assessments. The Intergovernmental Panel on Climate Change (IPCC) reports, for example, have played a major role in securing international consensus for the Paris climate agreement and the Sustainable Development Goals. The IPBES pollination assessment has resulted in a substantial rise in public awareness of the loss of pollinators and has received significant policy interest. Both of these assessments have identified important knowledge gaps and have, therefore, increased research (and funding) interest in scientific studies address these gaps. Since the IPBES Regional Assessment for Europe and Central Asia responds to a direct request from the Governments of IPBES member States, it aspires to inform decision-makers at local, national and international levels, to raise public awareness and to stimulate new research.

Figure 1 17 **Roadmap linking the chapters to the IPBES conceptual framework and the requests by Governments and multilateral environmental agreements. Source: Own representation.**



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CHAPTER 2

NATURE'S CONTRIBUTIONS TO PEOPLE AND QUALITY OF LIFE

Coordinating Lead Authors:

Berta Martín-López (Spain/Germany), Andrew Church (United Kingdom of Great Britain and Northern Ireland)

Lead Authors:

Esra Başak Dessane (Turkey), Pam Berry (United Kingdom of Great Britain and Northern Ireland), Claire Chenu (France), Mike Christie (United Kingdom of Great Britain and Northern Ireland), Magali Gerino (France), Hans Keune (Belgium), Elisa Oteros-Rozas (Spain), Sandrine Paillard (France), Axel G. Rossberg (United Kingdom of Great Britain and Northern Ireland/Germany), Matthias Schröter (Germany), Alexander P. E. van Oudenhoven (The Netherlands)

Fellow:

Elena Osipova (Russian Federation)

Contributing Authors:

Armağan Aloe Karabulut (Turkey), Başak Avcıoğlu Çokçalışkan (Turkey), Adem Bilgin (Turkey), Tom Breeze (United Kingdom of Great Britain and Northern Ireland), Elena Bukvareva (Russia), Pierre Duez (Belgium), Daniel P. Faith (Australia), Ilse Geijzendorffer (The Netherlands/France), Arjan Gosal (United Kingdom of Great Britain and Northern Ireland), L. Jamila Haider (Austria/Sweden), Conor Kretsch (United Kingdom of Great Britain and Northern Ireland), Jorge Lozano (Spain/Germany), Patrick Meire (Belgium), Jasmin Mena Sauterel (Germany), Markus Meyer (Germany), Marcos Moleón (Spain), Zebensui Morales-Reyes (Spain), Bram Oosterbroek (The Netherlands), Simon G. Potts (United Kingdom of Great Britain and Northern Ireland), Vitalija Povilaityte-Petri (Lithuania/Belgium), Adriana Ruiz Almeida (Spain), José A. Sánchez-Zapata (Spain), Stefanie Sievers-Glotzbach (Germany), Ewa Siwicka (Poland/United Kingdom of Great Britain and Northern Ireland), Alexey Sorokin (Russian Federation), Isabel Sousa Pinto (Portugal), Erik Stange (Norway), Pawel Szymonczk (Poland/United Kingdom of Great Britain and Northern Ireland), Marija Vugdelic (Montenegro)

Review Editors:

Francis Turkelboom (Belgium), Mimi Urbanc (Slovenia)

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CHAPTER **2**

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EXECUTIVE SUMMARY

Nature's contributions to people in Europe and Central Asia have changed markedly since the 1950s, promoting changes in the quality of life of its societies (*well established*). The ecosystems of Europe and Central Asia are currently delivering multiple contributions, although there is evidence of negative trends between 1960 and 2016 in the majority of regulating and some non-material contributions (*well established*) (2.2.1, 2.2.3, 2.2.5). Of nature's contributions to people in Europe and Central Asia, about 44% have been assessed as declining, particularly regulating contributions and learning derived from indigenous and local knowledge (*well established*) (2.2.1, 2.2.3, 2.2.5). The increasing trends in the delivery of specific material contributions, such as food and biomass-based fuels, have come at the expense of the long-term deterioration of regulating contributions (*well established*) (2.2.1, 2.2.2, 2.2.5). Some key regulating contributions, such as habitat maintenance, pollination, regulation of freshwater quantity, regulation of freshwater quality, formation and protection of soils, and regulation of floods decreased due to intensified management practices designed to produce more crops, livestock, aquaculture, woodfuels and cotton. Furthermore, the increasing demand in Western and Central Europe for food, wood products and biofuels is causing the impairment of ecosystems and nature's contributions to people in other regions of the world (*established but incomplete*) (2.2.2.3, 2.2.4, 2.3.4).

Trends of nature's contributions to people are consistent across the subregions of Europe and Central Asia. Declining trends are reported in Central Europe (61% of the scientific evidence), Western Europe (55%), Eastern Europe (54%) and Central Asia (48%). Increasing trends are mostly reported for Western Europe (35% of scientific evidence) (*established but incomplete*) (2.2.5).

Across all subregions of Europe and Central Asia, continuing declines in nature's capacity to provide regulating contributions to people since the 1960s are of particular concern, especially in the cases of nursery habitats of fish species and breeding and overwintering areas for migratory species, pollination, freshwater flow regulation, freshwater quality regulation, regulation of floods, soil quality and erosion control (*well established*) (2.2.1). However, since the 1990s an improvement in some of these and other regulating contributions from nature to people (i.e. air quality regulation and removal of animal carcasses) in Western and Central Europe occurred due to the implementation of European Union policies (*established but incomplete*) (2.2.1). Since the 1960s, the impacts of land-use change on natural ecosystems and inappropriate management practices in agriculture and fisheries have caused declines in pollinators (2.2.1.2), in regulation of freshwater quality (2.2.1.7), in erosion control and soil quality (2.2.1.8) and in fluvial flood regulation (2.2.1.9) in the four subregions (*well established*). The increases in forest area since the 1960s across parts of Europe and Central Asia have increased carbon storage in those areas, contributing to climate regulation. Increased urban green infrastructure improved the regulation of air temperature in cities and air quality regulation (2.2.1.3, 2.2.1.4). The declines of seagrass beds and kelp forests due to global warming, fishing pressure and marine pollution in the Atlantic, Baltic and Mediterranean Seas have negative consequences for the provision of nursery habitats for fish (2.2.1.1) and regulation of ocean acidification (2.2.1.5) (*established but incomplete*). Nevertheless, these marine habitats may increase in the Arctic Ocean led by seawater warming and will possibly enhance the regulation of ocean pH in the future (2.2.1.5) (*established but incomplete*). After the sharp declines of vultures since the 1950s, the recent recovery of vertebrate scavengers mainly due to natural recovery of populations and also the reintroduction and conservation programmes in Western Europe, has enhanced the removal of animal carcasses (2.2.1.5) (*established but incomplete*).

Nature's material contributions to people in Europe and Central Asia are highly diverse, including food, energy supply, materials that enter industrial processes, and medicinal resources (*well established*) (2.2.2.1). There are inherent trade-offs amongst those material contributions derived from different forms of land use and management. Trends in the use of material contributions reflect socio-economic change and market forces, but also limits to natural capacity (2.2.2.1) (*established but incomplete*). Intensification of management practices, technology, and investment have led to higher production levels for particular material contributions with high market value, including food and

biofuels (2.2.2, 2.3.5). The production of some products has experienced substantial growth in the region, particularly in Eastern Europe and Central Asia, including maize, cereals, fruits and vegetables, and meat (*well established*) (2.2.2.1.1). Capture of marine wild fish in the region reached a peak in the 1990s and since then has reduced by about 30% to permit recovery of stocks (*established but incomplete*) (2.2.2.1.2). This reduction was compensated for by a rapid expansion of aquaculture (*well established*) (2.2.2.1.2). Intensive extraction of food and materials combined with policy failures has driven the decline of natural resources, particularly of wild fish and maerl (2.2.2.1.2, 2.2.2.3.3). Also, the loss of indigenous and local knowledge has affected the use of medicinal plants and guard dogs for protecting livestock (2.2.2.3.4, 2.2.2.4). As a result of management for sustainable use, wood production in Europe and Central Asia has been stable since the 2000s and currently about 23% of this production is used as woodfuel (2.2.2.2). Production of biofuel and biodiesel remains small relative to woodfuel and the potential for expansion is limited due to impacts on ecosystems (*established but incomplete*) (2.2.2.2).

Nature's non-material contributions to people in Europe and Central Asia have implications for quality of life by providing opportunities for learning, inspiration, identity development, and physical and psychological experiences (*well established*) (2.2.3). Different measures for these contributions show contrasting trends and geographical unevenness across Europe and Central Asia (*well established*) (2.2.3). There are contrasting trends in measures for learning and inspiration. Informal learning based on interactions with nature has expanded partly due to increases in recreation and tourism linked to sustainable environmental management that promotes knowledge of nature (*well established*) (2.2.3.1.1). Other forms of informal learning and knowledge are in decline and can be linked to a loss of indigenous and local knowledge and linguistic diversity which is the basis of different forms of indigenous and local knowledge relating to nature. Across Europe and Central Asia, 12% of all languages are categorized as critically endangered and 14% as vulnerable (*well established*) (2.2.3.1.2). The overall evidence for physical and psychological experiences indicates an increasing trend. The demand for nature-based recreation and leisure has grown in Western Europe and in 2015 31% of European Union adults surveyed indicated that nature is their main reason for going on holiday, up from under 10% in 2008 (*well established*) (2.2.3.2, 2.3.3). Thirty-eight per cent of the European Union is characterized by a high outdoor recreation potential, but the places that can be used for nature-based recreational and aesthetic experiences in Western Europe are becoming fewer due to land use changes including urbanization, land-use intensification, rural abandonment, disappearance of common lands and water pollution (*well established*) (2.2.3.2). The support of identities relates to virtues and principles rather than to enjoyment resulting from physical and psychological experiences, but it is not possible to identify clear trends for this contribution from nature (*well established*) (2.2.3.3). Nevertheless, it is reflected in attitudes towards nature and, in the European Union, 76% of people agreed with the statement that "we have a responsibility to look after nature" (*well established*) (2.2.3.2). In support of their identities, people attribute an existence value to species and ecosystems, especially iconic and emblematic species (*well established*) (2.2.3.3). Species found in European and Central Asian forests, such as moose; and in marine waters, such as whales, are particularly highly valued (*established but incomplete*) (2.2.3.3). The maintenance of options is a contribution that depends on the existence of biodiversity, and its status and trends are reflected by those of biodiversity measures, including phylogenetic diversity. Society's appreciation of maintenance of options is only moderate, as indicated by previous assessments of Europe and Central Asia, and by the recent call for greater appreciation of maintenance of options from conservation NGOs (*established but incomplete*) (2.2.3.4).

Europe and Central Asia is currently food secure despite a decline in pollination; degradation of agricultural soils; decreases in water availability; increases in floods and droughts; decreases in wild fish catch; competition from agriculture with other land uses such as forests and urbanization; and loss of supporting farmer identity and food-related indigenous and local knowledge (*well established*) (2.3.1.1, 2.2.1.2, 2.2.1.5, 2.2.1.7, 2.2.1.8, 2.2.2.1, 2.2.3.1). This has been possible because of the mechanization and intensification of agriculture and because the region depends partly on imports of food and agricultural inputs as well as on large-scale land acquisition abroad (*established but incomplete*) (2.3.1.1). Food availability depends on different contributions from nature, particularly food production, protection of soils, regulation of water quantity and pollination. Food production from agriculture in Europe and Central Asia increased by 56% between the 1960s and the 1990s until the dissolution of the Soviet Union, the Yugoslav wars and the MacSharry reform of the European Union Common Agricultural Policy. Because of efforts to reduce surplus production in Western Europe between the 1960s and the 1990s, agricultural production has declined by 33% since the 1990s (*well established*) (2.2.2.1.1). This has been offset by an increase in imports from outside of Europe and Central Asia, primarily from South America and Africa (2.2.2.1.2, 2.2.4) and by large-scale acquisition of land in other regions of the world (0.63% of croplands worldwide, 0.57% acquired by countries from Western Europe) (2.3.1.1). There has also been a decrease in wild fish catches since the 1990s, partly due to more sustainable management practices. This decrease was compensated by an increase of 2.7% in fish production from aquaculture since 2000 (*established but incomplete*) (2.2.2.1.2).

Food quantity and quality depend upon soil quality, regulation of water flows and floods, pollination and food-related indigenous and local knowledge. Erosion of agricultural soil affects about 25% of agricultural land in Europe and Central Asia, and a decline of organic matter in agricultural soils has triggered decreased productivity in Central Asia (*established but incomplete*) (2.2.1.8). However, between 2000 and 2010, erosion control in the EU-27 increased by an average of 9.5%, and by 20% for arable lands, partly due to agricultural practices promoted by the Common Agricultural Policy (2.2.1.8). Since 1980, frequency and severity of floods have increased across Europe and Central Asia due to heavy precipitation events and decreased capacity to regulate fluvial floods (*established but incomplete*) (2.2.1.9), thus impacting crop productivity. Since 1961, Mediterranean and Central Asian countries have become more pollinator dependent due to their substantial production of highly pollinator-dependent fruits (*established but incomplete*) (2.2.1.2). However, the diversity, occurrence and abundance of wild insect pollinators have declined since the 1950s and severe losses of western honey bee populations have occurred in many Western European countries and former-USSR countries since 1961 (*established but incomplete*) (2.2.1.2). The loss of indigenous and local knowledge related to farming can affect food security by undermining intergenerational knowledge exchange within farming communities and contributing to the depopulation of rural areas (*established but incomplete*) (2.2.3.1.2, 2.2.3.2.1, 2.3.1.1).

Nature contributes in a range of ways to safe drinking water that is currently ensured for 95% of the people in Europe and Central Asia, despite a 15% decrease in water availability per capita since 1990 (*well established*) (2.3.1.3). Access to clean water depends strongly on the regulation of both water quality and water quantity. These two regulating contributions have been impaired by pollution and overexploitation of freshwater bodies and the decrease in the areal extent of floodplains and wetlands (*well established*) (2.2.1.6, 2.2.1.7). However, the rate of decrease in water quality has lessened in the last decade in Western Europe, due to the implementation of the Water Framework Directive (*established but incomplete*) (2.3.1.3, 2.2.1.7). Access to drinking water is currently sufficient in Western and Central Europe (>99% of people), while Eastern Europe (95%) and Central Asia (85%) have had lower, but increasing, access to drinking water since 1995 (*well established*) (2.3.1.3). Water extraction as a percentage of renewable water resources decreased from 30 to 15% between 1993 and 2012 (*well established*) (2.3.1.3). However, overall water availability per capita has decreased by 15% since 1990, while this decrease was 42% since 1960 in Western Europe (*well established*) (2.2.1.5). Water scarcity in most countries of the European Union has decreased slightly since the 1990s, but over-exploitation still threatens freshwater resources (*established but incomplete*) (2.3.1.3). The Mediterranean region is facing scarcity of water (*established but incomplete*) (2.3.1.3).

Access to sufficient quantities of clean water also depends on water quality and water flow regulation (*well established*) (2.2.1.6, 2.2.1.7). Water quality regulation has decreased in the region since the 1950s, due to the declining naturalness of freshwater ecosystems and areal extent of wetlands (*well established*) (2.2.1.7). Between 2009 and 2015, the coverage of water bodies in the European Union with a “good ecological status” decreased from 43% to 32% (2.2.1.7). However, water quality in Western Europe has improved during the last decade due to the implementation of the Nitrates and Water Framework Directives (*well established*) (2.2.1.7). In Central and Eastern Europe, water quality is decreasing (*well established*) due to increased water pollution and the conversion of natural ecosystems (2.2.1.7). Water flow regulation shows mixed, but generally decreasing trends for the region, particularly in Western and Central Europe between 2000 and 2011 (*established but incomplete*) (2.2.1.6).

Some areas of research into linkages between nature and health have illustrated the value of biodiversity and most of nature’s contributions to people for human health (*well established*) (2.3.2). These linkages include the contribution of biodiversity and nature’s contributions to people to contemporary and traditional medicine, and to healthy nutrition through dietary diversity and support for food security (*well established*) (2.2.2.4, 2.3.2, 2.3.2). Dietary diversity, however, is not necessarily a good indicator of healthy nutrition: a relatively high diversity of unhealthy diets in Western Europe through increases in fat and protein supply can contribute to increases in obesity rates (*well established*) (2.3.1.1). Other linkages between nature and health include the influence of biodiversity and nature’s contributions to people on infectious disease risk (*unresolved*) (2.3.2.2), and the value of green spaces in promoting mental health and physical fitness (*established but incomplete*) (2.3.2.1). There has been a decline in indigenous and local medical knowledge across Europe and Central Asia (*well established*) (2.2.2.4), but medicinal plants have been increasingly used in complementary and alternative medicine outside of local and indigenous communities in recent decades (*established but incomplete*). Unsustainable patterns of exploitation threaten the survival of some medicinal plants (*established but incomplete*) (2.2.2.4).

Urban dwellers across Europe and Central Asia value green spaces for health, psychological well-being and emotional attachment (*well established*) (2.2.3.2). Increased urbanization poses significant challenges for human health – including a rise in non-communicable diseases associated with modern lifestyles, such as obesity, cardiovascular diseases, depression and anxiety disorders, and diabetes (2.3.2). Efforts to increase access of urban dwellers to green space and open countryside may help address some of these health issues through beneficial physical and psychological experiences (*established but incomplete*), though more research is needed into differentials between communities and social groups in terms of access to greenspace and the health benefits obtained from them (*unresolved*) (2.3.2).

The value of nature's contributions to cultural heritage, identity and stewardship is indicated through people's engagement with nature for leisure and tourism, spiritual and aesthetic experiences, gathering of wild food, learning, developing indigenous and local knowledge and also by the desire of people, social groups and governments to protect and conserve areas and iconic species even when they do not use them (*well established*) (2.2.3). There has been a loss in knowledge of ecosystems and species linked to a marked general decline in indigenous and local knowledge and linguistic diversity (*well established*) (2.2.3.1.2). Protected areas, as indicators of valued and iconic places, have grown in number and extent so that globally the proportion of the Earth's surface protected has risen from 8% in 1990 to 14.7% in 2016 (*well established*) (2.2.3.2). The designation of protected areas, however, is geographically uneven in Europe and Central Asia with relatively few areas in Central Asia (2.2.3.3, 2.3.4) (*well established*). Protected areas and other green spaces have increasingly been used since 1950 for tourism, leisure, formal and informal learning with outdoor learning often providing additional value for skill and knowledge development for teachers and learners (*well established*) (2.2.3.1, 2.3.3). In some countries interactions between material and non-material contributions to cultural practices enhance identity, such as berry and mushroom picking (*well established*) (2.3.3). Shepherds attach considerable identity value to guard dogs, especially to breeds associated with particular geographical areas (*well established*) (2.2.2.3.4). The belief systems of many peoples are strongly influenced by spiritual and religious interactions and ecosystems are viewed as alive in many indigenous and local knowledge systems in Europe and Central Asia (*well established*) (2.3.3). The decline in linguistic diversity weakens indigenous peoples' stewardship, heritage and identity especially among young members of these communities as it results in a loss of knowledge of ecosystems and species (*well established*) (2.2.3.1.2, 2.3.3.). Indigenous and local knowledge has significant value for some local communities in Europe and Central Asia contributing to land rights claims, fisheries management and economic development linked to visitors consuming local products and experiencing lifestyles linked to indigenous and local knowledge (*established but incomplete*) (2.3.3).

Nature in Europe and Central Asia is important for delivering a wide range of contributions, which are valued by people. These values are expressed in multiple dimensions, including through economic markets, willingness to pay or cultural preferences (*well established*) (2.3.5). Integrated valuation approaches demonstrate that nature's contributions have substantial monetary and non-monetary values that can inform policy goals (*well established*) (2.3.5). Regulating and non-material contributions are as important in terms of value as material contributions (*established but incomplete*) (2.3.5.2, 2.3.5.3). Traditionally, nature's material contributions have been valued based on market prices and in this assessment monetary values are standardized to a common currency and base year (International $ 2017). Mean net profits of nature's material contributions to people from agricultural production across EU-28 countries ranged from $233 / ha / yr (cereals) to $916 / ha / yr (mixed crops), while wood supply from forests was $255 / ha / yr (*established but incomplete*) (2.3.5.1). Evidence from Europe and Central Asia demonstrates that nature's regulating contributions to people also have significant non-market monetary values and these are higher than non-market values for material and non-material contributions (*established but incomplete*) (2.3.5.2, 2.3.5.3). For example, habitat creation and maintenance is estimated to have a median value of (2017) International $ 765 / ha / yr (*unresolved*) and regulation of freshwater and coastal water quality is estimated at (2017) International $ 1965 / ha / yr (*established but incomplete*) (2.3.5.2). Nature's non-material contributions to people, such as physical and psychological experiences have a median value of (2017) International $ 1117 / ha / yr (*unresolved*), while other non-material contributions were demonstrated to be the most valued contributions by people in social-cultural valuations (*established but incomplete*) (2.3.5.2, 2.3.5.3). The (often large) ranges in values of nature's contributions reflect heterogeneity of preferences across regions, social groups, local contexts and methodological differences (*established but incomplete*) (2.3.5.2, 2.3.5.3). This assessment has demonstrated the importance of nature's contributions to people in terms of their market, non-market monetary and socio-cultural values. Hence, there is strong evidence to support the inclusion of the plurality of values in policy goals such as the Aichi Biodiversity Targets and Sustainable Development Goals (2.3.5.4).

Nature's contributions to quality of life of societies in Europe and Central Asia are not equally experienced

across different locations and social groups across the region, resulting in distributional inequity (*established but incomplete*) (2.3.4). The benefits derived from nature's contributions and the harm from a loss of nature's contributions are geographically uneven, which creates distributional inequity as the impacts on quality of life of changes in ecosystems are linked to where beneficiaries live (*established but incomplete*) (2.3.4). There is also a time component as ecosystem service utilization today may destroy the basis for future service provision (*established but incomplete*) (2.2.3.4). 15% of people in Central Asia lack access to safe drinking water compared to only 1% in Western Europe (*well established*) (2.3.1.3, 2.3.4.2). However, intra-regional equity in the access to food and a balanced diet is increasing (*well established*) (2.3.1.1). Equal access to food can be threatened by large scale land-acquisition mainly by organizations from both Western European and outside the region in Central and Eastern Europe and Central Asia as it compromises the right of people in these areas to control their own food systems (*established but incomplete*) (2.3.1.1). In the European Union, access to green spaces is not equally distributed among the inhabitants of cities (*established but incomplete*) (2.2.3.2, 2.3.4.2). Public access to forests for recreational experiences is uneven across the countries of Europe and Central Asia with high levels of access to 98-100% of forest and other wooded land in Nordic and some Baltic countries as well as in several Central Europe countries including Bosnia and Herzegovina, Slovenia and Serbia. Lower levels of access are found in some Western Europe countries such as UK (46%) and France (25%) (*well established*) (2.3.4.2).

Europe and Central Asia uses more renewable natural resources than are produced within the region, either through overuse or net import, as indicated by the negative difference (deficit) between biocapacity (production) and ecological footprint (consumption) (*well established*) (2.2.4). The region depends on net flow imports of renewable natural resources and material contributions from nature (*well established*) (2.2.4). Western and Central Europe and Central Asia have a biocapacity deficit while Eastern Europe has a reserve (*well established*) (2.2.4). Western Europe's ecological footprint is 5.1 global hectares per person, while its biocapacity is 2.2 hectares. Central Europe's footprint is 3.6 hectares (2.1 ha biocapacity); Eastern Europe's is 4.8 hectares (5.3 ha biocapacity) and Central Asia's is 3.4 hectares (1.7 hectares biocapacity) (*well established*) (2.2.4). The regions footprint negatively affects biodiversity, food security and other contributions from nature to people in other parts of the world (*established but incomplete*) (2.2.4, 2.3.4). Human appropriation of net primary productivity (HANPP) is a measure that assesses biomass extraction from ecosystems for food, fodder, fibres and bioenergy and for large parts of Western Europe, HANPP is lower than HANPP embodied in consumption indicating a reliance on regions outside of Western Europe (*well established*) (2.2.4). HANPP for Central and Eastern Europe and Central Asia is similar or slightly higher than HANPP embodied in consumption, but the European Union has been increasingly importing embodied HANPP especially from South America (*well established*) (2.2.4). There are significant differences in interregional flows of nature's contributions to people across subregions: Central and Western Europe import more contributions than Eastern Europe and Central Asia (*well established*) (2.2.4). Food availability in Central and Western Europe relies significantly on land for crop production in Brazil, Argentina, China and the United States of America (*well established*) (2.2.4). Central and Western Europe depends on food and feed imports equivalent to the annual harvest of 35 million hectares of cropland (2008 data), a land area the size of Germany. Western Europe became less self-sufficient in crop production between 1987 and 2008, while the rest of Europe and Central Asia has become more self-sufficient (*well established*) (2.2.4).

FOREWORD TO CHAPTER 2

"This is like home, you can't tell it. It has to be felt. This is the single sentence you can say. You don't have to add anything else. In springtime when you go out and smell the fresh air, it cannot be told, the feeling of how wonderful it is." (Sandor Barta, cattle herder, in Kis *et al.*, 2017).

In this chapter, we provide an assessment of each of nature's contributions to people (NCP) and to the quality of life of societies in Europe and Central Asia. We recognize that these contributions are diverse, reflecting the multiple societies that inhabit the region and the multiple interlinked dimensions of nature and society. For that reason, the present chapter seeks to respect and to represent the multiple values of nature's contributions to people and to include the different knowledge systems that provide understanding of our relationship with nature.

2.1 INTRODUCTION

2.1.1 How this Chapter 2 relates to the IPBES conceptual framework

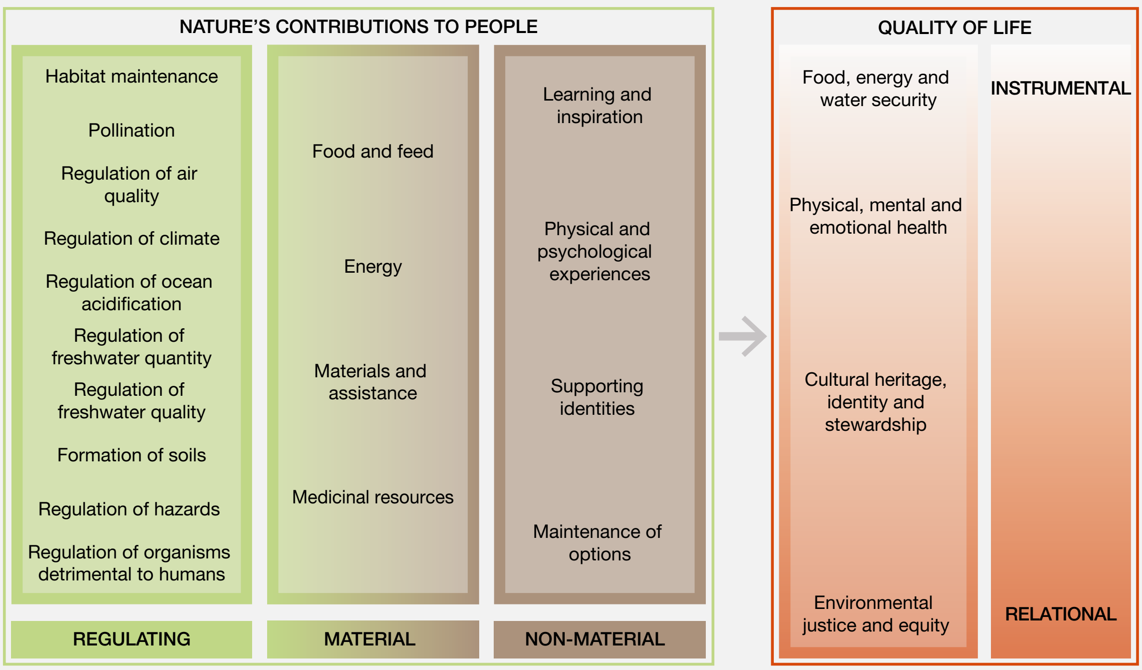
This chapter addresses the boxes of the IPBES conceptual framework "nature's contributions to people" (NCP) and "good quality of life" and the interactions between them. Therefore, it assesses the status, trends and future dynamics of nature's material, regulating and non-material contributions to people (IPBES, 2017a). We use the term "ecosystem services" when referring to the literature that uses this term, and "nature's contributions to people" when synthesizing, summarizing and assessing information. This chapter also assesses the implications of changes in nature's contributions to people for the quality of life of people in terms of instrumental and relational values (see Section 1.5.2), including food, energy and water security, health, cultural heritage, identity and stewardship, and equity **(Figure 2.1)**. The chapter also examines the multiple values of nature's contributions to people by presenting an integrated valuation, including monetary and non-monetary valuation. Assessing the link between nature's contributions to people and quality of life requires diverse valuation methods that include market-based and non-market monetary methods as well as socio-cultural valuation methods (Jacobs *et al.*, 2017; Pascual *et al.*, 2017). In this chapter, we provide an assessment of nature's contributions to people and their relationships with values and quality of life in Europe and Central Asia, bringing together scientific, technical and indigenous and local knowledge (ILK) systems.

2.1.2 Contextual dimensions of nature's contributions to people within the IPBES Regional Assessment for Europe and Central Asia

In this assessment, three generic social and ecological dimensions of nature's contributions to people are distinguished –capacity, use and value-, and different indicators assigned to them. The aim was not a systematic assessment of indicators for all dimensions, but rather to provide an overview of indicators of nature's contributions

Figure 2 1 **Representation of the focus of Chapter 2: status and trends of nature's contributions to people (NCP) (Section 2.2) and their quality of life (Section 2.3) in terms of multiple values.**

The grading of green and brown colours indicates whether the different contributions (regulating, material and non-material) are more associated with natural or with cultural systems, respectively, and to highlight that values are intertwined with both systems.



to people that relate to one of these dimensions. **Table 2.1** gives an overview of which particular dimension of nature's contributions to people is assessed in this chapter for each contribution.

The first dimension is *ecosystem service capacity* - the potential of a system to make a particular contribution to people. The second dimension is *ecosystem service use* - the actual appropriation or appreciation of nature's contributions to people by a beneficiary. The third dimension is *ecosystem service value* - the importance attached to contributions by different groups of beneficiaries. While nature's contributions to people can be valued in different ways (Jacobs *et al.*, 2017; Pascual *et al.*, 2017), the presence of such values determines to which elements in nature, e.g. a species, a population or an ecosystem, they are attributed.

Table 2 1 **Indication of which dimension is assessed in this chapter per contributions from nature to people.**

	Nature's contributions to people	Ecosystem service capacity	Ecosystem service use	Ecosystem service value
1	Habitat creation and maintenance	• Nursery capacity of habitats • Surface of habitats with nursery function	• Breeding and overwintering areas for migratory species	• Non-market monetary values • Non-monetary values
2	Pollination	• Wild insect pollinators diversity and occurrence • IUCN red lists status for wild pollinators • Number of honey bee colonies	• Agriculture's dependence on pollinators • % supply of honey bees relative to demand	• Annual market value of production that is directly linked with pollination services • Non-market monetary values • Non-monetary values
3	Regulation of air quality	• Reduction in concentration of the pollutant by nature • Balance between emissions and vegetation capture • NO_2 and other pollutants removed by ecosystems	• Reduction in concentration of the pollutant • Premature deaths due to air pollution • Years of life lost due to air pollution	• Non-market monetary values • Non-monetary values
4	Regulation of climate	• Carbon storage and sequestration by different land uses • Temperature decrease (reduced heat stress)	• CO_2 (and greenhouse gas) concentrations	• Non-market monetary values • Non-monetary values
5	Regulation of ocean acidification	• Marine vegetated habitats (e.g. seagrasses, kelp forests) surface and performance • Rates of pelagic primary production	• Increases in ocean pH • Existence of refugia for calcifying organisms	
6	Regulation of freshwater quantity and flow	• Freshwater quantity regulation • Freshwater availability (for human use) • Freshwater flow regulation • Water retention • Water regulation • Stream flow, base flow	• Freshwater extraction • Surface water extraction • Freshwater use	• Non-market monetary values • Non-monetary values
7	Regulation of freshwater quality	• Surface of floodplains and wetlands • Ecological status of water bodies • Nitrate removal rate in a river	• Concentration of nitrogen and phosphorous in inland freshwater ecosystems • Quality of drinking water and bathing water • Winter means of dissolved inorganic nitrogen (nitrate + nitrite + ammonium), oxidized nitrogen (nitrate + nitrite) and phosphate concentrations in seas	• Non-market monetary value • Non-monetary values
8	Formation and protection of soils	• Capacity of ecosystems to avoid erosion: C factor of USLE erosion model • Soil fertility • Maintenance of soil structure • Soil organic carbon content • Available nutrients, available organic contaminants	• Erosion rates	• Non-market monetary value • Non-monetary values

	Nature's contributions to people	Ecosystem service capacity	Ecosystem service use	Ecosystem service value
9	Regulation of hazards and extreme events	• Habitats designated for flood protection • Flood mitigation capacity of wetlands • Flood regulation	• Number and intensity of coastal and fluvial flood events • Damage caused by flood events	• Non-market monetary value • Non-monetary values
10	Removal of carcasses	• IUCN red lists status for vertebrate scavengers • Population trends of vertebrate scavengers	• Amount of animal and livestock carcasses removed by vertebrate scavengers • Emissions of CO_2 resulted by the substitution of natural scavenging with artificial removal of carcasses	• Avoided costs • Non-market monetary value
11	Food and feed	• Agriculture area per capita • Cultivated area per agricultural population • Organic agricultural area	• Production of cereals, fruit, vegetables, maize • Production of crops processed: olive oil, rapeseed oil, sunflower oil, wine • Livestock primary production: eggs, meat, milk • Marine wild capture seafood • Inland wild fish captures • Aquaculture production	• Market values • Non-market monetary value • Non-monetary values
12	Energy		• Woodfuel production stocks • Annual production of biofuel • Biodiesel and ethanol production • Woodfuel consumption stocks • Trade balance of biofuels • Trade balance of biodiesel and ethanol	• Market value of woodfuel • Non-market monetary value • Non-monetary values
13	Materials and assistance	• Density of timber stocks • Surface of cork oak forests • Status of mearl bed habitats	• Production of roundwood • Production of cotton • Cork harvested • Production of turpentine, resin and rosins • Production of kelp • Extraction of maerl	• Market value of some materials • Non-market monetary value • Non-monetary values
14	Medicinal, biochemical and genetic resources	• Number of medicinal plants • Endangered status of medicinal plants	• Use of medicinal plants	• Non-market monetary value of genetic resources • Non-monetary values
15	Learning and inspiration	• Protected areas and outdoor spaces used for learning	• Linguistic Diversity Index • Level of endangerment of languages • Transmission of indigenous and local knowledge	• Non-market monetary value • Non-monetary values
16	Physical and psychological experiences	• Surface of Protected Areas • Recreational potential index • Percentage of forest area designated or managed for recreation purposes • Richness of species collected for wild food or hunted	• Nature as the main reason for going on holidays • Number of marine and freshwater anglers • Participant rates (%) in nature-based recreation activities	• Market value of mushrooms • Market value of berries • Non-market monetary value • Non-monetary values

	Nature's contributions to people	Ecosystem service capacity	Ecosystem service use	Ecosystem service value
17	Supporting Identities	• Protected Areas (IUCN categories Ia Strict Nature Reserve, Ib Wilderness Area, II National Park and IV Habitat/species management area) • Sacred Natural Sites per country • Forest area primarily designated or managed for spiritual or cultural values (Food and Agriculture Organization of the United Nations)	• Species appearance in news articles • Attitudes towards nature preservation	• Non-market monetary value • Non-monetary values
18	Maintenance of options	• Total number of endemic species • Phylogenetic diversity	• Use of genetic diversity by pharmaceutical companies • Recent and unanticipated benefits from biodiversity	• Avoided costs of unanticipated benefits from biodiversity

2.2 STATUS AND TRENDS OF NATURE'S CONTRIBUTIONS TO PEOPLE IN EUROPE AND CENTRAL ASIA

This section assesses the status (from 2011 to 2016) and trends (from 1950) of nature's contributions to people in Europe and Central Asia based on a systematic literature review conducted in three main stages: (i) generation of search strings (see supporting material Appendix 2.1[1]); (ii) systematic search of primarily published peer-reviewed scientific articles, grey literature and indigenous and local knowledge; and (iii) the extraction of information from 25 relevant papers per contribution in each subregion of Europe and Central Asia. The assessment also included indicators available at regional and subregional levels and indigenous and local knowledge derived from a Europe and Central Asia "ILK dialogue workshop" held in January 2016 in Paris (Roué & Molnar, 2017) (see supporting material Appendix 2.2[2]). We report on the general status and trends in Europe and Central Asia and in its subregions of Western, Central and Eastern Europe, and Central Asia; however, a detailed list of references can be found in supporting material Appendix 2.3[3]**.**

It is important to point out that, across the region, there are many examples where indigenous and local knowledge is

1. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.1_protocol_of_the_systematic_review_used_for_chapter_2_of_the_eca_assessment.pdf
2. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf
3. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.3_extra-references.pdf

Box 2 1 The role of indigenous and local knowledge of transhumance shepherds for preserving some of nature's contributions to people.

Transhumance is a traditional farming practice of moving livestock from one grazing ground to another in a seasonal cycle. It is based on indigenous and local knowledge that has proven to be a determinant for the provision of nature's regulating contributions to people (seed dispersal, fire prevention or soil fertility), as well as nature's material and non-material contributions to people, such food, wood, ecotourism or local identity (Oteros-Rozas *et al.*, 2013a; Oteros-Rozas *et al.*, 2014). The use, conservation and transmission of transhumance-related local knowledge has been shown to be mostly linked with the practice of transhumance on foot. Transhumance on foot would not be possible without ancestral knowledge and collaborative practices. Drove roads, maintained for and by transhumant shepherds through the migration of their herds, are biodiversity reservoirs (Azcarate *et al.*, 2013) as well as corridors contributing to landscape connectivity (Galvin, 2008). Seeds can be dispersed along hundreds of kilometres by transhumant sheep on their migration (Manzano & Malo, 2006).

In Spanish "dehesas" (open woodlands resulting from the clearing of original evergreen oak woodland and shrubland areas), shepherds' seasonal management of grasslands allows for holm oak regeneration in a context where tree ageing is a major challenge for biodiversity conservation and overall sustainability (Carmona *et al.*, 2013). Fire prevention, as a result of livestock consumption of flammable biomass has also been tightly linked with transhumance management (Oteros-Rozas *et al.*, 2013a; Zumbrunnen *et al.*, 2012). The customary practice of "redileo" and the enclosure of animals in changing resting areas along the drove roads, contribute to soil fertility (Oteros-Rozas *et al.*, 2012).

essential for preserving nature's contributions to people, for example in the case of transhumance shepherds (see **Box 2.1**). Other examples of the relevance of indigenous and local knowledge to the maintenance of nature's contributions to people, such as pollination, habitat maintenance, food and feed, medicinal resources and physical and psychological experiences are those derived from the management of cultural landscapes, such as "dehesas", "montados" or "bocages" **(Box 2.1)**.

2.2.1 Status and trends of nature's regulating contributions to people

2.2.1.1 Habitat creation and maintenance

2.2.1.1.1 Nurseries

Habitat as a nursery for juveniles of a particular species refers to where "its contribution per unit area to the production of individuals that recruit to adult populations is greater, on average, than production from other habitats in which juveniles occur" (Beck *et al.*, 2001). An overview of the nursery function as a contribution from nature to people is provided by Liquete *et al.* (2016a) who conclude that it is a concrete benefit to people, especially through food provision or recreation. For example, a positive effect has been demonstrated between the presence of nursery habitat and fish stocks of sole (*Solea solea*) in the Seine estuary in France (Cordier *et al.*, 2011). The importance of conserving nursery areas has also been demonstrated for commercially important invertebrate species, such as queen scallops (*Aequipecten opercularis*), soft-shell clam (*Mya arenaria*) and sea urchin (*Psammechinus miliaris*). The importance of nursery habitat for juveniles is also relevant in the cases of maerl grounds, kelp forests, *Cystoseira* forests, seagrass meadows and reefs, among others.

Maerl beds harbour significantly higher numbers of juveniles of these species than impacted areas (Kamenos *et al.*, 2004). However, maerl beds have been undergoing a decline in condition and extent across most of their range in European Union (Hall-Spencer *et al.*, 2008; JNCC, 2007; OSPAR, 2010), mainly due to commercial extraction (see Section 2.2.2.3), as well as negative impacts of mussel farming, dredging for scallops and bivalves, aquaculture and eutrophication (Grall & Hall-Spencer, 2003; Hall-Spencer & Bamber, 2007; Hall-Spencer *et al.*, 2008; JNCC, 2007).

In the European Union marine environment, kelp forests also provide important habitat for a wide range of species (Araújo *et al.*, 2016; Smale *et al.*, 2013), including commercially important ones such as European lobster (*Homarus gammarus*). They also act as nurseries for invertebrates and fish, such as Atlantic cod (*Gadus morhua*), as well as key mating and feeding grounds for many North Atlantic fish species, such as Ballan Wrasse (*Labrus bergylta*) and Goldsinny Wrasse (*Ctenolabrus rupestris*) (Bertocci *et al.*, 2015; Casal *et al.*, 2011; Smale *et al.*, 2013). While knowledge gaps exist in terms of demonstrating the actual effect of kelp forest abundance and density on associated fisheries, most studies show a positive kelp-fisheries relationship (Bertocci *et al.*, 2015). Recent studies show a dominant decreasing trend in kelp forest distribution and abundance across parts of Western, Central and Eastern Europe due to global warming, sea urchin grazing, harvesting, pollution and fishing pressure (see **Figure 2.2**)

Table 2 2 **Kelp species in UK and Irish waters and their predicted change in abundance or range of each species in response to continued environmental change. Source: Smale *et al.* (2013).**

Species	Distribution	Depth range (m)	Length (m)	Lifespan (years)	Predicted change
Laminaria hyperborea	Arctic-Portugal	0-30	1-3	5-18	Decrease
Laminaria digitata	Arctic-France	0-15	1-2	4-6	Decrease
Laminaria ochroleuca	UK-Morocco	0-30	1-3	5-18	Increase
Saccharina latissima	Arctic-France	0-30	1-3	2-4	Decrease
Alaria esculenta	Arctic-France	0-35	1-2	4-7	Decrease
*Saccorhiza polyschides**	Norway-Morocco	0-35	2-3	1	Increase
Undaria pinnatifida	Global NIS	0-15	1-3	1	Increase

* *S. polyschides* is not a true kelp of the order Laminariales (being of the order Tilopteridales), but is included as this "pseudokelp" can perform a similar ecological role as the dominant canopy former.

(Araújo *et al.*, 2016; Casal *et al.*, 2011). Distribution and abundance of some kelp species is predicted to further change in response to ocean warming in the Atlantic (see **Table 2.2**) (Smale *et al.*, 2013) (see Section 2.2.1.5).

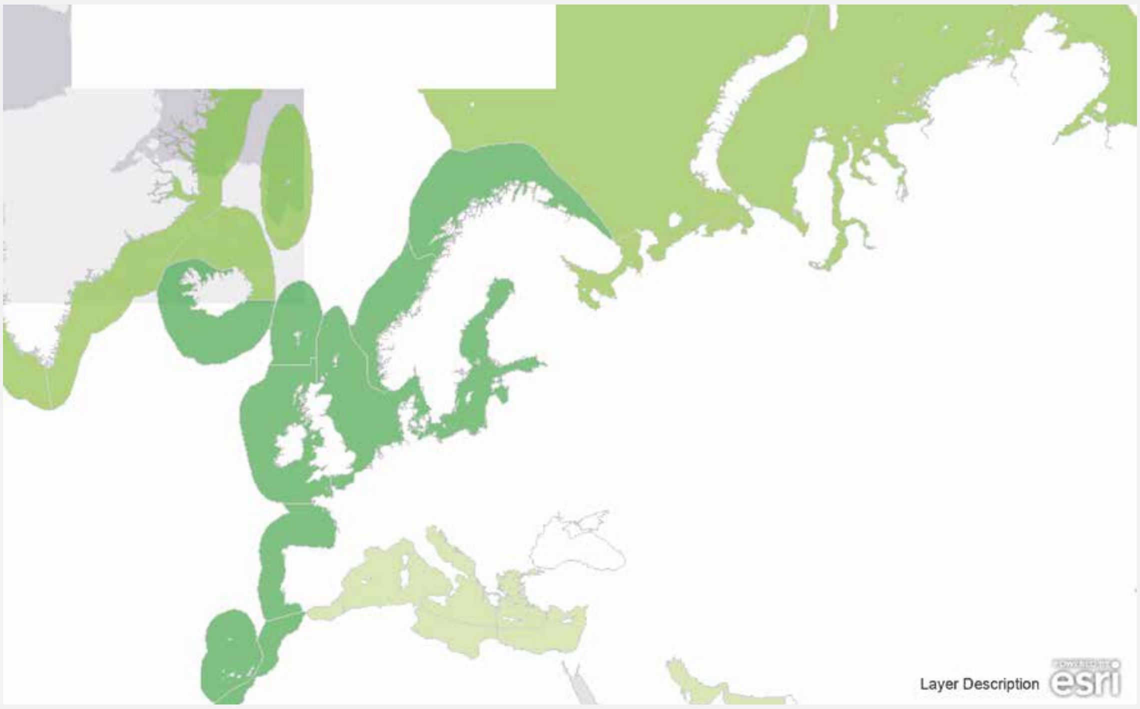
Cystoseira brown algae also provide biogenic structure, food and shelter for many organisms including fish. These habitats have, however, been declining or disappearing throughout the Mediterranean Sea due to a decrease in water quality and building development on the coast (Cheminée *et al.*, 2013; Mangialajo *et al.*, 2013). In Corsica, the depletion of large and continuous forests of *C. balearica* with a surface area of more than 2,500 m^2 could result in a significant loss of Wrasse (*Symphodus spp.)* juveniles, which are dependent on this habitat (Cheminée *et al.*, 2013).

Also in the Mediterranean Sea, many commercial fish species rely on seagrass beds which provide permanent habitat, allowing full life cycle completion and providing temporary nurseries for juvenile development, feeding areas for various life cycle stages and refuge from predation (Jackson *et al.*, 2001). Eelgrass (*Zostera marina*) meadows play a similar role in the Baltic and North Atlantic (Boström *et al.*, 2014). Seagrasses have declined worldwide and particularly in the Mediterranean, Baltic and Atlantic Seas, with negative consequences for the provision of nursery habitats (Boström *et al.*, 2014; Mccloskey & Unsworth, 2015; Waycott *et al.*, 2009).

Biogenic reefs, i.e. reefs where structure is created by the animals themselves, are also important fish habitats, as their complex structures provide refuge for fish and substrate for benthic fauna and macroalgal forests which, in turn, provide refuge and feeding areas for fish species (Støttrup *et al.*, 2014). A positive relationship between reef habitats and fish species abundance was demonstrated by a study on reef restoration in Denmark on the example of commercially important species cod and saithe (Støttrup *et al.*, 2014). Many biogenic reef habitats on the European coasts of the Atlantic Ocean and the North Sea have been in decline due to various anthropogenic pressures (OSPAR, 2010).

Other nursery and spawning habitats have also been reported in national assessments. For example, in Finland the most important nursery habitats include bladderwrack (*Fucus vesiculosus*) and common eelgrass (*Zostera marina*) meadows for fish species, wooded mires for many forest grouse species and spawning rivers for salmon (Boström *et al.*, 2014; Jäppinen & Heliölä, 2015). The state of Atlantic salmon (*Salmo salar*) spawning rivers in the Baltic Sea has

Figure 2 2 **Kelp abundance in parts of Western, Central and Eastern Europe. Source: TNC (n.d.).**



KELP ABUNDANCE BY PROVINCE

4 — ABUNDANT | 3 — WIDESPREAD | 2 — COMMON | 1 — PRESENT | 0 — NONE | NO DATA

also been assessed by the Helsinki Commission, showing that the number of salmon spawners had increased since the mid-1990s in some rivers of the Bothnian Bay (ICES, 2013).

2.2.1.1.2 Breeding and overwintering areas for migratory species

A number of scientific publications discuss population declines in a range of migratory species, including migratory birds of Western, Central and Eastern Europe *(Berthold et al., 1998; Sanderson et al*., 2006). This includes European breeding birds wintering in Sub-Saharan Africa (Sanderson *et al.*, 2006). Over half (50.4%) of fully migratory species were reported to be in decline between 1990 and 2000, falling, however, to 35.7% between 2000 and 2012 (Gilroy *et al.*, 2016). Despite this decline in wintering populations, overall waterbirds show an increasing trend in the European Union, being higher for those listed on Annex I of the Birds Directive (**Figure 2.3**) (Wetlands International, 2015).

2.2.1.2 Pollination

Pollination by animals plays a vital role as a regulating contribution from nature to people with the majority of wild flowering plant species (Ollerton *et al.*, 2011) and crop types (Klein *et al.*, 2007) benefitting from it, at least in part. Both wild and managed pollinators play significant roles in crop pollination, and crop yield or quality depend on both the abundance and diversity of pollinators (IPBES, 2016).

Pollinator diversity contributes to crop pollination even when managed species are abundant, and a diverse community of pollinators generally provides more effective and stable crop pollination than any single species.

Pollinators provide a wide range of material contributions, such as the food, fibre, building materials, medicines and other products derived from pollinator-dependent plants (see Section 2.2.2). Other products are directly produced by some species of bees such as honey, pollen, wax, propolis, resin, royal jelly and bee venom (IPBES, 2016). These are important for nutrition, health, medicine, cosmetics, religion and cultural identity and so contribute to a good quality of life (IPBES, 2016).

Since the 1950s wild insect pollinators in Europe and Central Asia have declined in diversity and occurrence, and also in abundance for some taxa where data are available (see Chapter 3). IUCN Red Lists for continental Europe (here extending from Iceland in the west to the Urals in the east) show that 37% of bee and 31% of butterfly species have declining populations (excluding data deficient species) and 9% of both taxa are classified as threatened (Nieto *et al.*, 2014; Van Swaay *et al.*, 2010). Severe losses of managed colonies of the western honey bee have been reported in many Western European countries and former-USSR countries since 1961 (Aizen & Harder, 2009).

Agriculture in Europe and Central Asia has become more pollinator dependent since 1961, with Mediterranean and Central Asian countries being the most reliant on pollination

Figure 2 3 **Trends in wintering populations of 50 waterbird species in the European Union according to their status on the Birds Directive. Source: Wetlands International (2015).**

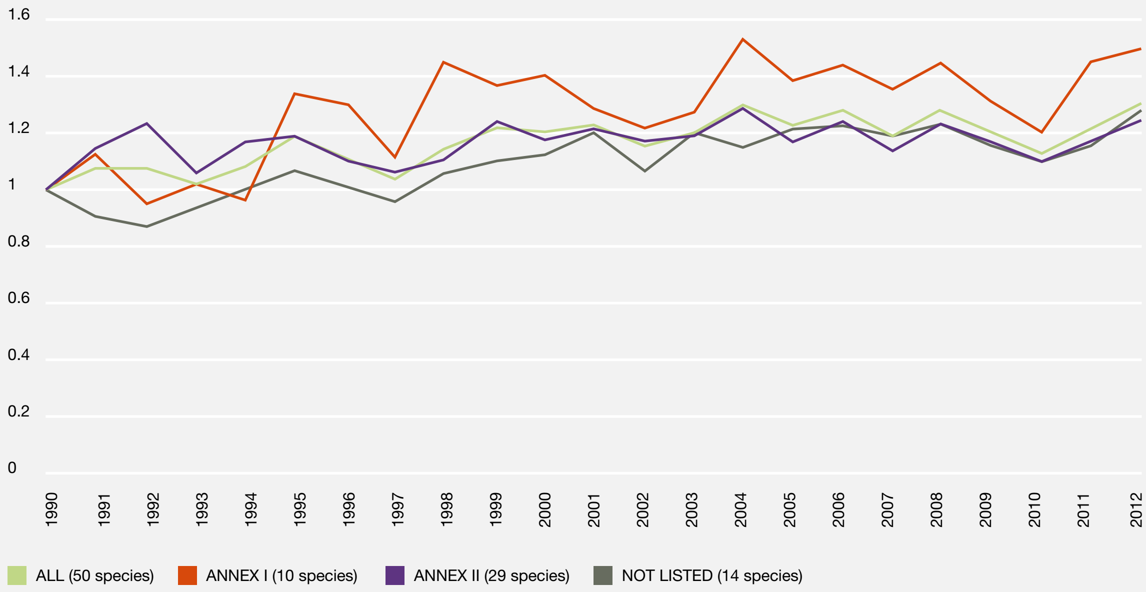


Figure 2 4 **Agriculture's dependence on pollinators (i.e., the percentage of expected agriculture production volume loss in the absence of animal pollination (categories depicted in the coloured bar) in 1961 A and 2012 B. Source: Based on data from FAO (2013a) and following the methodology of Aizen *et al.* (2009).**

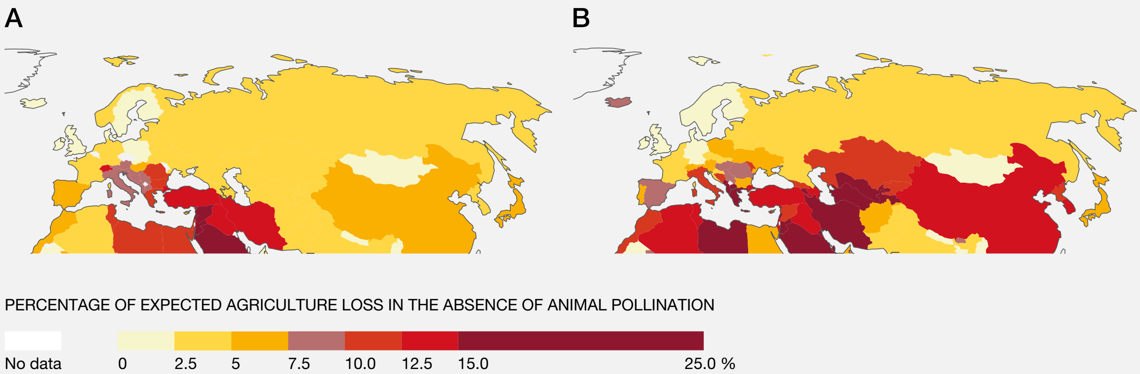
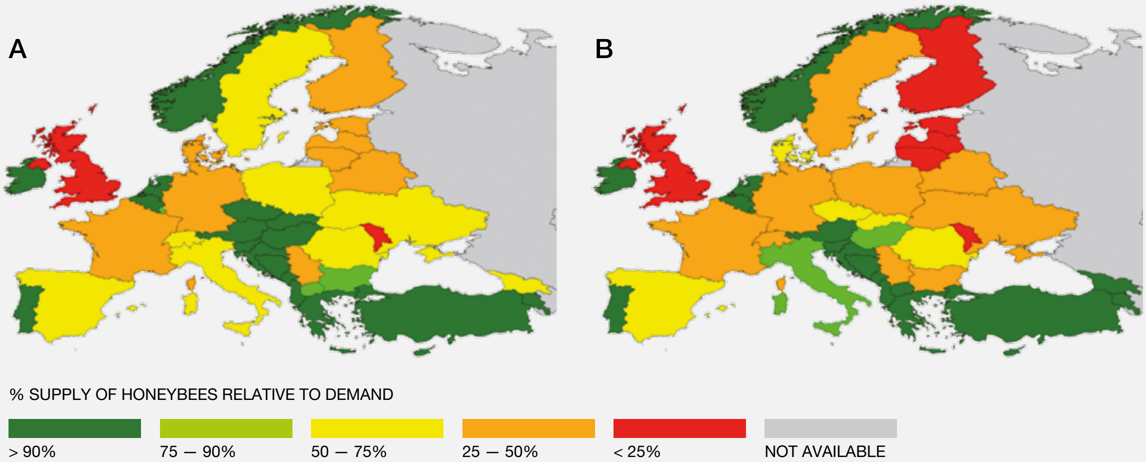


Figure 2 5 **A comparison of the pollination service capacity of honey bees in 2005 A and 2010 B in Western Europe (except Israel), Central Europe and parts of Eastern Europe. Source: Breeze *et al.* (2014).**



services for crop production, due to the substantial production of highly pollinator-dependent fruits (see **Figure 2.4**). The potential capacity of managed honey bees in Western, Central and Eastern Europe to supply pollination services to pollinator-dependent crops is insufficient to meet demand in many countries and the shortfall has increased between 2005 and 2010 because of changes in crop markets (see **Figure 2.5**; Breeze *et al.*, 2014). This suggests a high and increasing reliance on wild insects for crop pollination services. Without a systematic monitoring scheme, however, it is not possible to accurately assess the importance of wild pollinators at a local scale (e.g. April *et al.*, 2016). Although some attempts have been made to model available pollinator natural capital (e.g. Schulp *et al.*, 2014a), to date they have not considered pollinator behaviour. More suitable models have been developed (Olsson *et al.*, 2015; Ricketts & Lonsdorf, 2013) but have not yet been applied beyond case study or hypothetical sites. In addition, a variety of indicators have been used for mapping pollination, however, almost all are based on very indirect (e.g. land cover variables) or relative measures of pollination and lack empirical validation of reliable representation of pollination delivery.

Pollination contributes to a *good quality of life* through: the role of pollinators underpinning the productivity of many of the world's crops which contribute to healthy diets; beekeeping, pollinator-dependent plant products and honey which support livelihoods; and pollinator-dependent landscapes which help provide a rich and meaningful cultural and spiritual life (IPBES, 2016). Throughout Europe and Central Asia there has been a 14% increase in honey production (from 314,874 to 358,191 tonnes per year) between 1992 and 2012. This change has, however, been uneven between regions, presenting a decline of 27% in Western Europe and 63% in Central Asia, while an increase of 29% in Eastern Europe and 31% in northern Central Europe (FAO, 2017). In addition to honey and other direct calorific value of products derived from pollinator-dependent food crops, these products also benefit human health via supply a major proportion of micronutrients such as vitamin A, Iron and Folate; the fractional dependency of these micronutrient production on pollination is particularly high in southern areas of Western and Central Europe (Chaplin-Kramer *et al.*, 2014).

2.2.1.3 Regulation of air quality

The regulation of air quality by ecosystems is complex, depending on the atmospheric pollutant in question, emission levels, scale, and ecosystem characteristics. The contribution of vegetation varies according to multiple plant factors including species, leaf area, height, presence of wax or hair, evergreen versus deciduous lifeform and surface roughness. This needs to be balanced against their pollution resilience, as well as their potential to decrease air quality by trapping pollutants, emitting gases including biogenic volatile organic compounds (BVOC) and methane (Janhäll, 2015; Sæbø *et al.*, 2012), and producing allergens (Asam *et al.*, 2015). In many countries, greenhouse gas emissions are decreasing as countries seek to comply with commitments (EEA, 2015a) and the European Union Air Quality Directive (Directive 2008/50/EC)[4], but trends in air quality regulation by ecosystems vary according to the balance between emissions and capture by vegetation. Between 2000 and 2010, in the European Union, nitrogen dioxide (NO_2) removal by urban green areas increased by 0.8% (European Commission, 2015b). In Spain air quality has slightly decreased overall, but air quality regulation by forests improved between 1960 and 2010 as forest area increased due to land abandonment, with mountain areas showing mixed trends of forest area and rivers, lakes and wetlands showing decreases of forest area (Spanish NEA, 2013).

Three aspects of the regulation of air quality by ecosystems are briefly reviewed here: (i) the broad contribution of different ecosystems; (ii) the impacts of parks and trees at the local scale in cities; and (iii) ecosystem contributions to emissions. Forests and trees are particularly important at both the regional and local level, especially in cities, for capturing pollutants through both wet and dry deposition. A simple estimation of air pollution capture and removal, based only on dry deposition velocity[5] (as a measure of capacity of removal by vegetation) shows that for nitrogen oxides (NO_x), mountains with forests and natural grassland have a high capacity (primarily due to the higher level of pollutant capture by forests), while forests in Sweden and Finland and vegetation in parts of Central and Western Europe have intermediate capacity **(Figure 2.6 A)**. When combined with local pollution concentrations in urban and peri-urban areas, it shows that trees in southern Scandinavia and parts of Central and Southern Western Europe are particularly important **(Figure 2.6 B)**. However, this can vary according to factors including pollutant (type and emission level), topography and location. For example, in Limburg Province, Netherlands, the vertical capture of PM_{10}[6] (mean kg km^{-2} yr^{-1}) was estimated as: heath 2056, forest 2001, peat 968, cropland 956 and urban 535 (Remme *et al.*, 2014), with heaths capturing more than forests, as they are closer to the emission sources.

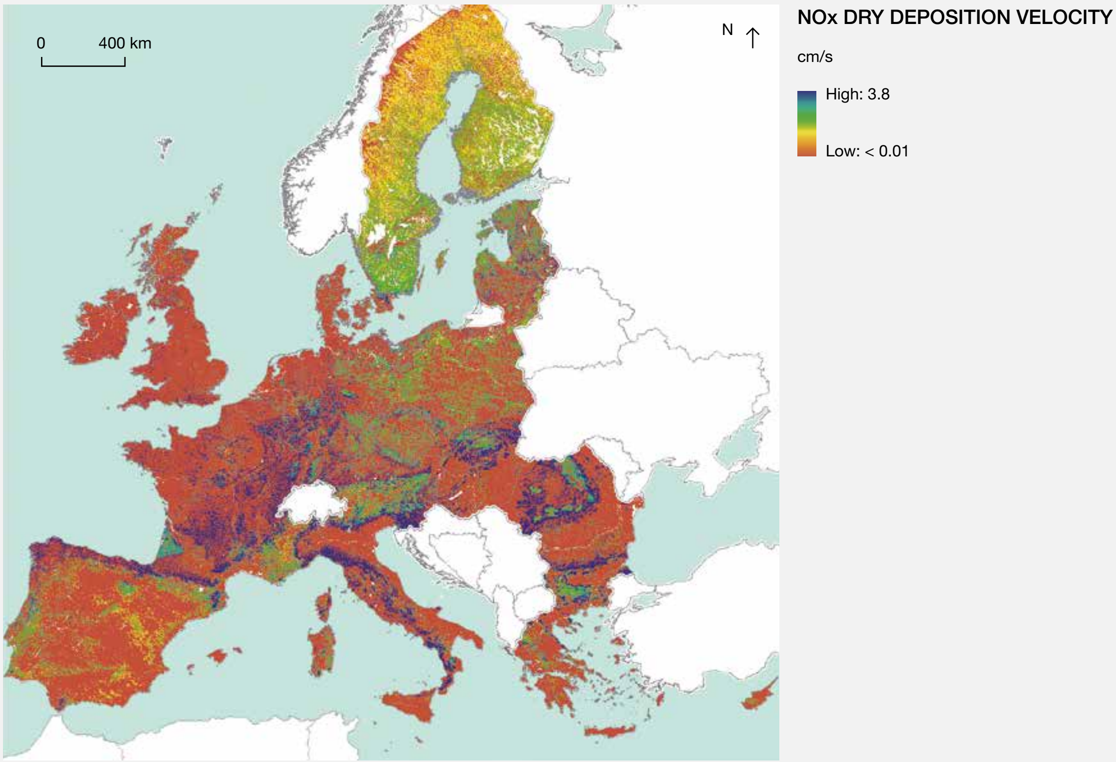
The total net benefit of vegetation in cities for capturing pollutants can be small relative to total emissions. For example, urban forests in Barcelona in 2008 removed 305.6 t of air pollutants and 19,036 t CO_2eq, representing 2.66% of PM_{10} (particulate matter 10 micrometers or less in diameter), 0.43% of NO_2, and 0.47% of CO_2eq of emissions (Baró *et al.*, 2014). The tree canopy in Greater London is estimated to remove between 0.7% and 1.4% of PM_{10} from the urban boundary layer (Tallis *et al.*, 2011). Measurements of NO_2, anthropogenic volatile organic compounds (VOCs) and particle deposition in two Finnish cities suggest that urban vegetation removes little pollution in northern areas (Setälä *et al.*, 2013). Nevertheless, the amounts locally removed can be very important.

Several studies demonstrating the removal of different pollutants by trees or parks in cities of the European Union show similar patterns, although quantitative results are mostly not directly comparable since the studies use different units. Studies of different Italian cities showed that generally evergreen broadleaved forests capture more ozone (O_3) than coniferous forest, followed by mixed broadleaved and coniferous forest, with deciduous broadleaved forest capturing the least (e.g. Bottalico *et al.*, 2016; Manes *et al.*, 2016). For PM_{10} the sequence decreases from mixed broadleaved and coniferous forest, to coniferous forest, evergreen broadleaved forest and deciduous broadleaved forest (Manes *et al.*, 2016). Seasonal differences include deciduous trees capturing more PM_{10} and O_3 in summer when in leaf (e.g. Manes *et al.*, 2016; Marando *et al.*, 2016), while evergreens captured more in autumn and winter (Marando *et al.*, 2016). Research on European urban trees found that *Quercus* and *Platanus spp.* have the highest PM removal efficiency (Grote *et al.*, 2016). Thus, the selection of species planted can affect air quality regulation. In cities, trees can also reduce the dispersion of pollutants, leading to increased local concentrations (Janhäll, 2015).

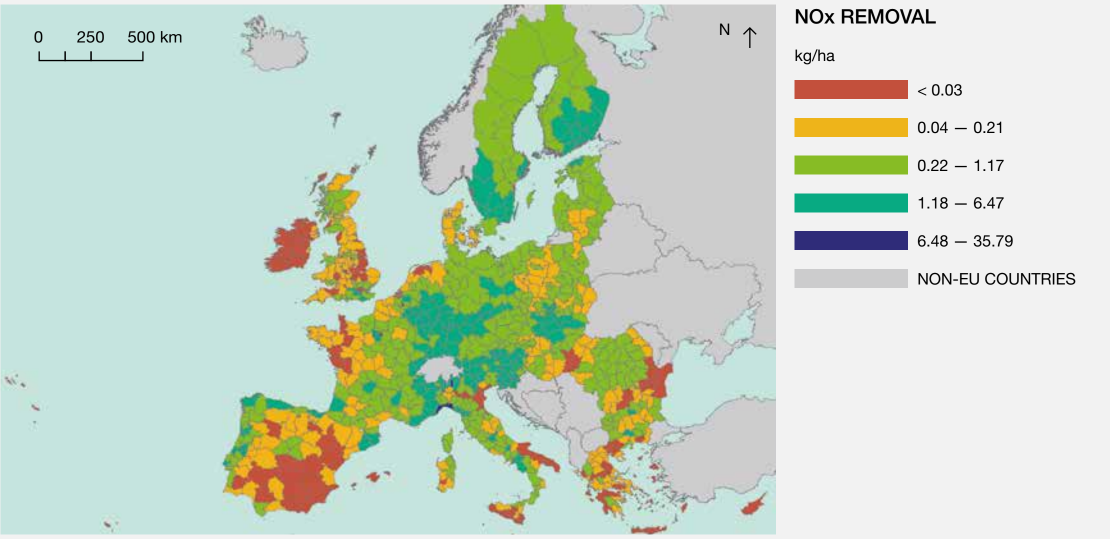
4. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0050
5. Rate of deposition of particles and gases (in this case) on vegetation
6. PM_{10} is particulate matter 2.5 to 10 micrometers in diameter

Figure 2 6 **A Velocity of dry deposition of nitrogen oxides in cm/sec in parts of Western and Central Europe. Source: European Commission (2011).**
B Removal of nitrogen oxides (kg/ha) by trees in urban and peri-urban areas. Source: European Commission (2011).

A

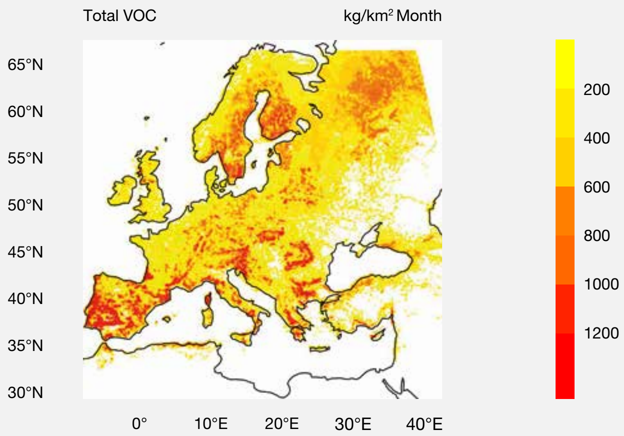


B



Ecosystems can be sources or precursors of gases, which affect air quality. For example ammonia and methane are involved in the photochemical formation of O_3, with agricultural fertilizer application and livestock contributing to ammonia emissions and livestock and wetlands to methane emissions (Kayranli *et al.*, 2010). Trees can emit biogenic volatile organic compounds (BVOCs), especially isoprenes, as well as allergens such as pollen (Grote *et al.*, 2016). Modelling of BVOC emissions shows particularly high levels in parts of southern parts of Western Europe due to a combination of species and high temperatures, while in Scandinavia it is a result of the forest cover **(Figure 2.7)**.

Figure 2 7 **Modelled emissions of biogenic volatile organic compounds (VOC) from terrestrial vegetation in the western parts of Europe and Central Asia in 2000. Source: Steinbrecher *et al.* (2009).**



Air pollution can also indirectly affect ecosystems, through soil and water acidification, eutrophication, or crop and vegetation damage from O_3 (EEA, 2016a), which all can reduce the ability of ecosystems to cope with particulate and gaseous pollutants. For example, in forests the critical O_3 level (20,000 μg/m³/h during the summer season) was exceeded in 2013 in 66% of the 33 member countries of the European Environment Agency (EEA) (except in Turkey), with more northern countries in that area falling below this level, while in southern parts of Western Europe the critical level may be exceeded by a factor of four or five (EEA, 2016a).

Air quality impacts quality of life, especially human health in cities (Queenan, 2017). For example, for 40 countries of Western and Central Europe in 2012, exposure to PM2.5[7], O_3 and NO_2 was responsible for 432,000, 75,000 and 17,000 premature deaths, respectively. The highest rates of years of life lost per 100,000 inhabitants due to PM2.5 were in Central and Eastern European countries, and for O_3 the Western Balkans, Hungary and Italy (EEA, 2015a). Its direct and indirect impacts on processes, such as eutrophication and acidification, affect ecosystem health and species composition (Jones *et al.*, 2014), which can influence their ability to supply other contributions from nature to people.

2.2.1.4 Regulation of climate

Ecosystems are important in climate regulation as they affect greenhouse gas fluxes, contributing both to emissions and storage, which could enhance climate warming or climate mitigation, respectively. Nearly all countries in Europe and Central Asia have submitted "intended nationally determined contributions" under the Paris Agreement, with ecosystems playing a role in their mitigation plans. Ecosystems can also influence heat transfers by reflecting or absorbing incoming solar radiation and moisture transfers through modifying water flows and evapotranspiration, as well as affecting microclimate, primarily through reducing temperature extremes (Edmondson *et al.*, 2016).

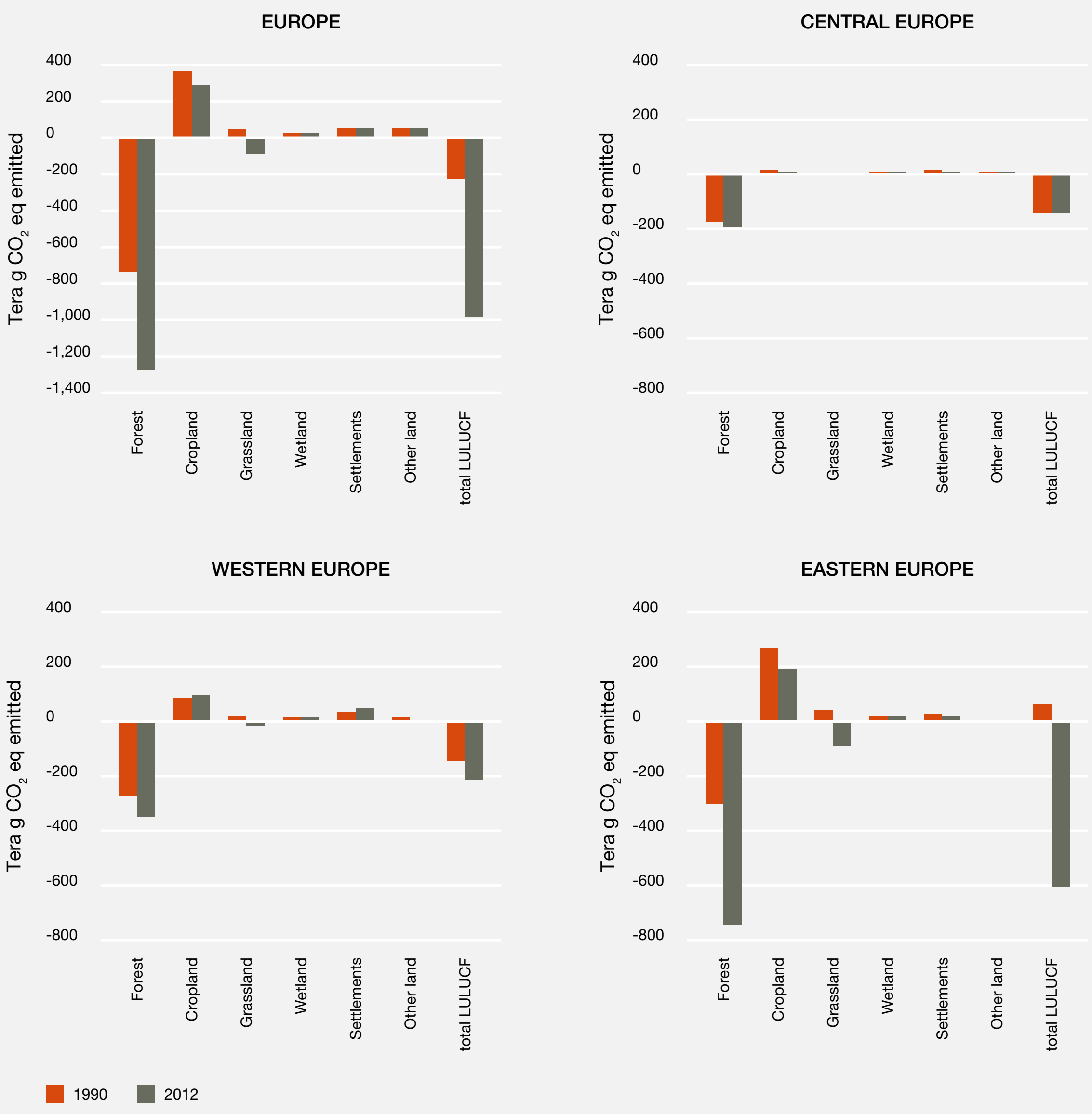
There is considerable uncertainty about the changes in carbon flux and balance. It has been estimated that, between 1950 and 2007, increased carbon biomass stocks in Europe's forests represented 10% of the EU-15[8] cumulated fossil fuel emissions (Ciais *et al.*, 2008), while between 1990 and 2012 there was a net decrease in greenhouse gas emissions from land use, land-use change and forestry (LULUCF) changes due to increased carbon storage **(Figure 2.8)**, primarily as a result of increases in forest area, with 87% of the positive balance coming from Eastern Europe, 19% from Central Europe and 9% from Western Europe. It has been estimated, based on models and observations, that in continental Europe between 2000 and 2005, the balance of greenhouse gases was –29 ± 194 TgC yr^{-1} for croplands, forests and grasslands, as CO_2 taken up mostly by forests and grasslands nearly balanced CH_4 and N_2O emissions (mostly from cropland), while for the 25 member States of the European Union at that stage the balance showed emissions of 34 ± 99 TgC yr^{-1} (Schulze *et al.*, 2009). In Central Asia, net removals of greenhouse gases by land use, land-use change and forestry (LULUCF) between 1992 and 2012 increased from -5.3 to -25.1 Tg CO_2eq (FAO, 2017), mostly due to increased area of grasslands.

7. PM2.5 is particulate matter 2.5 micrometers or less in diameter

8. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom

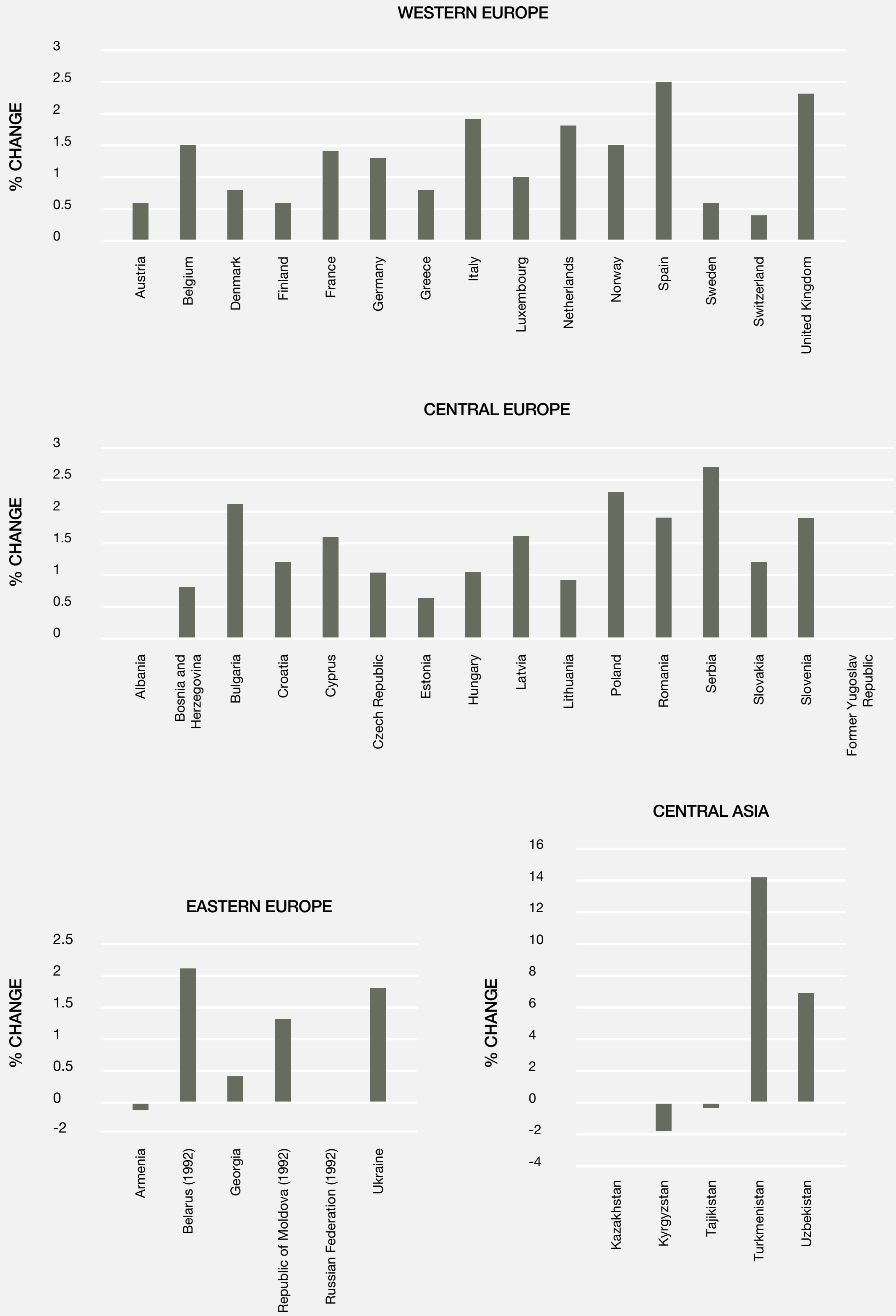
Figure 2 8 **Net annual greenhouse gas emissions and removals for the land use, land-use change and forestry (LULUCF) sector (1990–2012) for Western, Central and Eastern Europe in $TgCO_2$ equivalent.**

Source: Based on reporting by the United Nations Framework Convention on Climate Change (UNFCCC, 2014). Central Asia countries are not included as they have not reported for the entire period. Note that the vertical axis for Europe (Western, Central and Eastern Europe combined) has a different scale.



Net increases in emissions and decreases in carbon storage could have several causes, including wetland drainage, loss of wetlands and forests due to urban expansion, agricultural intensification, other land use changes, and emissions from northern peatlands due to climate change. In nearly all countries of Europe and Central Asia, forests are the most important net carbon sink and carbon stocks in living forest biomass between 1990 and 2015 were increasing or stable (see **Figure 2.9**). For some countries, however, wetlands can be more important in regulating climate but, given the decrease in wetland area in many parts of continental Europe (Dixon *et al.*, 2016; EEA, 2016c) (see Section 2.2.1.6), they may not be able to maintain this contribution from nature to people into the future. In Russia, vegetation (primarily boreal forests and peatlands) and soils hold 16% (336 Gt) of the world's carbon stores, with soils making the greater contribution. With climate change, the tundra zone could become a net emitter, especially of methane (Bukvareva *et al.*, 2015).

Figure 2 9 **Annual rate of change (%) in carbon stock in living above-ground and below-ground forest biomass in Europe and Central Asia between 1990 and 2015. Source: Own representation based on FAO (2015c).**



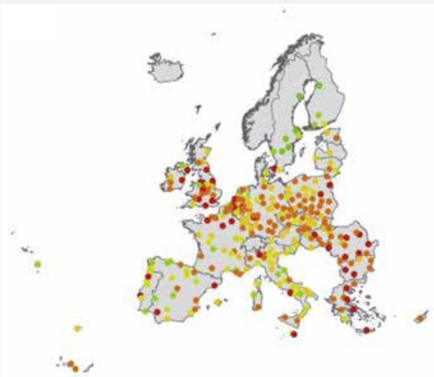
In Europe and Central Asia, soils represent a large carbon stock (Jones *et al.*, 2012; Schulze *et al.*, 2010) but the storage capacity varies depending on land use and soil type. Peat soils are undergoing major carbon losses due to drainage and cultivation (Akker *et al.*, 2016). Cropland soil organic carbon is also declining in many areas of Europe and Central Asia (see Section 2.2.1.7), but agricultural soils represent a large potential sink if appropriate management practices are applied (Lugato *et al.*, 2014). Figures vary for the area of cropland abandoned following the dissolution of the USSR (Schierhorn *et al.*, 2013), but authors agree that this led to major carbon sequestration in soils (Kurganova *et al.*, 2015). A process-driven ecosystem model (Vuichard *et al.*, 2008) estimated that the conversion of 20 million ha of cropland to grassland resulted in an accumulated carbon sink of 64 TgC between 1991 and 2000. Estimates vary, however, due to the use of different methods and data and allowing for the conversion to forests, with the range being from –64 to –694 TgC sequestered (Dolman *et al.*, 2012). Schierhorn *et al.* (2013), using a different process-based model, estimated that between 1990 to 2009 the 31 million ha of abandoned cropland in Western Russia, Ukraine, and Belarus combined, provided a net carbon sink of 470 TgC. In Central Asia, between 1982 and 2000, there was a decrease of soil organic carbon stocks of about 828 TgC, mainly due to the conversion of native rangelands into agricultural land, and to a lesser extent (5% of carbon losses) due to rangeland degradation (Sommer & de Pauw, 2011). Nitrogen deposition can increase terrestrial carbon sequestration and its effect is greatest in Central Europe, although across all subregions of Europe this effect is decreasing due to reduced deposition (Zaehle *et al.*, 2011).

Ecosystems, especially in urban areas, can be effective in microclimate regulation, through reducing local surface temperatures by shading, and air temperatures by evaporative cooling and albedo effects. Local climate regulation has been estimated for 301 large urban zones in the EU-27, using the amount of energy emitted by a surface (surface emissivity) and an approximation of the evaporation potential of the land surface (f-evapotranspiration) to calculate the effect of different land covers on urban air temperatures (Larondelle *et al.*, 2014). Climate regulation was found to be low across most of Western, Central and Eastern Europe, but high in Sweden, Finland and some cities in Spain, France and Italy, with a more heterogeneous pattern elsewhere (see **Figure 2.10**). This primarily reflects the percentage of forest and tree cover in the core urban area and its hinterland.

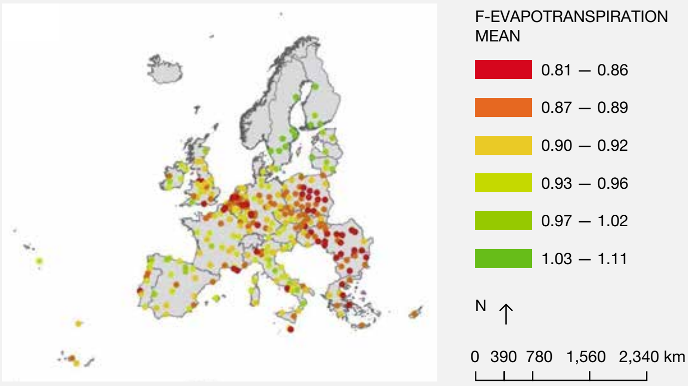
A global meta-analysis of the cooling potential of urban parks found an average reduction of ambient daytime temperature by 0.94°C and of nighttime temperature by 1.15°C (Bowler *et al.*, 2010), although a few studies found small increases in temperature. The magnitude of the effects varies according to climatic region, size of park or forest (Bowler *et al.*, 2010) and the species involved (e.g. Leuzinger *et al.*, 2010). For example, a comparison of temperatures in a street and the National Garden in Athens, Greece, found the greatest differences at night of up to 6.3°C cooling by the park (Zoulia & Santamouris, 2008), while in Manchester, UK, tree shading was found to reduce air temperatures by 1–2°C (Armson *et al.*, 2012) and in an intra-urban park in Moscow, winter temperatures can be 0.74°C higher and summer temperatures 1.64°C lower than in the city centre (Shahgedanova *et al.*, 1997).

Climate regulation by ecosystems contributes to other contributions from nature to people (e.g. habitat maintenance (Section 2.2.1.1), erosion control (Section

Figure 2 10 **Urban heat regulation in cities in the EU-27, based on an approximation of the evaporation potential of the land surface (f-evapotranspiration). Low values indicate greater cooling. Core city areas on the left; larger urban areas on the right. Source: Larondelle *et al.* (2014).**



CORE CITY AREAS



LARGER URBAN AREAS

2.2.1.8), water quality (Section 2.3.1.6)), while carbon sequestration in soils can increase food security (Section 2.3.1.1). Furthermore, the reduction of urban temperatures in hot weather (Section 2.3.2) can lower rates of heat-related mortality and morbidity, especially in elderly and chronically ill individuals and socially vulnerable people and those with respiratory diseases (Hajat *et al.*, 2010). A study of 12 Western and Central European cities suggested that this is particularly important in the Mediterranean region (Michelozzi *et al.*, 2009).

2.2.1.5 Regulation of ocean acidification

Ocean acidification has been shown to affect marine organisms, having especially negative effects in calcifying organisms such as bivalves, brittle stars, sea urchins, coralline algae and corals (Cornwall *et al.*, 2017; Cornwall *et al.*, 2015; Kroeker *et al.*, 2013) and on the contributions they provide to people (Lemasson *et al.*, 2017). Some of these organisms live in or nearby coastal vegetated ecosystems, which have been shown to regulate atmospheric CO_2 concentrations and seawater pH (Cornwall *et al.*, 2013; Hendriks *et al.*, 2014) with effects on calcification processes of marine organisms important to humans (e.g. corals, bivalves or sea urchins) (IPBES, 2017a). Marine macrophytes, such as large brown macroalgae and seagrasses, are net CO_2 consumers, and their metabolism creates pH fluctuations in seagrass meadows and kelp forests where they are dominant species and very abundant. This regulation of pH can entail increases of 1 pH unit during the day (Middelboe & Hansen, 2007). This up-regulation can depend on many factors, such as plant biomass and structure, hydrodynamics, irradiance and day-length (Krause-Jensen *et al.*, 2016). Vegetated habitats may, therefore, contribute to regulating ocean acidification and creating refugia for calcifying organisms (Hurd, 2015; Krause-Jensen *et al.*, 2016). There is increasing evidence that pH increase can lead to an overall buffering of ocean acidification (Buapet *et al.*, 2013; Hendriks *et al.*, 2014; Krause-Jensen *et al.*, 2015; Krause-Jensen *et al.*, 2016). Nevertheless, pH in these habitats typically fluctuates, with higher pH during daytime due to CO_2 uptake by photosynthesis and lower pH at night due to respiration and release of CO_2. In fact, some studies postulate that macrophytes may amplify the negative effects of ocean acidification, at least for some organisms (Pettit *et al.*, 2015; Roleda *et al.*, 2015). The potential role of regulating ocean acidification of marine vegetated habitats may depend on the balance between positive effects in the daytime and negative effects during the night (Krause-Jensen *et al.*, 2016). For example, long days in the Arctic vegetated habitats have been shown to promote the provision of refugia for calcifying organisms during summer (Krause-Jensen *et al.*, 2015; Krause-Jensen *et al.*, 2016), when organisms reproduce and are most vulnerable to ocean acidification (Kroeker *et al.*, 2013; Lemasson *et al.*, 2017). However, the long polar nights should result in a down-regulation of pH, potentially amplifying negative effects of ocean acidification during winter. However, calcifying organisms are likely less susceptible to low pH in the later conditions (Kroeker *et al.*, 2013).

Despite the importance of marine vegetated habitats, declines of seagrass beds and kelp forests have been reported in many parts of Europe and Central Asia (Araújo *et al.*, 2016; Boudouresque *et al.*, 2009) (see Sections 2.2.1.1. and 3.3.2.3). For example, decline of the seagrass *Posidonia oceanica* has been reported across the entire Mediterranean Sea, and during the last 50 years between 11 and 52% of the documented surface area originally occupied by the species has been lost, with many existing meadows deteriorating (Telesca *et al.*, 2015). It is predicted that this trend will continue and the functional extinction of *P. oceanica* meadows is foreseen by the middle of this century (Jorda *et al.*, 2012), even if seagrasses are likely to benefit from increased CO_2 worldwide (Zimmerman *et al.*, 2017). Therefore, organisms associated with seagrass communities that are deteriorating may be exposed in the future to lower pH regimes due to the loss of pH-buffering capacity (Hendriks *et al.*, 2014). By contrast, these marine vegetated habitats may increase in the Arctic Ocean, led by warming of seawater (Krause-Jensen & Duarte, 2014). The predicted poleward expansion of macrophytes with seawater warming and reduced sea-ice cover (Jueterbock *et al.*, 2013) may increase the potential for pH up-regulation during summer in Arctic marine systems (Krause-Jensen *et al.*, 2016). Similarly, increased pelagic primary production, as forecast for parts of the Arctic Ocean, may also create local niches of high pH (Arrigo *et al.*, 2008; Popova *et al.*, 2012).

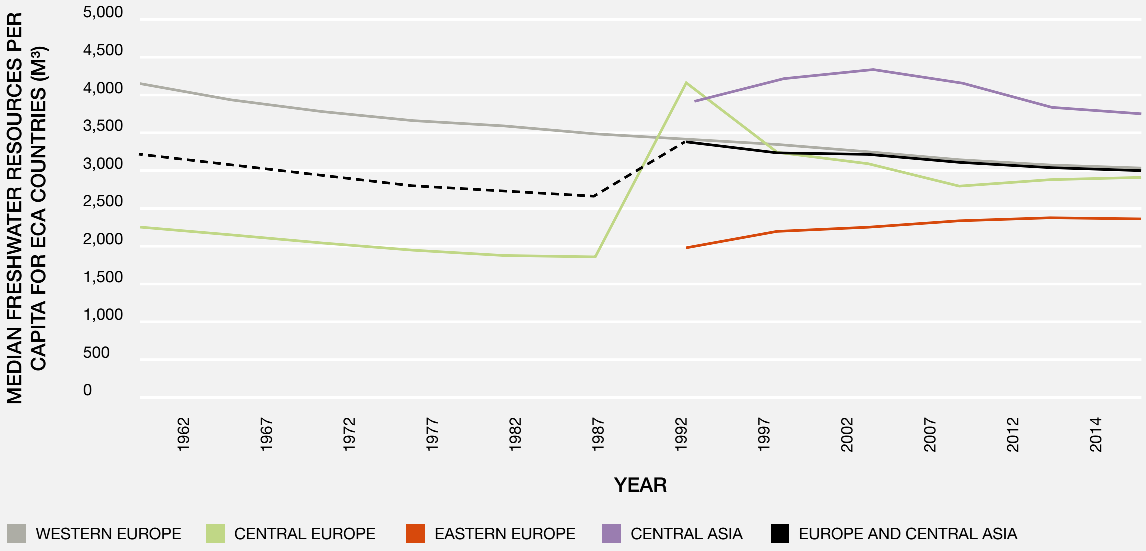
2.2.1.6 Regulation of freshwater quantity and flow

This contribution from nature to people involves the contribution of ecosystems to the regulation of the quantity and flow of surface and groundwater used for drinking, irrigation, and industrial purposes. Besides contributing to direct use, ecosystems can also regulate water flow to water-dependent natural habitats that in turn affect people downstream, including via floods and droughts. See supporting material Appendix 2.2[9] with quotes from indigenous and local knowledge holders describing this contribution, in relation to seasonal water flows.

This section distinguishes between freshwater provision and water flow regulation. Freshwater supply describes freshwater available for human use. Water flow regulation,

9. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

Figure 2 11 **Trend of renewable internal freshwater resources per capita (median, in cubic meters) for Europe and Central Asia (ECA) and the four subregions. Note that the trend for Europe and Central Asia until 1992 (dashed lines) is based on Western and Central Europe only. Source: Own representation based on FAO (2016).**



on the other hand, is described in terms of supply through the indicators of water retention, stream flow and base flow.

The general trend in freshwater supply in Europe and Central Asia, taking into account renewable internal freshwater resources per capita provided by the Food and Agriculture Organization of the United Nations (FAO, 2016), shows an overall decrease since 1992 **(Figure 2.11)**. Freshwater demand, taking into account water use and water abstraction, shows a mixed but overall decrease for all subregions of Europe and Central Asia (EEA, 2015e; FAO, 2013) since the 1990s. Between 2000 and 2011, water abstraction has decreased for countries in the European Union (European Commission, 2015b).

Generally mixed but mostly decreasing trends in water flow regulation were found for parts of Western, Central and Eastern Europe (Stahl *et al.*, 2010; UNEP & UNECE, 2016). Between 2000 and 2011, water flow regulation decreased for most ecosystems in the European Union (European Commission, 2015b). Regions with increased or stable water flow regulation are characterized by large areas of natural vegetation or extensive agriculture (Sturck *et al.*, 2014).

Water supply in Western Europe, measured in freshwater availability, has been decreasing since the 1980s (FAO, 2016) **(Figure 2.11)**. Decreased freshwater availability was also reported for Spanish riparian areas and rivers (Vidal-Abarca Gutiérrez & Suárez Alonso, 2013). Mixed trends for water availability were found for Germany and Austria (Karabulut *et al.,* 2016). Water demand in Western Europe, taking into account water use and surface water abstraction, has decreased since the early 1990s, although current trends are mixed (EEA, 2015e; Eurostat, 2016b). Water use has remained stable in the southern part but has decreased in the western part of Western Europe (EEA, 2015e). Groundwater extraction in Mediterranean river basins in France, Greece and Spain was reported to have increased (Skoulikidis *et al.*, 2017), while overall groundwater extraction in Spain has decreased (Vidal-Abarca Gutiérrez & Suárez Alonso, 2013). Mixed trends for water use were found for the Danube basins in Germany and Austria (Karabulut *et al.*, 2016) as well as water provision in the Llobregat basin in Spain. Mixed but predominantly increasing stream flow was found for Western Europe, although large differences exist between the north and the south (Stahl *et al.*, 2010). Decreasing stream flow in the last decades was reported for the Mediterranean countries as well as Austria and Germany (Skoulikidis *et al.*, 2017; Stahl *et al.*, 2012). Decreased water flow regulation was reported for Spanish riparian areas (Vidal-Abarca Gutiérrez & Suárez Alonso, 2013). Mixed trends for stream flow were found in Switzerland (Lutz *et al.*, 2016). Increased stream flow was found for the majority of the northern countries of Western Europe (Stahl *et al.*, 2010, 2012), as well as in the Hula Wetland, Israel.

Water supply in Central Europe, measured in freshwater availability, has decreased since the 1990s, although this trend has been mixed in the past decade (FAO, 2016) **(Figure 2.11)**. Mixed trends in water availability were discerned for Central European countries within the Danube basin (Karabulut *et al.*, 2016). Water demand, taking into account water use and surface water abstraction in Central Europe, has declined sharply since the early 2000s, but this trend has been mixed in the past decade (EEA, 2015e; Eurostat, 2016b). Mixed trends for water abstraction have been reported for Central European Mediterranean river basins (Karabulut *et al.*, 2016), whereas water abstraction in Cyprus has increased (Skoulikidis *et al.*, 2017). Mixed but predominantly increasing stream flow was found for Central Europe (Stahl *et al.*, 2010). Decreasing water flow during recent decades was reported for Cyprus, the Czech Republic and Slovakia, as well as the Sava River in Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro and Albania (Lutz *et al.*, 2016; Skoulikidis *et al.*, 2017; Stahl *et al.*, 2010). Stable water flow and ground water levels in the past were found in Slovenia and Poland.

Water supply in Eastern Europe, measured in freshwater availability, has increased since the 1990s and this trend has stabilized in the past decade (FAO, 2016) **(Figure 2.11)**. Information on water demand in Eastern Europe is limited to a few countries, however, freshwater abstraction in the Republic of Belarus and the Republic of Moldova is reported to have decreased steadily over recent decades. A mixed trend for water demand was reported in the Eastern European countries of the Danube basin (Karabulut *et al.*, 2016). Stream flow has decreased in most parts of Eastern Europe (Stahl *et al.*, 2012). Water flow regulation in Russia was found to have increased between 1990 and 2015 (Miura *et al.*, 2015).

Water supply in Central Asia, measured in freshwater availability, shows a mixed, but generally decreasing trend since the 1990s, and has continued to decrease over the past decade (FAO, 2016; SAEPF *et al.*, 2012) **(Figure 2.11)**. Water availability per capita has decreased in Turkmenistan and Uzbekistan, while stable water availability was reported for the Aral Sea basin (Uzbekistan). Total water withdrawal in Central Asia has been stable in the past, while water withdrawal by agriculture, industry and cities has decreased (Alexander & West, 2011; FAO, 2013). There is some evidence of on-going stable water use in Uzbekistan (Aral Sea basin), as well as excess water use for irrigation on a local scale (Conrad *et al.*, 2016). Mixed trends for water use were reported for Uzbekistan, due to strong regulation in response to droughts. Water extraction in the Kyrgyz Republic has decreased, although recent trends are mixed. Water use and availability have decreased in Turkmenistan and Uzbekistan (FAO, 2013). Water flow regulation throughout Central Asia shows a mixed trend, following patterns in precipitation and drought occurrences (FAO, 2013; SAEPF *et al.*, 2012).

Regulation of freshwater quantity and flow mostly contributes to quality of life by supporting water and food security (Section 2.3.1). Water security, which is furthermore underpinned by water quality regulation (Section 2.2.1.7) and other contributions from nature to people, is mostly sufficient and has increased in Europe and Central Asia since the late 1980s. More mixed trends and insufficient water security, notably in rural areas, are reported for Eastern Europe and Central Asia. Europe and Central Asia as a whole is food secure but food security is affected by, among others, decreasing water availability and excessive water withdrawal.

2.2.1.7 Regulation of freshwater and coastal water quality

This contribution from nature to people refers to nature's ability to remove or break down excess nutrients and other pollutants. The combination of physical, chemical and ecological processes in rivers, wetlands and marine ecosystems acts as a natural filter removing substances such as sediments and nutrients linked to nitrogen and phosphorus. Water quality regulation, therefore, depends on both the emission of pollutants into the water, and on the capacity of the natural systems to process or transform these substances and physically block them by sediments. For example, natural, restored and constructed wetlands in the European Union are estimated to remove 75% of the nitrate from agricultural runoff via denitrification (Blackwell & Pilgrim, 2011). Nature-based solutions associated with artificial wetlands and restoration of riparian zones have been demonstrated as cost effective measures for water quality improvement in Estonia, Norway, Sweden, Italy, Belgium and the UK (e.g. Kumar *et al.*, 2017; MWO, 2012; Zedler & Kercher, 2005). The capacity of ecosystems to deliver this contribution to people shows sharp local variations along the rivers inside watersheds. If upland riverbeds are well conserved and pollution is limited, water quality can be well regulated. Downstream, rivers are often impacted by land use intensification, riparian wetlands reduction, overexploitation of water resources and alteration of the river bed morphology. In the latter case, the capacity of rivers to regulate water quality is diminished.

The capacity to provide this contribution in Europe and Central Asia has reduced over recent decades due to the conversion and habitat loss of rivers, wetlands and coastal systems (see Section 3.2.2.2), leading to a 60% decrease in the areal extent of floodplains and wetlands and loss of watersheds' ecological integrity (Geijzendorffer *et al.*, 2017). In 2017 it was estimated that 38% of rivers' surface in the European Union have good or high ecological status, 42% moderate state and 20% poor or bad status (Grizzetti *et al.*, 2017). In 2009, 43% of water bodies still showed a good or high ecological status (EEA[10]), indicating a reduction of rivers with good status over the past eight years.

10. https://www.eea.europa.eu/soer-2015/europe/freshwater

Despite the loss of ecological integrity and areal extent of floodplains and wetlands, the water quality of rivers in the European Union has been improving since the 1990s as a result of the reduction of pollutants (due to the Nitrates Directive (91/676/EEC) and European Union Water Framework Directive (2000/60/EEC)) or as a result of transnational efforts such as the Convention on the Protection of the Rhine. The improvement in water quality is, therefore, the consequence of reductions in pollution, rather than an enhancement of the ecosystems' capacity to provide this contribution from nature to people. The quality of drinking water and bathing water, and the effectiveness of wastewater treatment, continue to improve across the European Union (EEA, 2016e). For example, the percentage of bathing water sites meeting the minimum water quality standards has increased to 96.1% in 2015.

In Western Europe, the capacity to regulate water quality has been diminished since 1990. For example, in Spain and Germany, it is considered the most degraded regulating contribution from nature to people (Spanish NEA, 2013). In the Mediterranean basin, the regulation of water quality by wetlands has been jeopardized by the decreasing ecological integrity and scarce water availability (Geijzendorffer *et al.*, in press; MWO, 2012). However, in other areas, water quality regulation by ecosystems has remained stable (e.g. England) (UK NEA, 2011) or has increased (e.g. Netherlands) (de Knegt, 2014). Despite this general negative trend, water quality in Western Europe has improved due to pollution reduction. After the adoption of the European Union Nitrates Directive and Water Framework Directive, water pollution showed a downward-trend. Still, many water bodies remain affected by dissolved inorganic nutrients and pesticides (EEA, 2015d).

In Central Europe, the overall decreasing trend, due to increased pollution and conversion of floodplains and wetlands, is illustrated in Turkey, Austria, Hungary, Romania and the Danube floodplain (e.g. Hainz-Renetzeder *et al.*, 2015; Karadeniz *et al.*, 2009; Pehlivanov *et al.*, 2014). In addition, the demand for water purification is increasing due to agriculture and urban expansion. In Eastern Europe, water quality currently displays a downward trend due to nitrogen surpluses from intensive agriculture or the conversion of natural ecosystems (e.g. Bouraoui & Grizzetti, 2014). In Russia, the capacity to regulate water quality by forests and tundra of Siberia and eastern Russia has remained stable in the past (Stolbovoi, 2002). However, in the southern regions of Russia, the Southern Urals and Western Siberia, this capacity was found to be lower (Stolbovoi, 2002). For Central Asia, published data is not available.

Regarding the regulation of water quality in coastal and marine waters, the concentrations of dissolved inorganic nitrogen, oxidized nitrogen and orthophosphate have remained stable between 1985 and 2012 in Seas of Europe **(Figure 2.12)** (EEA, 2015c). Monitoring stations in the southern area of the North Sea (historically affected by eutrophication) show a decreasing trend in nitrogen and phosphorus concentrations **(Figure 2.12)**. The Baltic Sea, which is also affected by eutrophication, shows a decreasing trend in nitrogen concentration, but an increase in phosphate concentrations **(Figure 2.12)** (EEA, 2015c). The adoption of national marine strategies fostered by the Marine Strategy Framework Directive (2008/56/EC) has supported the improvement of water quality in coastal and marine waters of the European Union.

The contributions of water quality regulation to quality of life are manifold, with particular interest for water security (Section 2.3.1.3), health (Section 2.3.2), and the enjoyment of recreational experiences in nature (Section 2.2.3.2). The restoration and construction of wetlands, together with the Nitrates, Water Framework the Marine Strategy Framework Directives of the European Union, are driving the decrease in water pollution. However, the loss of areal extent of wetlands and floodplains can jeopardize the future delivery of this contribution from nature to people.

2.2.1.8 Formation and protection of soils

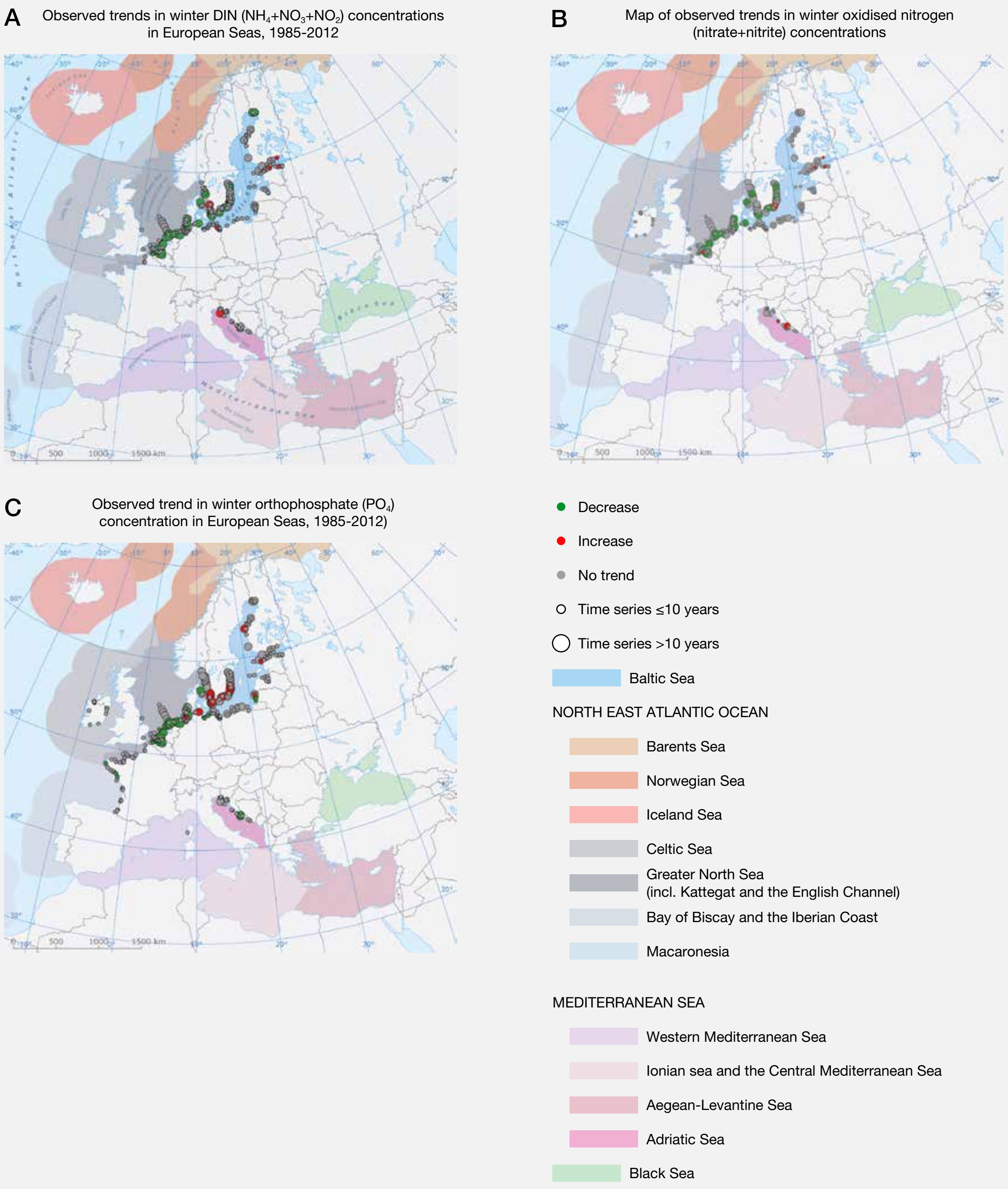
This contribution from nature to people relates to: (i) the central role of soils, which have high levels of biodiversity and which are crucial to several other contributions such as food and feed provision, freshwater quantity and quality regulation, climate regulation, hazards regulation; and (ii) the control of erosion. In addition, threats to soil such as erosion, loss of organic matter and biodiversity contamination, salinization, compaction, acidification and sealing) can severely decrease the ability of soils to deliver this contribution (FAO, 2015b).

2.2.1.8.1 Soil functioning: soil quality

Soil's essential functions are to capture, store and release carbon, nutrients and water; detoxify contaminants and purify water; degrade and recycle wastes; control pests; host a wide diversity of organisms; and create habitat for roots, fungi and invertebrates. The capacity of soil to perform these functions is called soil quality (Karlen *et al.*, 1997). Soil's quality depends on its inherent physical, biological and chemical properties. Soil biota play a major role in this regard (European Commission, 2016b).

Several indicators are used for soil quality (Karlen *et al.*, 1997; European Commission, 2014b), soil fertility (e.g., Burkhard *et al.*, 2014; Mueller *et al.*, 2014; Tóth *et al.*, 2013), and for soil's ability to naturally attenuate contaminants (e.g., Makó *et al.*, 2017; Stone *et al.*, 2016; Van Wijnen *et al.*, 2012). Soil organic carbon content, a widely used and

Figure 2 12 **Stations of European Seas (Iceland Sea, Norwegian Sea, Celtic Sea, North Sea, Baltic Sea, Bay of Biscay and the Iberian Coast, Mediterranean Sea, Adriatic Sea and Black Sea) with available data for the period reported (1985–2012) showing a statistically significant decrease (green), increase (red) or no trend (grey) of A winter dissolved inorganic nitrogen, B oxidized nitrogen and C orthophosphate concentrations. Source: EEA (2015c).**

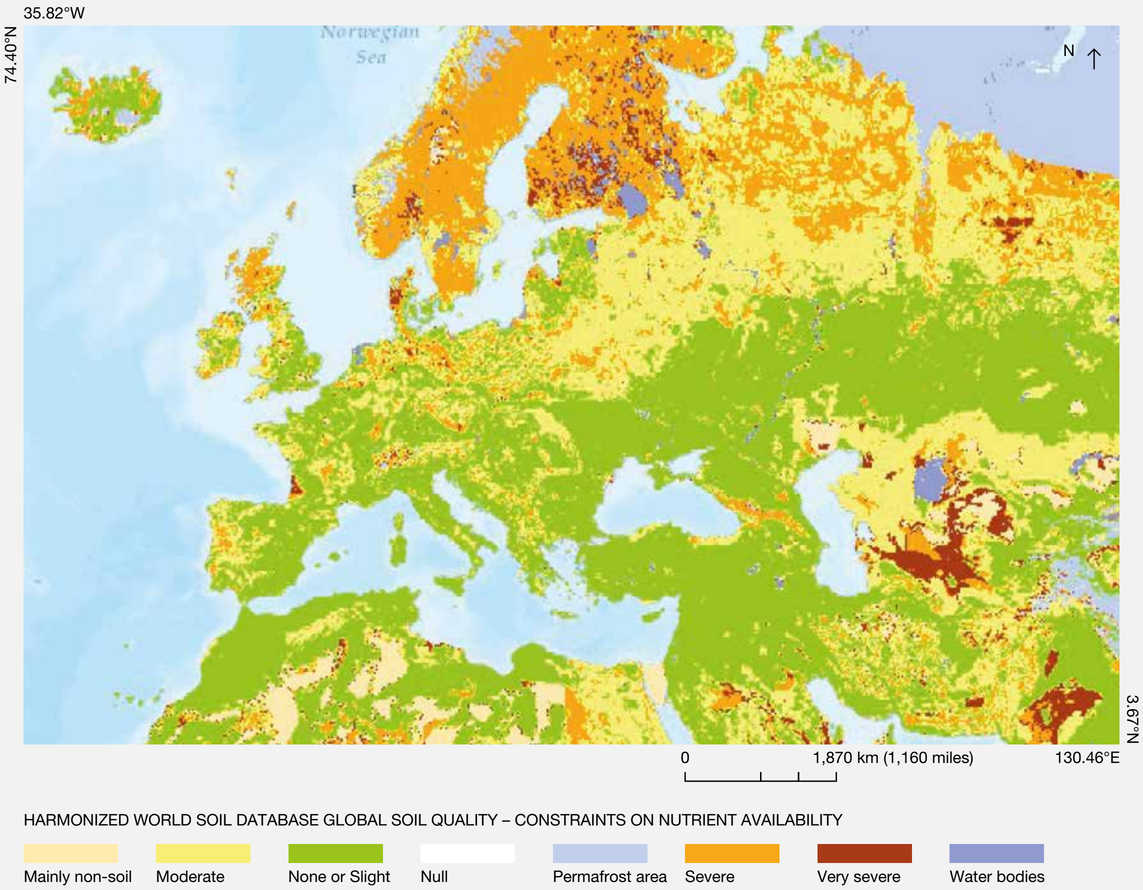


frequently available indicator of soil quality (Lorenz & Lal, 2016) is used here.

Most cultivated soils of Europe and Central Asia are intrinsically fertile except the drylands of Central Asia and salinized soils of Central Asia and Mediterranean Europe (FAO, 2015b; UNEP & UNECE, 2016) **(Figure 2.13)**. The organic carbon content of soils is very variable across land uses and soil types in Europe and Central Asia, generally low in cultivated soil, and high in forest and permanent grassland. Trends also vary with land use. While most grassland soils and forest soils accumulate

Figure 2 13 **Soil quality indicated by constraints on nutrient availability.**

The more fertile the soils, the fewer constraints there are on nutrient availability to plants (none or slight, moderate, severe, very severe) (Fischer *et al.*, 2012). Source: Map extracted from Data Basin at https://databasin.org/datasets/20dcb500682c4ec891e2fc881c2ed65c.



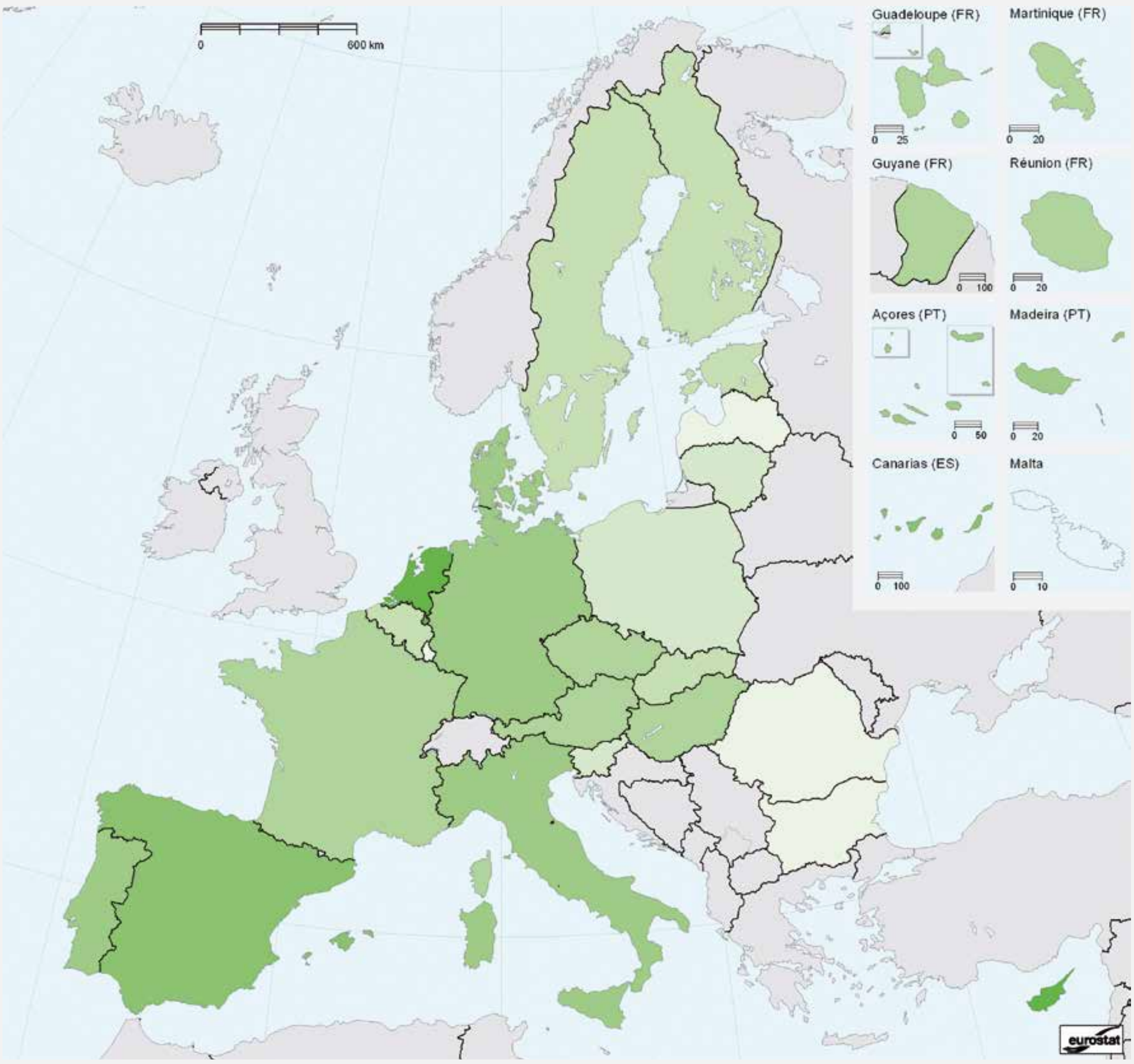
carbon, cultivated soils tend to loose carbon due to previous conversion from grassland or forest to intensive and continuous arable land and to drainage (Jones *et al.*, 2012). This loss has been widely documented in Western Europe (e.g. Capriel, 2013; Goidts & Wesemael, 2007; Heikkinen *et al.*, 2013), in Central Europe where about 70% of Turkish agricultural soils are losing soil organic matter (FAO, 2015b), in Eastern Europe (Sychev *et al.*, 2016) where more than 56 million ha of agricultural mineral soils are losing organic matter (FAO, 2015b), and in Central Asia (Causarano *et al.*, 2011; Sommer & de Pauw, 2011) where the cultivation of virgin lands in Kazakhstan between 1982 and 2000 resulted in the loss of approximately 570 million tonnes of carbon from soils (FAO, 2015b; Sommer & de Pauw, 2011). When alternative cropping practices such as conservation agriculture, organic agriculture or agroforestry are implemented, soil organic carbon loss is reversed, along with soil quality (e.g. Torralba *et al.*, 2016).

Land use changes occurring in Europe and Central Asia since 1990, such as afforestation and large-scale abandonment of cropland in the former USSR, resulted in increases in soil carbon content (Fuchs *et al.*, 2016; Kurganova *et al.*, 2015). A recent trend regarding the maintenance of fertile soils in Europe and Central Asia is the net loss of soil due to urbanization and sealing that occurs predominantly in Western Europe (Montanarella *et al.*, 2015; EEA 2015) and preferentially at the expense of cropland **(Figure 2.14)** (EEA, 2015b).

2.2.1.8.2 Erosion control

Soil erosion is the accelerated removal of soil from the land surface by water, wind or tillage. It threatens the sustainability of agriculture and forestry because of the loss of fertile topsoil, as well as causing damages off-site to settlements and infrastructure and affects the quality of surface waters. The severity of water erosion depends mainly on slope, soil erodibility, and soil cover by plants and litter (Lal, 2001b). Wind erosion depends on soil erodibility and soil cover (Lal, 2001a). Erosion, therefore, takes place mainly on vegetation-free surfaces and, therefore, primarily affects arable land. Soil erodibility depends particularly on soil texture and soil organic matter content (Le Bissonnais & Arrouays, 1997).

Figure 2 14 **Change in agricultural land use expressed as a percentage of total agricultural area (%). 2000–2006, EU-27. On average 50% of land conversion in the European Union is at the expense of agricultural land. Source: Eurostat (2017).**



Administrative boundaries: @EuroGeographics © EuroGeographics © UN-FAO © Turkstat
Cartography: Eurostat, European Commission
Source: Joint Research Centre, European Commission

Data for EL, MT and UK not available.

<= 0.081 | 0.081 — 0.1 | 0.1 — 0.2 | 0.2 — 0.3 | 0.3 — 0.4 | 0.4 — 0.8 | 0.8 — 1.5 | > 1.5

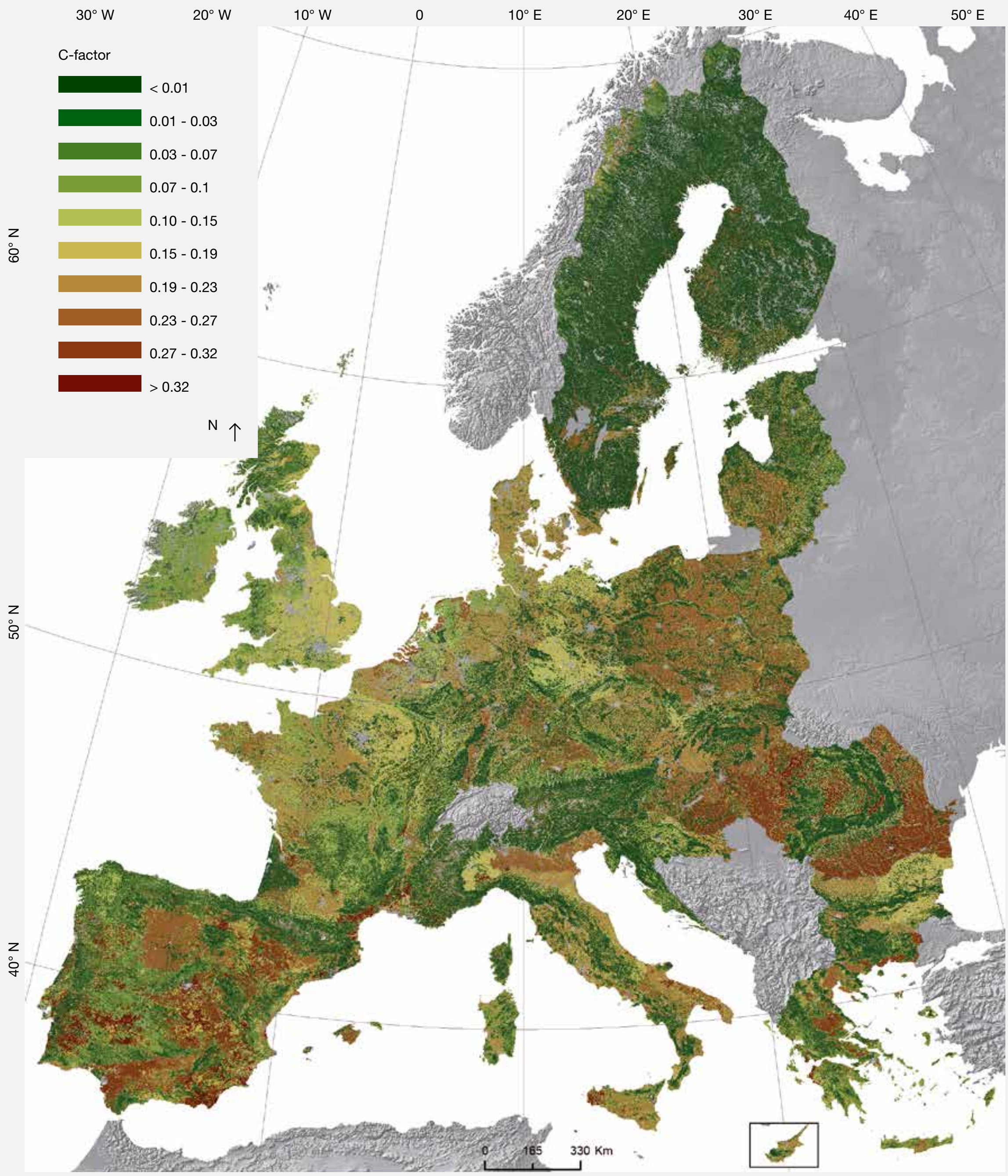
Erosion is the main soil degradation process in Europe and Central Asia (Stolte *et al.*, 2015). Water erosion dominates and affects a quarter of the EU-27 surface area (Jones *et al.*, 2012; Panagos *et al.*, 2015b), 26% of agricultural land in Russia (or 3.5% of total land) (FAO, 2015b) and about 30% of agricultural land in Moldova and Ukraine (FAO, 2015b). Wind erosion is less important in Western and Central Europe, affecting 10% of surface area (Borrelli *et al.*, 2014; Jones *et al.*, 2012), but dominates in Central Asia, where 23% of agricultural land is affected - nearly 80% of that in Uzbekistan (FAO, 2015b).

Erosion control can be defined as the erosion avoided due to the vegetation cover or to a well-aggregated soil (Guerra *et al.*, 2016). The soil cover factor (C) of the "universal soil loss equation" model for water erosion or its revised version, accounting for the effect of vegetation on water erosion, is used as an indicator of the capacity to control erosion (European Commission, 2014b; Panagos *et al.*, 2015a). In the Mapping and Assessment of Ecosystem Services project, erosion control by vegetation was estimated as: (i) the difference of eroded soil with and without vegetation; and (ii) the capacity of ecosystems to avoid erosion (European Commission, 2015b).

Vegetation cover is very heterogeneous in the EU-27 **(Figure 2.15)** (Panagos *et al.*, 2015a) and in Eastern Europe and Central Asia **(Figure 2.16)** in relation to climate. With a lower C factor, the capacity of ecosystems to avoid soil erosion is thus lower in Mediterranean areas of Europe and Central Asia **(Figure 2.17)** (Kulikov *et al.*, 2016). Vegetated soil cover has decreased in many areas of Europe and Central Asia in relation to intensive cultivation, rangeland degradation and desertification (FAO, 2015b; Gupta *et al.*, 2009; Le *et al.*, 2014). Management practices such as conservation agriculture, cover crops and residue return, when implemented locally, increased the C factor (Holland, 2004; Panagos *et al.*, 2016; Panagos *et al.*, 2015a).

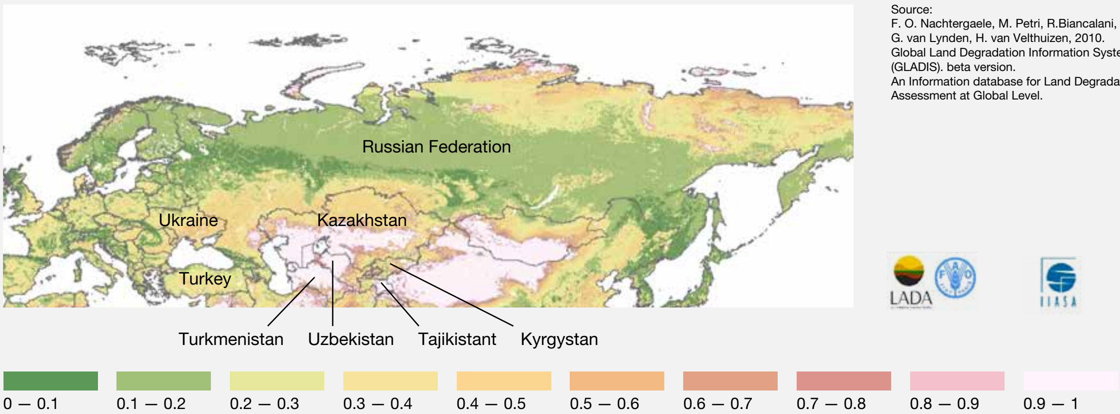
Figure 2 15 **Soil erosion cover management factor (C factor) for the European Union. Source: Panagos *et al.* (2015a).**

This factor, which decreases with soil cover (1 to 0) is a multiplicative factor to estimate the amount of eroded soil per unit surface using the revised universal soil loss equation (RUSLE) model.



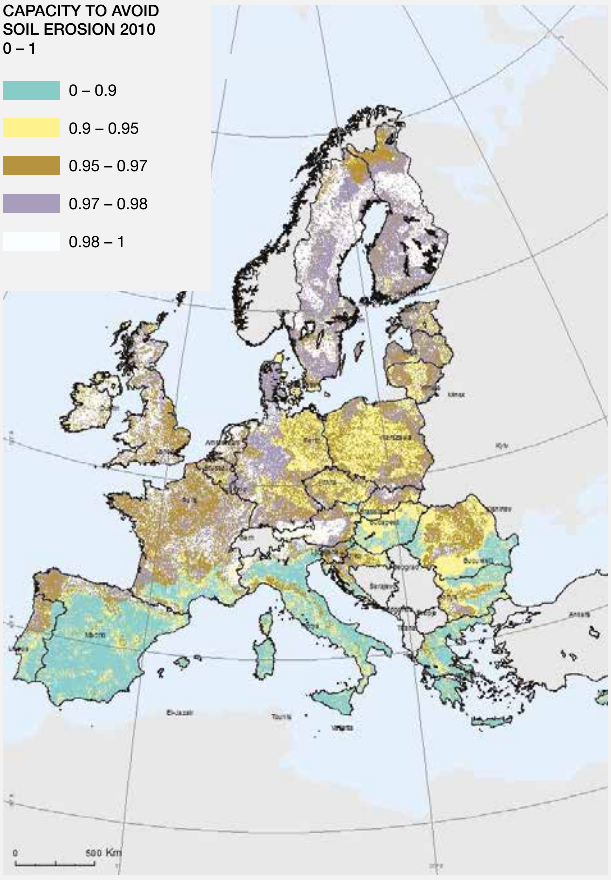
Erosion control decreased on agricultural land over the last two decades in Europe and Central Asia and is still decreasing in many areas of Central Asia (FAO, 2015b; Gupta *et al.*, 2009) and the East European plain in Eastern Europe (FAO, 2015b; Golosov *et al.*, 2011; Sorokin *et al.*, 2016). By contrast, erosion control has increased in the EU-27 between 2000 and 2010 by an average of 9.5%, and by 20% for arable lands (Panagos, *et al.*, 2015b) and in Mediterranean Europe between 2001 and 2013 (Guerra *et al.*, 2016). Common Agricultural Policy intervention measures, promoting practices such as reduced tillage, residue return, cover crops,

Figure 2 16 Soil erosion cover management factor (C factor) for Eastern Europe and Central Asia. Source: Nachtergaele *et al.* (2010).



Source:
F. O. Nachtergaele, M. Petri, R.Biancalani, G. van Lynden, H. van Velthuizen, 2010. Global Land Degradation Information System (GLADIS). beta version. An Information database for Land Degradation Assessment at Global Level.

Figure 2 17 Capacity of ecosystems to avoid erosion (0= lowest capacity; 1=highest capacity). Source: European Commission (2015b).



conservation agriculture, contour farming and grass strips can explain this trend (Panagos, *et al.*, 2015b). In Central Asia, the surface area of cropland under conservation agriculture, albeit very small, has more than doubled between 2007 and 2011 (Buhlmann *et al.*, 2010; Nurbekov *et al.*, 2016).

2.2.1.9 Regulation of natural hazards and extreme events

The Europe and Central Asia region is exposed to a range of natural hazards, including droughts, floods, landslides and avalanches, storms and wildfires. In the European Union, floods account for 40% of the damages by natural hazards and affect 50% of the population (European Commission, 2015c). With flooding being the most damaging natural hazard, this section focuses on trends of coastal and fluvial flood regulation, while we first briefly report on the general trends in the regulation of other natural hazards. Note that information on nature's capacity to regulate natural hazards is generally lacking for Europe and Central Asia, while information on the occurrence of natural hazards is more abundant.

The severity, frequency and persistence of meteorological and hydrological droughts have increased in Europe and Central Asia since the 1960s, although there are large differences across the region (EEA, 2016d; EM-DAT, 2017). Drought frequency in south-western and central Mediterranean Europe has increased, but has decreased in northern parts of Western Europe and parts of Eastern Europe (EEA, 2016d). The continued degradation and decline of wetland area (Section 2.2.1.7) has contributed to the reduced capacity to regulate droughts (Kumar *et al.*, 2017).

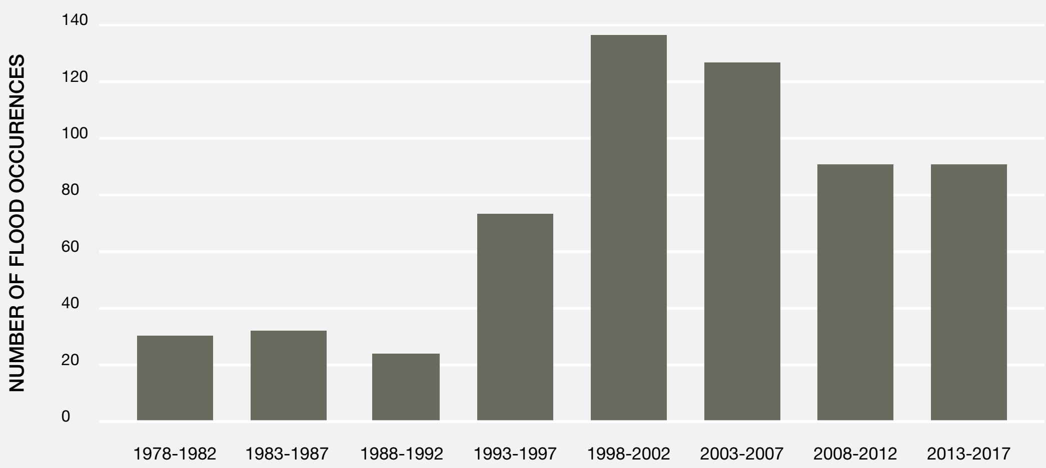
The severity and frequency of landslides and avalanches have mixed trends for the region (EM-DAT, 2017), while an increase in fatal landslides is observed for Western, Central and Eastern Europe (Haque *et al.*, 2016). The regulation of landslides is directly related to the amount of protected forest cover, especially in mountainous areas, and their protection status has changed little in recent decades (Miura *et al.*, 2015).

The frequency and severity of wildfires has generally increased throughout Europe and Central Asia (EM-DAT, 2017) and this trend continues, notably in Eastern Europe (Gauthier *et al.*, 2015) and causing changes in Mediterranean forests (Pausas *et al.*, 2008). The regulation of wildfires depends strongly on the plant composition of forests, protective forest management, and preservation of forest health, the latter being negatively affected by climate change.

In coastal areas, floods are caused by storm surges and sea level rise, whereas fluvial flooding predominantly occurs due to intensive and enduring rainfall within a catchment (Reed, 2002). Nature's capacity to attenuate flooding is reported in terms of the extent to which floods are regulated, whereas the occurrence and severity of floods, as well as the damage caused. The impact of natural hazards depends on the number of people affected, which is increasing as more people live in risk prone areas, such as river floodplains or coastal areas (Dawson *et al.*, 2009).

Information on nature's capacity to regulate floods in Europe and Central Asia is limited and generally shows a mixed trend. Increasing trends are reported for some countries of the European Union and Russia since the 2000s (European Commission, 2015b), but decreasing trends are reported

Figure 2 18 **Trends of flood occurrence for Europe and Central Asia. Source: Own representation based on EM-DAT (2017).**



for densely populated areas with intense rainfall and where most floodplain landscapes and wetlands have been heavily transformed (Heintz *et al.*, 2012; Solín *et al.*, 2011). In addition, the frequency and intensity of floods increased significantly from the 1980s to 2000, after which the number of floods stabilized at a high occurrence and severity (EEA, 2016b; EM-DAT, 2017) (see **Figure 2.18**). Almost 1,500 river floods have been reported for the European Union since 1980, of which more than half have occurred since 2000 (EEA, 2016b), although this increasing trend has a large inter-annual variability (EEA, 2016b; EM-DAT, 2017). The increasing number of severe floods is related to higher frequency of heavy precipitation events and decreased capacity to regulate fluvial floods.

Although there are reported increasing trends for flood regulation for some Western European countries since the 2000s (European Commission, 2015b), general trends are mixed and not well established. However, the number of coastal and river floods in Western Europe has increased since the 1980s, with a strong peak in 2000, and has remained stable but fluctuating in the last decade (EEA, 2016b; EM-DAT, 2017). The strongest increase in number of floods was reported for the southern part of Western Europe, while this number has decreased for most of the northern countries in this subregion (EM-DAT, 2017). The number of severe and very severe floods follows the same trend, with the sharpest increases reported for Spain, Germany and France (EEA, 2016b). Western European countries, such as Germany and France, are ranked among the 20 countries world-wide most affected by weather-related catastrophes in the past 20 years, including floods or landslides after heavy rains (Kreft *et al.*, 2016). The most affected countries in the period 1995-2014 in terms of deaths caused by these climate-change events were Italy, Spain and France (Kreft *et al.*, 2016).

In Central Europe, increasing trends for flood regulation since the 2000s are reported (European Commission, 2015b), but general trends are mixed. Studies in Bulgaria, Hungary and Poland demonstrated decreased flood regulation over time, in addition to increases in precipitation (Acreman *et al.*, 2007; Mrozik, 2016; Pehlivanov *et al.*, 2014). The number of floods in Central Europe has increased significantly since the 1980s, and this trend has continued in the last decade (EEA, 2016b; EM-DAT, 2017). The number of severe river floods follows the same trend, with the sharpest increase reported for Bulgaria, Poland and Slovenia (EEA, 2016b). Periodic overload of drainage systems and local inundations were reported for Poland, as a result of transformation of areas of permeable surfaces (arable land) into impermeable areas (built-up areas) (Mrozik, 2016). Mixed trends of flood frequency were reported for Slovakia, while land cover change negatively affected the capacity to regulate floods (Solín *et al.*, 2011). In addition, the Central European subregion, particularly Romania and Slovenia, has suffered higher damage due to climate-change events than Western Europe (Kreft *et al.*, 2016).

No clear trends in flood regulation have been reported for Eastern Europe. However, the loss of forests and woodlands is assumed to negatively impact the capacity for natural flood mitigation (Bradshaw *et al.*, 2007; Schmalz *et al.*, 2016). In the Danube River Basin, the extent of floodplains has been reduced to 68% of their pre-regulation extent (Hein *et al.*, 2016). Overall, the number and intensity of floods in Eastern Europe has increased greatly since the 1980s, with a peak in 2000, and has remained mixed in the last decade (EM-DAT, 2017). Regular severe floods have been reported throughout the subregion including for Russia (EM-DAT, 2017). Russia has also been among the most affected countries in the period 1995-2014 in terms of deaths caused by extreme climatic events (Kreft *et al.*, 2016).

No clear trends in flood regulation have been reported for Central Asia. The overall number and intensity of floods in the subregion has increased slightly since the 1990s, but has remained stable over the past decade (EM-DAT, 2017). Severe floods have been reported almost annually (EM-DAT, 2017).

Global warming and sea level rise are projected to increase the occurrence and frequency of flood events in large parts of continental Europe (EEA, 2016b; European Commission, 2015c). In addition, coastal flooding is expected to increase especially on the Mediterranean coast (Buyck *et al.*, 2015; European Commission, 2015c). People and their quality of life are increasingly exposed as the capacity to regulate and mitigate floods is likely to continue to decrease with current urbanization trends (Zedler & Kercher, 2005).

2.2.1.10 Regulation of detrimental processes: removal of animal carcasses

Vertebrate scavengers in Europe and Central Asia are represented by old world vultures, which are obligate scavengers that depend totally on carrion, and facultative scavengers, i.e. mostly mammalian carnivores, suids, raptors and corvids, which exploit carrion opportunistically (Moleón *et al.*, 2014). There are five vulture species in Europe and Central Asia: griffon *(Gyps fulvus)*, Himalayan (*G. himalayensis)*, cinereous *(Aegypius monachus)*, Egyptian *(Neophron percnopterus)* and bearded vulture *(Gypaetus barbatus).* Vultures and particularly griffons (the most abundant species in the region) are especially efficient in locating and consuming carcasses (Morales-Reyes *et al.*, 2017c; Sebastián-González *et al.*, 2015) but, within Europe and Central Asia, their range is limited to the southern parts of Western, Central and Eastern Europe and Central Asia. Other raptors, particularly eagles (*Aquila* spp.) and kites (*Milvus* spp.), together with corvids (mainly *Corvus* spp.) are also key scavengers in Europe and Central Asia. Among mammalian facultative scavengers, canids (e.g., wolves *Canis lupus*, jackals *C. aureus*, and foxes *Vulpes* spp. and *Alopex lagopus*), bears *(Ursus arctos)*, wolverines *(Gulo gulo)*, and wild boars *(Sus scrofa)* are important for scavenging (Mateo-Tomás *et al.*, 2015). Empirical evidence suggests that scavenging networks that include obligate scavengers are more efficient in the removal of carrion, including wild animal and livestock carcasses (Moleón *et al.*, 2014; Morales-Reyes *et al.*, 2017c; Sebastián-González *et al.*, 2015). In Europe and Central Asia, vertebrate scavengers remove an important fraction of the carrion biomass available (DeVault *et al.*, 2003; DeVault *et al.*, 2016; Mateo-Tomás *et al.*, 2015), contribute to pest and disease regulation (Ogada *et al.*, 2012) and nutrient cycling (Beasley *et al.*, 2015; Wilson & Wolkovich, 2011). Indigenous and local knowledge holders also describe the role of vertebrate scavengers in providing this contribution from nature to people: *"Even beasts are made by God and have a purpose, even the bad ones like wolves, they have their own role, they eat the corpses of dead animals, and they cleanse the landscape."* (Ivascu & Rakosy, 2017) (See supporting material Appendix 2.2)[11].

Most scientific evidence about the role of scavengers in carcass removal is from Western Europe, coinciding with the largest populations of vultures in this subregion (Margalida *et al.*, 2010). For example, it has been estimated that the Spanish vulture population removes between 134 and 200 tonnes of bones and between 5,551 and 8,326 tonnes of carrion from the landscape every year (Margalida & Colomer, 2012). In addition, the artificial removal of extensive livestock carcasses in Spain imposed by sanitary European Union regulations (Margalida *et al.*, 2010) meant the emission of over 77,000 tonnes of CO_2 eq. to the atmosphere per year and the annual payment of about $50 million to insurance companies by farmers and administrations (Morales-Reyes *et al.*, 2015). In the Massif Central (France) alone, up to 33.1 tonnes of CO_2 per year could be saved if vultures were allowed to access livestock carcasses (Dupont *et al*., 2012). In Central Europe, particularly in Serbia, jackals annually remove more than 3,700 tonnes of animal remains (Ćirović *et al.*, 2016).

The population of obligate and facultative scavengers determines the capacity for carcasses removal. Vultures have suffered sharp declines in Europe and Central Asia due to intended and unintended poisoning (e.g. Mateo-Tomás *et al.*, 2012), electric infrastructures such as wind farms and electric pylons (Carrete *et al.*, 2009; Sánchez-Zapata *et al.*, 2016) and, occasionally, veterinary drugs such as diclofenac (Green *et al.*, 2016; Margalida *et al.*, 2014a; Margalida *et al.*, 2014b). In fact, avian scavengers are the most threatened functional group of birds in Europe and Central Asia (Sekercioglu *et al.*, 2004). However, the trends of vulture populations vary across Europe and Central Asia (see **Table 2.3**, supporting material Appendix 2.4[12]). In Western Europe, where the major strongholds of vultures exist, particularly in Spain (home to >90% of European vultures; Margalida *et al., 2010*), vultures have recovered over recent decades after strong declines since the 1950s (Donázar *et al.*, 2016) due to reintroduction and conservation programmes (e.g. Eliotout *et al.*, 2007; Xirouchakis, 2010). By contrast, the situation of vultures in Central Europe is critical, although different conservation programmes seek to recover their populations (e.g. Demerdzhiev *et al.*, 2014; Grubač *et al.*, 2014; Kirazli & Yamac, 2013). Available information for Eastern Europe and Central Asia is very scarce for obligate scavengers, while facultative scavengers overall exhibit an increasing trend in distribution range and population size across these subregions (Chapron *et al.*, 2014; **Table 2.3**, supporting material Appendix 2.4[12]).

There are several drivers that can threaten the supply of this contribution from nature to people including the conflicting policies that might change the capacity of obligate and facultative scavengers to remove animal carcasses. For example, sanitary policies might restrict the access of scavengers to the carcasses of domestic and wild ungulates (Margalida *et al.*, 2010; Margalida & Moleón, 2016). The implementation of sanitary regulations after the outbreak of bovine spongiform encephalopathy in the European Union (Donázar *et al.*, 2009) had a negative impact on vulture conservation (Margalida & Colomer, 2012) and the functional role of facultative scavengers such as kites and wolves (Blanco, 2014; Lagos & Bárcena, 2015). Nevertheless, recent changes in the European Union sanitary regulation have largely improved this situation (Morales-Reyes *et al.*, 2017b). In addition, the intensification in livestock raising and the decline of traditional farming practices may threaten the removal of carcasses by scavengers (Olea & Mateo-Tomás, 2009). Finally, farmers' perceptions and their conflicting relations with facultative scavengers due to livestock predation can influence their tolerance towards these animals (Morales-Reyes *et al.*, 2017a).

The removal of carcasses by scavengers contributes to different dimensions of people's quality of life. The removal of scavengers may increase the incidence of infectious diseases (Ogada *et al.*, 2012). In addition, supplanting the ecosystem service provided by scavengers in agroecosystems with artificial removal of livestock could raise greenhouse gas emissions, with important environmental and economic costs (see above and Morales-Reyes *et al.*, 2015, 2017b). Vulture declines

11. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

12. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.4_avian_scavengers_trends.pdf

Table 2 3 **Conservation status (according to IUCN Red List categories) and population trend of main scavenger species (species selection based on Mateo-Tomás *et al.*, 2015) per subregion of Europe and Central Asia. Trends are reported as: increasing (+); decreasing (–); stable (0); fluctuating (F); heterogeneous trend within the subregion (mixed; see supporting material Appendix 2.4[12] for additional details of avian scavengers) or unknown (?). NA: data not available (i.e., there are no populations). Conservation status: EN: endangered; VU: vulnerable; NT: near threatened; LC: least concern. Source: Own representation based on Chapron *et al.* (2014); Deinet *et al.* (2013); Wilson *et al.* (2009); IUCN Red List of Threatened Species. Version 2017-1. www.iucnredlist.org; BirdLife International http://datazone.birdlife.org/info/euroredlist.**

Common name	Scientific name	Scavenger group	Functional group	Conservation status	Current population trend	Western Europe	Central Europe	Eastern Europe	Central Asia
Bearded vulture	*Gypaetus barbatus*	Vulture	Obligate scavenger	NT	–	mixed	mixed	mixed	?
Griffon vulture	*Gyps fulvus*	Vulture	Obligate scavenger	LC	+	+	mixed	mixed	?
Himalayan vulture	*Gyps himalayensis*	Vulture	Obligate scavenger	NT	0	NA	NA	NA	?
Egyptian vulture	*Neophron percnopterus*	Vulture	Obligate scavenger	EN	–	mixed	mixed	mixed	?
Cinereous vulture	*Aegypius monachus*	Vulture	Obligate scavenger	NT	–	+	mixed	mixed	?
Golden eagle	*Aquila chrysaetos*	Apex predator	Facultative scavenger	LC	0	mixed	mixed	mixed	?
Spanish imperi-al eagle	*Aquila adalberti*	Apex predator	Facultative scavenger	VU	+	+	NA	NA	NA
Black kite	*Milvus migrans*	Generalists	Facultative scavenger	LC	?	mixed	mixed	mixed	?
Red kite	*Milvus milvus*	Generalists	Facultative scavenger	NT	–	mixed	mixed	mixed	NA
Common buzzard	*Buteo buteo*	Generalists	Facultative scavenger	LC	0	mixed	mixed	mixed	?
Western marsh harrier	*Circus aeruginosus*	Predator	Facultative scavenger	LC	+	mixed	mixed	mixed	?
Raven	*Corvus corax*	Corvids	Facultative scavenger	LC	+	mixed	mixed	mixed	?
Common magpie	*Pica pica*	Corvids	Facultative scavenger	LC	0	mixed	mixed	mixed	?
Carrion crow	*Corvus corone*	Corvids	Facultative scavenger	LC	+	mixed	mixed	mixed	?
Eurasian jay	*Garrulus glandarius*	Corvids	Facultative scavenger	LC	0	mixed	mixed	mixed	?
Yellow-legged gull	*Larus michahellis*	Seabirds	Facultative scavenger	LC	+	mixed	mixed	?	NA
Grey wolf	*Canis lupus*	Apex predator	Facultative scavenger	LC	0	+	+	–	?
Brown bear	*Ursus arctos*	Apex predator	Facultative scavenger	LC	0	+	+	–	?
Polar bear	*Ursus maritimus*	Apex predator	Facultative scavenger	VU	?	–	NA	–	NA
Wolverine	*Gulo gulo*	Generalists	Facultative scavenger	LC	–	+	NA	–	NA
Golden jackal	*Canis aureus*	Generalists	Facultative scavenger	LC	+	+	+	?	?
Red fox	*Vulpes vulpes*	Generalists	Facultative scavenger	LC	0	0	0	0	?
Arctic fox	*Vulpes lagopus*	Generalists	Facultative scavenger	LC	0	0	NA	0	NA
Stone marten	*Martes foina*	Generalists	Facultative scavenger	LC	0	0	0	0	?

Common name	Scientific name	Scavenger group	Functional group	Conservation status	Current population trend	Western Europe	Central Europe	Eastern Europe	Central Asia
Pine marten	*Martes martes*	Generalists	Facultative scavenger	LC	0	+	+	+	?
Common genet	*Genetta genetta*	Generalists	Facultative scavenger	LC	0	0	NA	NA	NA
Eurasian badger	*Meles meles*	Generalists	Facultative scavenger	LC	0	0	0	0	?
Asian Badger	*Meles leucurus*	Generalists	Facultative scavenger	LC	?	NA	NA	?	?
Egyptian mongoose	*Herpestes ichneumon*	Generalists	Facultative scavenger	LC	0	0	NA	NA	NA
Wild boar	*Sus scrofa*	Omnivore	Facultative scavenger	LC	?	+	+	+	?

also have a negative impact on the cultural identity of farmers and the value they derive from knowing that these species exist (Morales-Reyes *et al.*, 2017a) (see Section 2.2.3.3).

2.2.2 Status and trends of nature's material contributions to people

2.2.2.1 Food and feed

2.2.2.1.1 Food and feed from terrestrial ecosystems

Agroecosystems, including croplands, grasslands and agroforestry systems, cover an important area of Europe and Central Asia, providing crops and animal-derived products that support the region's food security (Section 2.3.1.1) and food culture (see **Box 2.1** and **Box 2.2**). FAOSTAT provides extensive data on the quantity of this contribution delivered by nature to people. However, other terrestrial ecosystems, such as forests and scrublands, also provide food in the form of game, fruits and mushrooms, for which little quantification is available, but see Section 2.2.3.2. Comprehensive data on food quality has not been found, but the relationships between food production and the characteristics of diet and health are explored here and in Sections 2.3.1.1 and 2.3.2.

Overall the agricultural area per capita has been decreasing in Europe and Central Asia since the 1960s, particularly in Western Europe, however, the cultivated area per worker in the agriculture sector has almost tripled in Europe and Central Asia since the 1980s **(Table 2.4)**, a process that goes hand in hand with the mechanization and intensification of agriculture (**Table 2.4**, Section 4.5.2). Particularly, in the Mediterranean basin, quantity and quality of food delivered by agroecosystems is severely influenced by rural abandonment of mountainous and less productive areas and land-use intensification of fertile areas (Caraveli, 2000) (Section 4.5.2).

Food production from agriculture in Europe and Central Asia increased by 56% between the 1960s and the 1990s. It then suffered a decline of 33% until 2014. The three socio-political events that have most influenced these trends are: the dissolution of the USSR in 1989, affecting mostly Central Asia and Eastern Europe (Kraemer *et al.*, 2015); the Yugoslav Wars from 1991 to 1999 disturbing mostly Central Europe; and the Common Agricultural Policy of the European Union and its reforms (particularly since the MacSharry reform in 1992), influencing trends in Western and Central Europe.

The assessment of different agricultural products shows different trends across subregions. Cereals were mostly produced in Eastern Europe, where production has suffered fluctuations in recent decades (see **Figure 2.19**). Among cereals, however, maize is experiencing substantial growth (see **Figure 2.20**) because of its use for biofuel and feed production (see Sections 2.2.2.2 and 2.3.1.4). Fruit has been produced mostly in Western Europe, but Central Asia and Eastern Europe have been increasing their production in the past decade (see **Figure 2.19**). Countries in Eastern Europe are the largest producers of vegetables, which has been experiencing growth (from ca. 4.5 million tonnes in 1991 to more than 7 million tonnes in 2012), as rapidly as in Central Asia (from ca. 1 million tonnes in 1991 to more 3.5 tonnes in 2012) (see **Figure 2.19**). Important crops in Europe are those required for oil production (with increasing trends) and wine (with decreasing trend) (see **Figure 2.19**). Areas for organic agriculture in Western and Central Europe have been increasing since 2005 (in Western Europe from ca. 4% of the total agricultural area to more than 5%; in Central Europe from almost 1% to more than 4%) (see **Figure 2.21**) (FAO, 2017).

Table 2 4 **Historical trends of different indicators used to assess food provision as a contribution from nature to people. Red arrows indicate decreasing, yellow arrows indicate stable, green arrows indicate increasing and black arrows indicate mixed trends. Source: Own elaboration based on different data sources: FAOSTAT (2017); OECD (2017); World Bank (2017).**

CONTRIBUTION	INDICATOR	Western Europe	Central Europe	Eastern Europe	Central Asia	Europe and Central Asia
CROPS	Agricultural area (hectares per capita)	↓	↓	↓	↓	↓
	Cultivated area per agricultural population (hectares per capita)	↑	↑	↑	↕	↑
	Agricultural tractors per 1000 hectares of agricultural area	↕	↕	↓	→	↕
	Permanent crops (% of agricultural area)	↕	↕	↓	→	↕
	Production of cereals per person (kg / person)	↕	↕	↕	↕	↕
	Production of fruit per person - excluding melons (kg / person)	↕	↕	↕	↕	↕
	Fertilizer consumption (kilograms per hectare of arable land)	↕	↕	↓	↕	↕
	Intensity of total pesticides use (tons / hectare of cultivated area)	↕	↕	↕	↕	↕
	Substance use for seed treatment - fungicides and insecticides (tons / hectare of cultivated superficie)	↑	↕	↕	↑	↕
	Total actual renewable water resources withdrawn by agriculture (%)	↕	↓	↕	↓	↕
	Conservation agriculture area (% of cultivated area)	↑			↑	
	Organic agricultural area (% of total agricultural area)	↑	↑	→	→	↑
	Agricultural raw materials exports (% of merchandise exports in dollars)	→	↕	↕	↕	↕
	Agricultural raw materials imports (% of merchandise imports in dollars)	↓	↕	↓	↓	↕
	Cereal production (% of world production)	↕	↕	↕	↕	↕
LIVESTOCK	Domestic mammals per rural inhabitant (except pack animals)	↑	↕	↕	↕	↕
	Poultry animals per rural inhabitant	↕	↕	↕	↕	↕
	Pack animals per square km of agricultural area	↕	↓	↕	↑	↓
	Combine harvesters - threshers per 1000 hectares of agricultural area	↕	↕	↓	→	↕
	Milking machines per head of cattle	↕	↕	↓	↕	↕
	Meadows and permanent pasture (% of agricultural area)	→	↑	↑	→	↑
	Production of meat per person (kg / person)	↕	↕	↕	↕	↕
	Meat production (% of world production)	↓	↕	↕	↕	↕

The production of livestock primary production varies. Meat production increased between 1961 and 1990, when a sharp decline occurred in Eastern and Central Europe due to the dismantling of the Soviet Union (see **Figure 2.22**). However, since the early 2000s the trend changed in Eastern Europe and it is currently producing almost half of the meat in the region. Egg production follows a similar pattern, except in Eastern Europe with an increasing trend since 1996. Milk production has been decreasing since the 1990s (largely due to the introduction by the Common

Figure 2 19 **Historical trends for average country production (tonnes) in each subregion: crop primary production of cereals, fruit (excluding melons) and vegetable crops; and crops processed for olive oil virgin, rapeseed oil, sunflower oil and wine. Note that the vertical axes are on a different scale. Source: Own representation based on data from FAO (2017).**

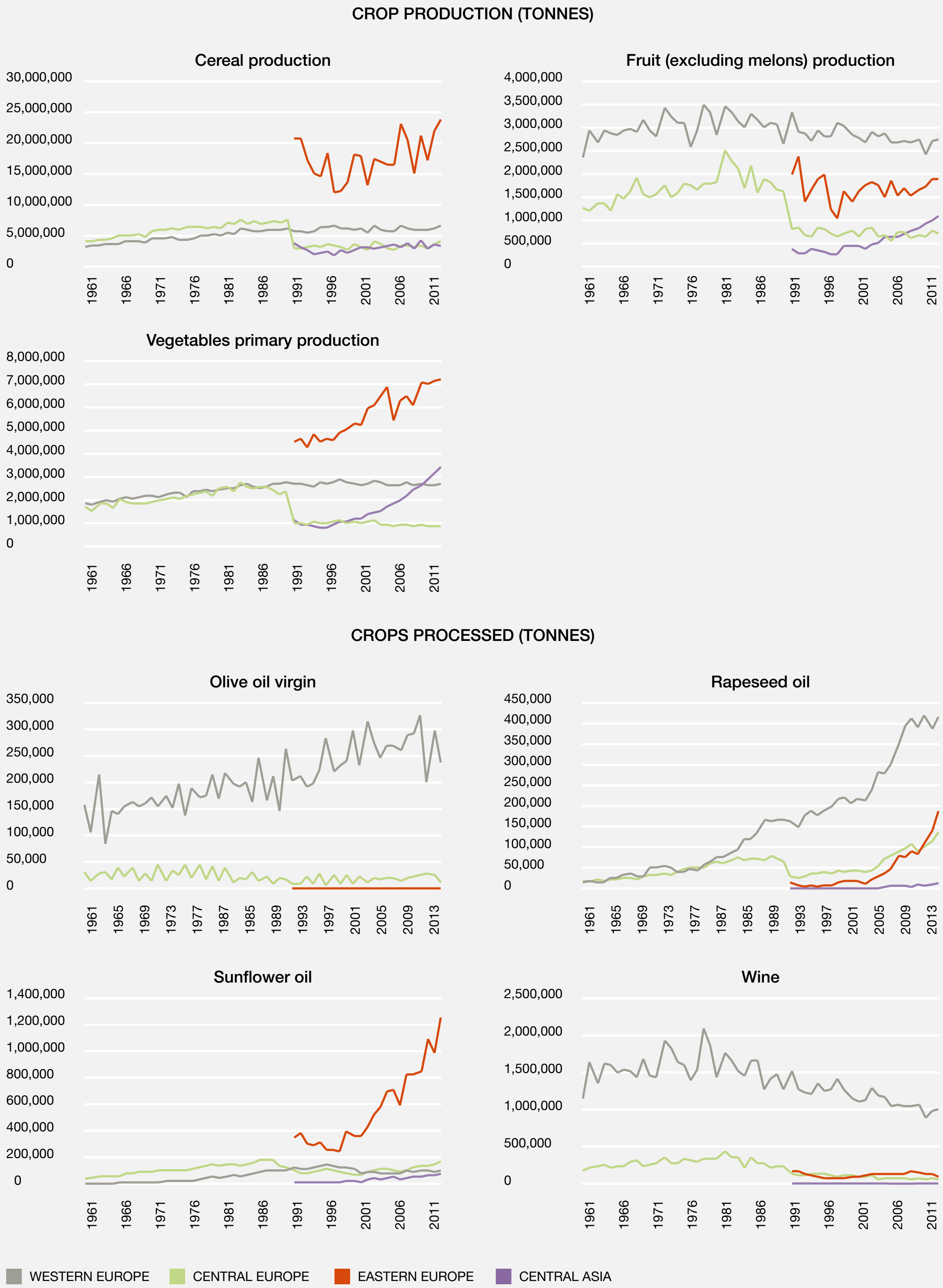


Figure 2 20 **Historical trends for average country production (tonnes) of maize in each subregion. Source: Own representation based on data from FAO (2017).**

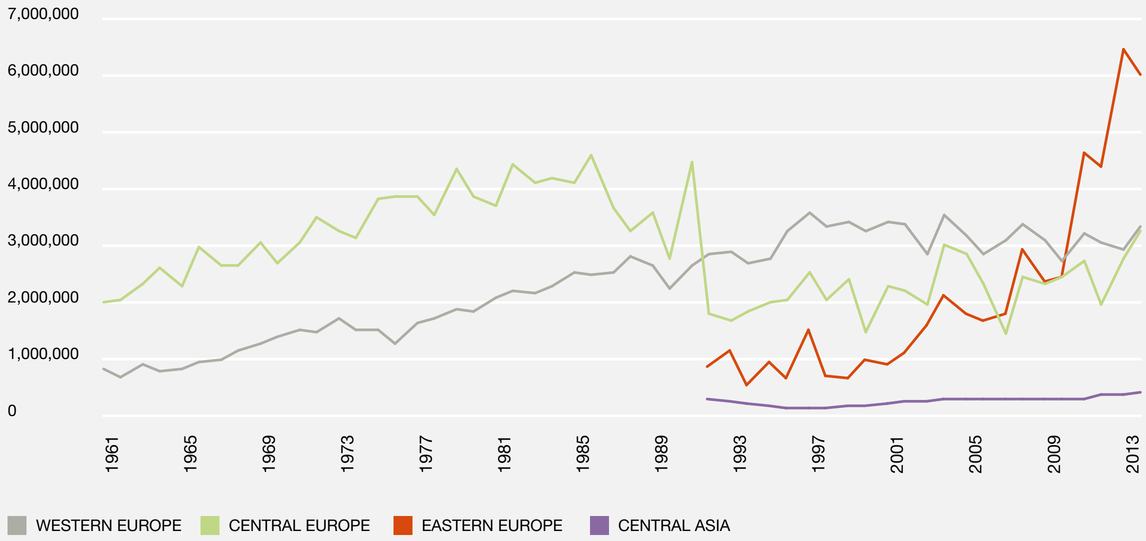
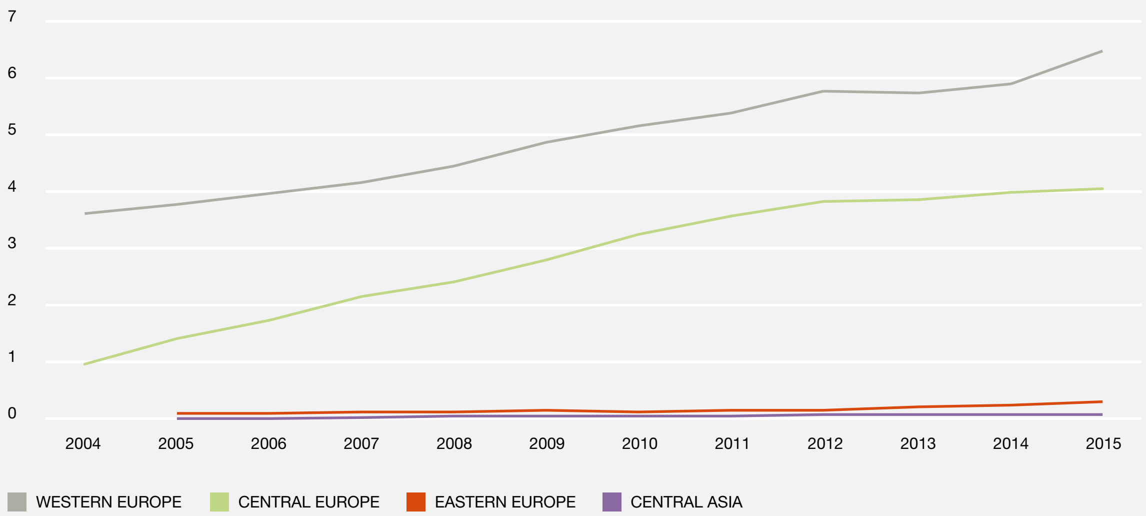


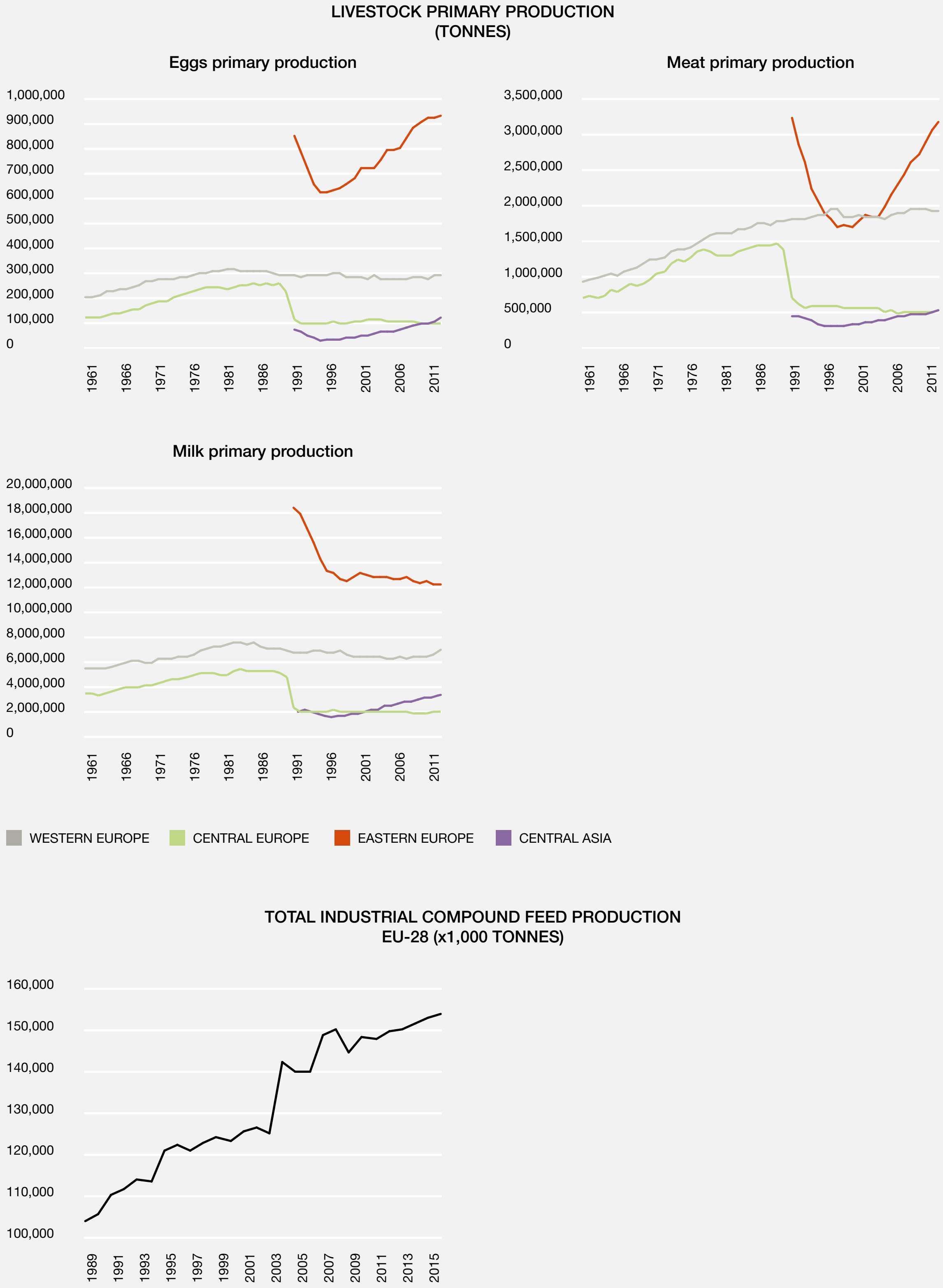
Figure 2 21 **Historical trends of organic agriculture area (% of total agricultural area) in each subregion. Source: Own representation based on data from FAO (2017).**



Agricultural Policy of the European Union of milk quotas), except in Central Asia. The countries with the largest production in the region in 2013 were Russia and Ukraine for eggs, Russia and Germany for meat, and Germany and Russia for milk. The production of livestock feed in EU-28 has experienced a sharp increase of more than 50% over the past three decades, consistent with the intra-regional trade balance of increasing import of ingredients of these feeding compounds such as soybeans, and with the above-mentioned intensification of livestock farming in the European Union.

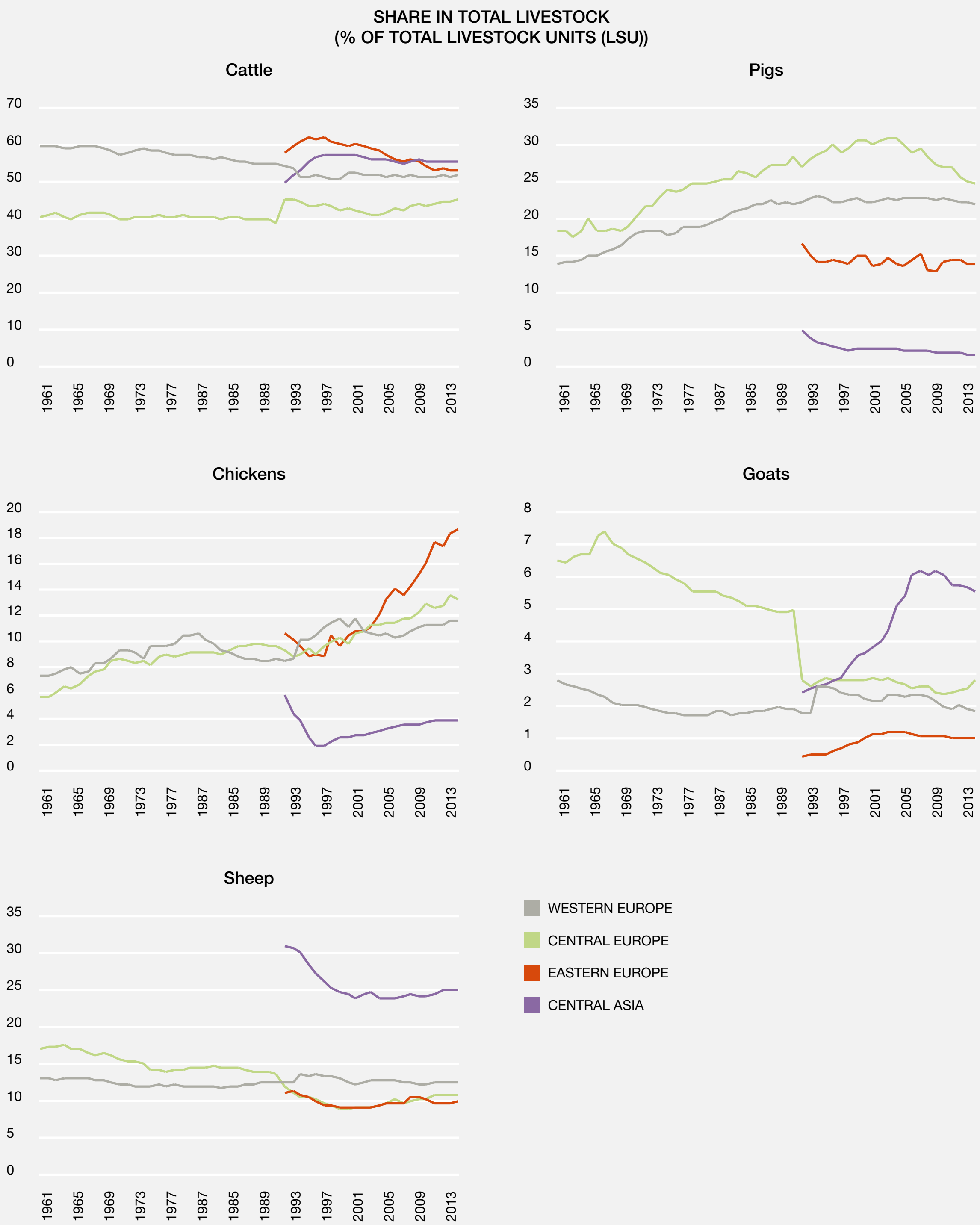
Cattle represent the largest share of livestock animals in Europe and Central Asia (see **Figure 2.23**). In Central Asia, sheep account for about 25% and goats for about 6% of livestock production. In Central Europe, pigs represent the second largest share (25% in 2013), but this has been decreasing since the early 2000s. Chicken account for almost 20% in Eastern Europe, with rapid increases in recent decades. Overall, the trend in the past decade is an increase in chicken production, maintenance of cattle production, and reduction of pigs, goats and sheep **(Figure 2.23)**.

Figure 2 22 **Historical trends for average country production of livestock primary production (tonnes) of eggs, meat and milk in the four subregions and total industrial compound feed in the EU-28. Source: Own representation based on data from FAO (2017) and FEFAC (2017).**



Forests provide nuts, mushrooms, herbs, spices, aromatic plants and game that have been used not only as food, but also for health and cultural purposes for millennia. Yet a recent report by the Food and Agriculture Organization of the United Nations acknowledges that there is a tendency to underestimate their role because they are poorly represented in international statistics, as in most cases their use and trade are confined to the informal sector (Sorrenti,

Figure 2 23 **Historical trends in the share of total livestock represented by cattle, pigs, chicken, goats and sheep in the subregions. Source: Own representation based on data from FAO (2017).**



2017). However, recent studies show that non-timber forest products still form the basis of livelihoods and play a significant role in food, nutrition and as a source of income, particularly in times of deep economic crisis (e.g. Elbakidze *et al.*, 2007).

2.2.2.1.2 Wild capture and cultured aquatic food production

Fishing has a long, rich tradition in Europe and Central Asia (Ståhlberg & Svanberg, 2011), and is still an important source of protein for indigenous people (Demeter, 2017). Across Europe and Central Asia, aquatic ecosystems make an important contribution to people's diets, directly as food and as feed for livestock. The largest contribution of aquatic ecosystems is wild-captured seafood, especially from the highly productive North East Atlantic. Seafood production from this area is 8.9 million tonnes per year (production data from 2014, if not otherwise stated). Wild capture of seafood from the Mediterranean and Black Sea area (restricted to Europe and Central Asian fleets) is much smaller (0.5 million tonnes per year), even when taking the smaller size of this area into account. This is largely due to lower nutrient concentrations in the Mediterranean. In relation to primary production, fisheries are similarly productive in the Mediterranean and Black Sea as, e.g., in the North Sea (Libralato *et al.*, 2008). A decline in production since the turn of the millennium (see **Figure 2.24**) is due to a transition to more sustainable management practices, after a phase of overexploitation where catch limits larger than those scientifically advised were regularly set (Carpenter *et al.*, 2016; Hilborn & Ovando, 2014).

Reported production of wild capture food from inland waters in Europe and Central Asia is dominated by freshwater (67%) and diadromous (31%) fisheries. Compared with marine production, wild capture food from inland waters is relatively small at 0.4 million tonnes per year, but it plays an important role especially in Eastern Europe and Central Asia, which are dominated by commercial fisheries (Aps *et al.*, 2004). Data prior to 1988 are insufficient for a regional assessment, but, as **Figure 2.25** shows, production of wild capture food from inland waters in Europe and Central Asia fell from 1988 to 2005, but since then has grown slightly. The decline in production in Eastern Europe since 1988 until the turn of the millennium **(Figure 2.25)** has been attributed to the serious depletion of many open access freshwater fishery resources caused by overfishing and "insufficient control and enforcement (illegal and unreported catches do not appear in statistics)" (Aps *et al.*, 2004).

Contrasting the situation for wild-capture fisheries, production from aquaculture has continuously increased since 1950, with the exception of a brief phase of contraction in Eastern Europe after the socioeconomic transformations around 1990 (see **Figure 2.26**). According

Figure 2 24 **Marine wild-capture seafood production in seas surrounding Europe and Central Asia. Colouring indicates contributions from the North East Atlantic Ocean (FAO Area 27, violet) and Mediterranean and Black Sea (FAO Area 37, grey). Source: Own representation based on data from FAO (2017).**

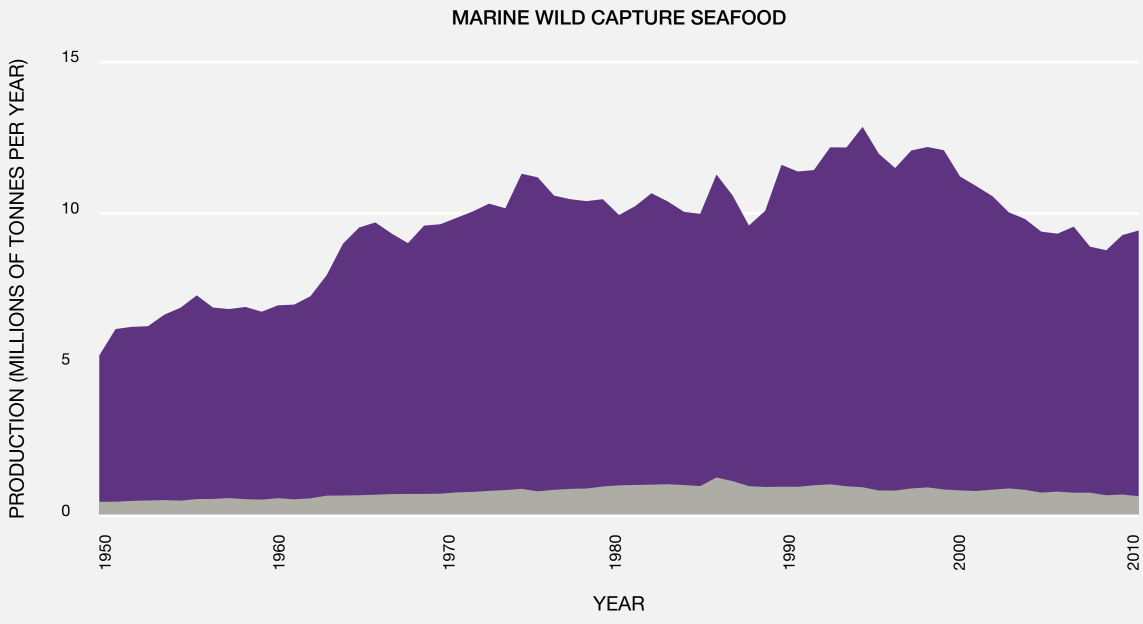


Figure 2 25 **Inland wild capture production of aquatic food in Europe and Central Asia. Colouring indicates contributions from Central Asia (violet), Eastern Europe (orange), northern parts of Central Europe (green), southern parts of Central Europe (white), and Western Europe (grey). Source: Own representation based on data from FAO (2017).**

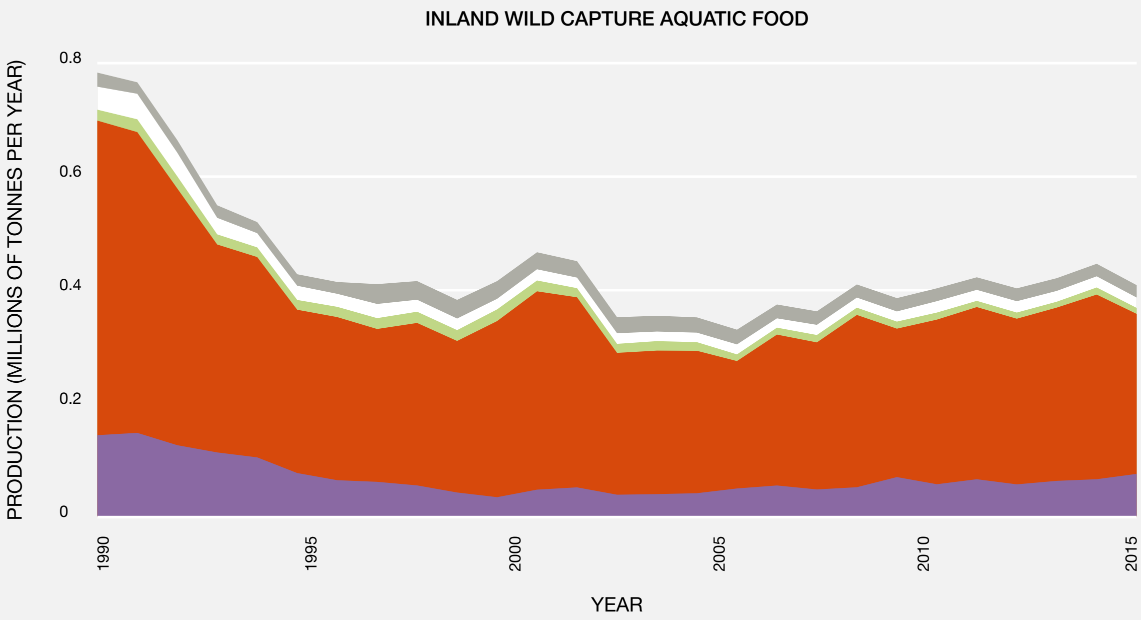
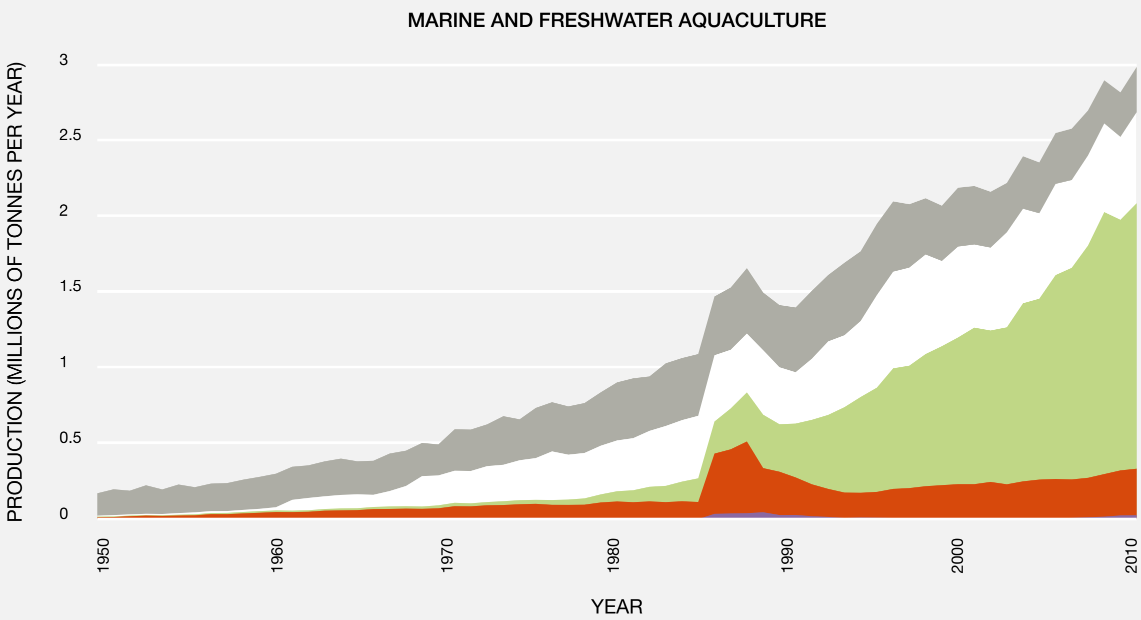


Figure 2 26 **Aquaculture production in Europe and Central Asia. Colouring indicates contributions from Central Asia (violet), Eastern Europe (orange), northern parts of Central Europe (green) and southern parts of Central Europe (white), and Western Europe (grey). Source: Own representation based on data from FAO (2017).**



to these data, production has grown at an average rate of 2.7% per year since 2000 and by 2014 reached 3.0 million tonnes per year. Salmon farming in northern parts of Western and Central Europe made an important contribution to this expansion. Overall, diadromous fish now contribute around 63% to total aquaculture production, followed by molluscs (21%), freshwater fish (10%) and marine (6%) fish. Despite this continuous rise in aquaculture production, Europe and Central Asia lags behind the global rate, where the proportion of aquaculture fish production now contributes 40% of production (FAO, 2014a). This indicates the potential for significant further expansion in Europe and Central Asia. However, as with wild-capture fisheries, aquaculture can have adverse environmental effects that might offset its benefits (Read & Fernandes, 2003).

2.2.2.2 Energy

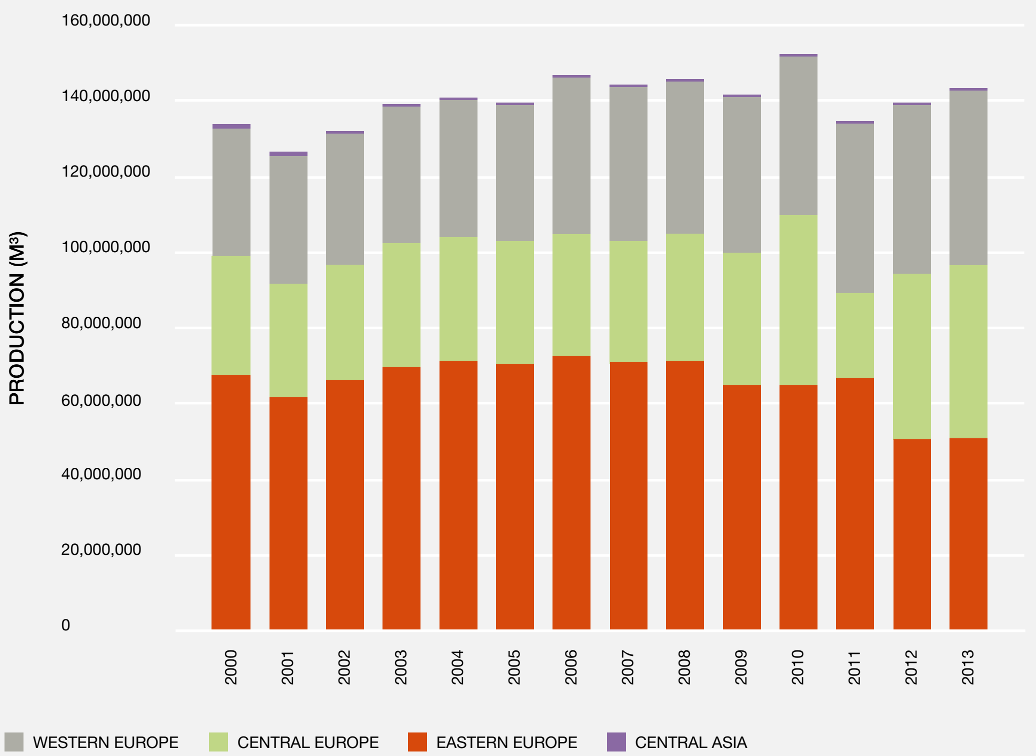
Various forms of biomass can serve as fuel including plants, animal dung, and agricultural residues. Plant matter is used directly or in processed forms such as charcoal and oil. Two forms of biomass-based energy are particularly relevant in Europe and Central Asia and therefore the focus of the following sections: woodfuel and biofuels.

2.2.2.2.1 Woodfuel

Woodfuel (including logs, charcoal, chips, bark, and sawdust) has a high energy density (comparative average values in MJ/kg - woodfuel: 16; charcoal: 28; coal: 30; natural gas: 37 and fuel oil: 4) (IEA, 2004). Its availability, accessibility and renewability make it attractive, especially in rural areas. According to statistics from the Food and Agriculture Organization of the United Nations, overall woodfuel production and consumption has been largely stable since 2000 (see **Figure 2.27**). Within Western Europe, woodfuel use is significant especially in Scandinavia. It is unclear whether the comparatively low woodfuel production in Central Asia according to statistics from the Food and Agriculture Organization of the United Nations (see **Figure 2.27**) (between 2000-2013 it varied between 190,000 and 1,000,000 m^3 p.a.) is due only to biogeographic and climatic differences, or also due to underreporting.

Driven by the European Union's legally binding targets in the Renewable Energy Directive (RED - 2009/28/EC), production of renewable energy within the EU-28 almost doubled between 2004 and 2013. Based on Eurostat, in 2013, total biomass (woodfuel and other biomass including municipal waste) accounted for 65% of the gross inland energy consumption of renewables in the

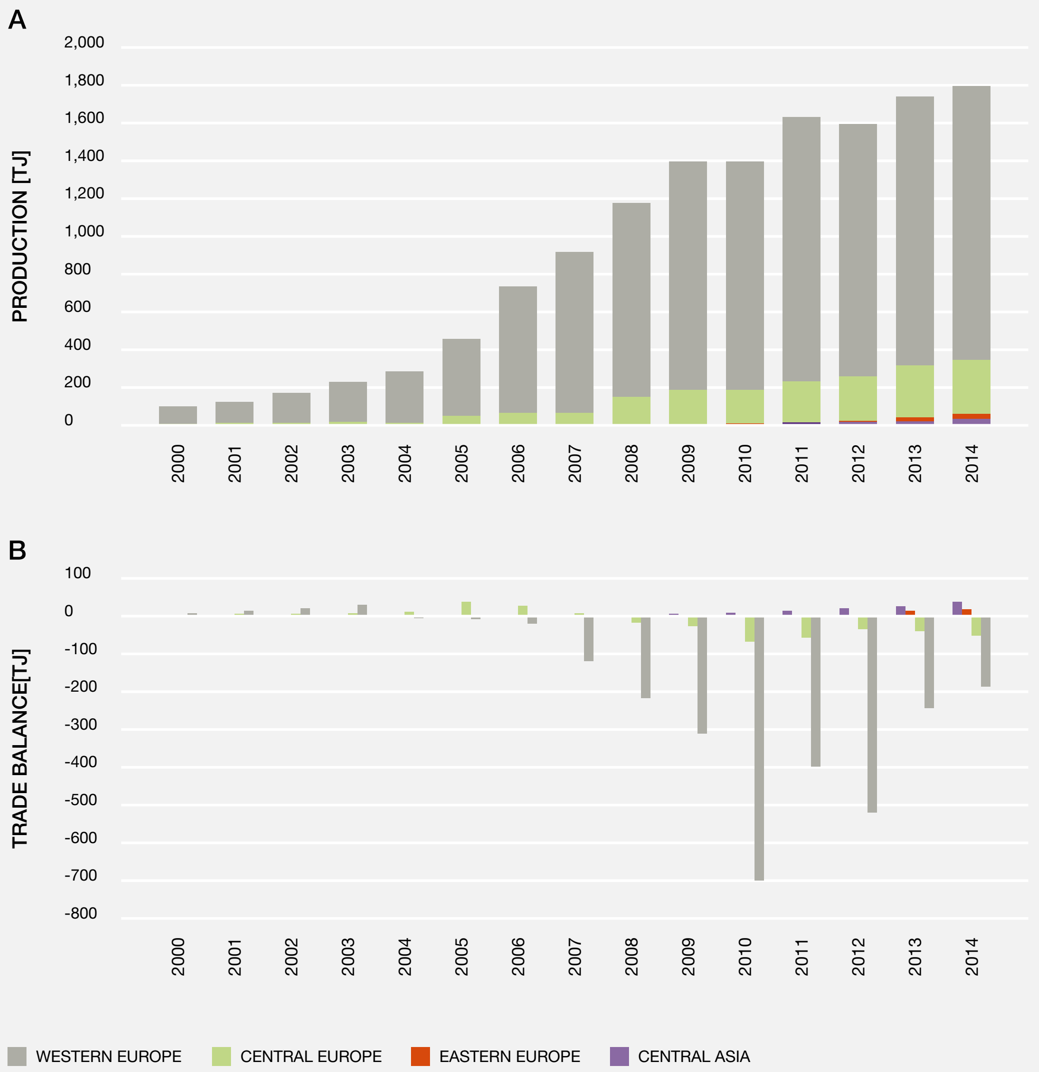
Figure 2 27 **Woodfuel production in Europe and Central Asia between 2000 and 2013. Source: Own representation based on data from FAO (2017).**



EU-28, of which wood and wood wastes contributed the highest share with 45%. Around 23% of the EU-28's total roundwood production of 425 million m³ in 2014 was used as woodfuel (Eurostat, 2017). Among the European Union member States, Sweden produced the most roundwood (70 million m³) in 2014, followed by Finland, Germany and France (each producing between 52 and 57 million m³). More than half of roundwood produced is used as fuel in Denmark, France and Cyprus (2013 and 2014), while Bulgaria, Croatia, Hungary and Lithuania reported proportions between 32 and 46%. However, direct woodfuel use by households is not included in these numbers, which is why they are likely to be underestimates.

In the European Union, woody biomass accounts for almost 50% of renewable energy consumption (Pelkonen *et al.*, 2014). In some widely forested countries, large proportions of total energy consumption originate from forest biomass, for example 30% in Sweden (Hansen & Malmaeus, 2016) and 25% in Finland (Jäppinen & Heliölä, 2015). Due to a long-standing tradition of forestry and forest management in Western and Central Europe, deforestation driven by woodfuel and other wood product extraction is not currently a threat for the region (UNEP & UNECE, 2016). On the other hand, dependence on woody biomass as a source of domestic energy continues to be prominent especially in rural and economically disadvantaged communities in Europe and Central Asia. In Central Asian countries such as Tajikistan,

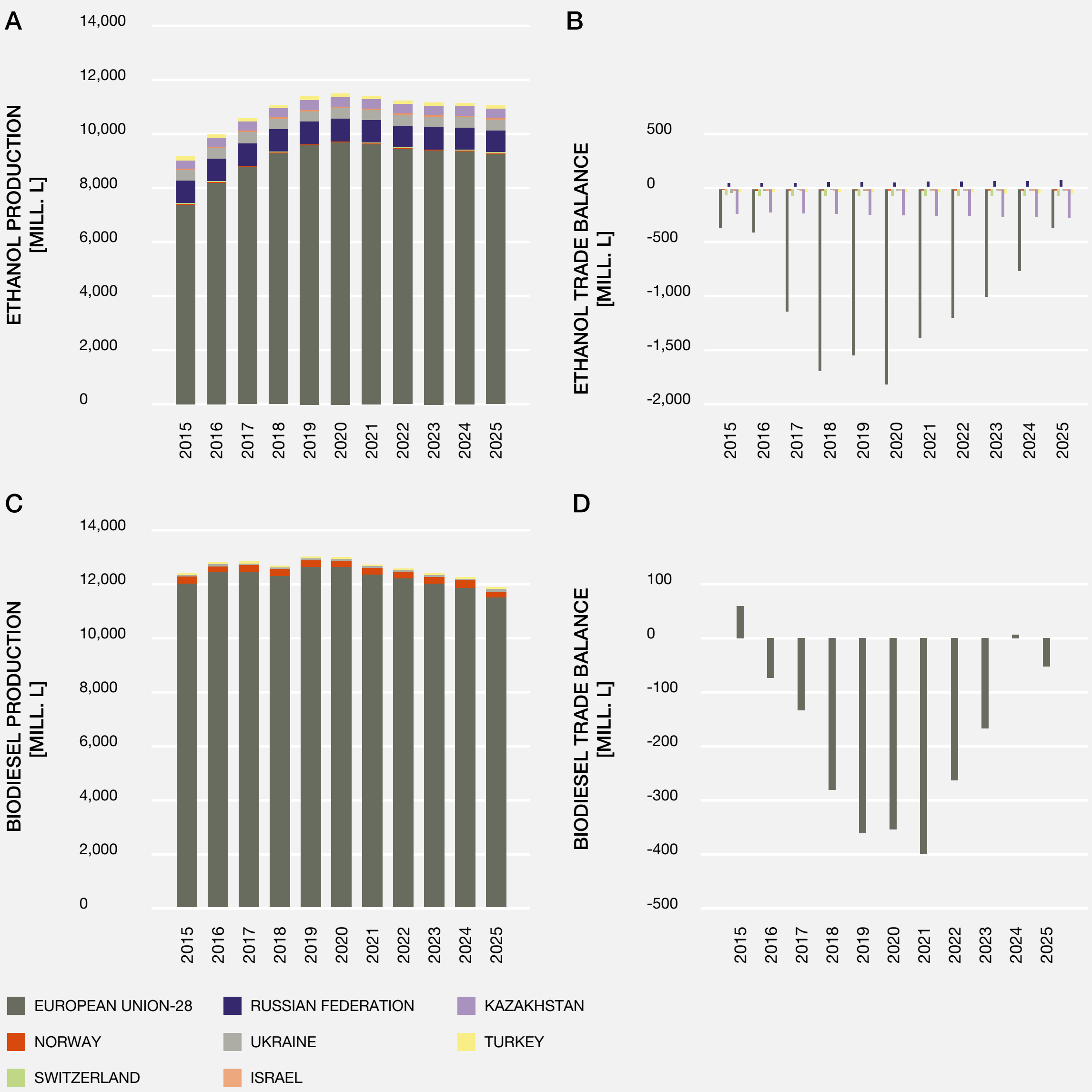
Figure 2 28 **A Biofuel production by regions in Europe and Central Asia from 2000 to 2014. B Trade balance of biofuels by regions in Europe and Central Asia from 2000 to 2014. Source: Own representation based on U.S. Energy Information Administration (2017).**



deforestation continues and overuse of forests for fuel is one of the main reasons for land degradation (Mustaeva *et al.*, 2015). In the Balkans and the South Caucasus, wood remains an important affordable energy source (Adeishvili, 2015). In Albania, for instance, firewood meets one-third or more of the total energy demand for heating and accounts for almost 90% of wood use (Markus-Johansson *et al.*, 2010). In certain areas of Europe and Central Asia, restraining economic conditions lead to considerable illegal woodfuel harvesting. In Turkey, for example, off-the-record logging for woodfuel (estimated 4,300,000 m^3) reached more than half the permissible woodfuel harvests (7,000,000 m^3) in 2010 (Pak *et al.*, 2010). In the Ukraine, the economic recession and the gas crisis caused by the Russian-Ukrainian conflict is reported to have significantly increased firewood thefts (Roué & Molnar, 2017).

Woody biomass demand from countries with ample forest resources such as Sweden and Finland is foreseen to increase (Jonsson, 2013) and generally in Western, Central and Eastern Europe the shift towards a carbon neutral society is expected to further boost the demand for woodfuel (Bostedt *et al.*, 2016). This intensification of biomass removals from forests may have trade-offs in forest productivity, biodiversity and soil quality (Bouget *et al.*, 2012; Verkerk *et al.*, 2014).

Figure 2 29 **A and C Biodiesel and ethanol production in selected countries in Europe and Central Asia from 2015 to 2025. B and D Trade balances of biodiesel and ethanol in selected countries in Europe and Central Asia from 2015 to 2025. Source: Own representation based on OECD-FAO (2016).**



Historically, woodfuel collection is among the earliest uses of forests by humans (Pelkonen *et al.*, 2014). Local ecological knowledge related to forest management is just as rooted in Europe and Central Asia as woodfuel utilization. An example from the communities inhabiting the lowland landscapes of Transcarpathian region *Zakarpats'ka oblast'* in western Ukraine points to a tradition of accessing firewood as dry wood and during forest logging (Roué & Molnar, 2017). The locals state the need for young forest stands in addition to old, diverse structured forests: "*For firewood we went only here, on the Lapos. That was the closest, and there was thin, dry wood, which could be broken by hand.*" (ibid) (See supporting material Appendix 2.2[13]).

2.2.2.2.2 Provision of biofuels

The term "biofuel" generally refers to liquid transportation fuels made from biomass materials, such as ethanol and biodiesel. Biofuel production rose by a factor of ten between 2000 and 2014 in Western Europe **(Figure 2.28)**. Simultaneously, imports increased both in Central and Western Europe, but the import dependence was much higher in Central Europe. Central Asia and Eastern Europe had only a negligible share **(Figure 2.28)**. In terms of energy content, current annual production of biofuel **(Figure 2.28)** remains small compared to that of woodfuel (140,000,000 m^3 correspond to 1,000,000 – 2,400,000 tJ energy).

13. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

An outlook for Europe and Central Asia shows a slight increase in ethanol production until 2020, which is expected to become stable by 2025 **(Figure 2.29)**. For biodiesel, production is expected to peak by 2019 and to decline until 2025. The EU-28 as major producer is equally a major consumer with a strongly negative trade balance for both ethanol and biodiesel production. It is expected to roughly equalize until 2025. Only for Kazakhstan, a continuously negative trade balance for ethanol is expected. However, impacts of the production of energy crops on the environment and on other contributions from nature to people limit their use (Meyer & Leckert, 2017). Major concerns exist concerning the potential of GHG emission offset, regulation of soil quality, water quality and quantity, biodiversity, and indirect land-use change that displaces ecological impacts outside of the biofuel production region (Efroymson *et al.*, 2013; McBride *et al.*, 2011). These trade-offs could be considered in policy by implementing, for instance, stricter rules for biofuel certification that consider the environmental and social impacts within and beyond the feedstock production region (Meyer *et al.*, 2016).

In the future, agricultural residues, as one example of second-generation biofuel feedstocks, can also contribute substantially to energy production. Studies for the European Union consider that around 25 to 60% of agricultural residues could be available for this purpose (Bentsen & Felby, 2012).

Figure 2 30 **Annual production of roundwood in Europe and Central Asia, 1961–2014 in cubic metres. Source: FAO (2017).**

Figure 2 31 **Annual roundwood removal in Western, Central and Eastern Europe (for Eastern Europe only data for the Russian Federation is available) in 1,000 m^3. Source: Own representation based on Eurostat (2017).**

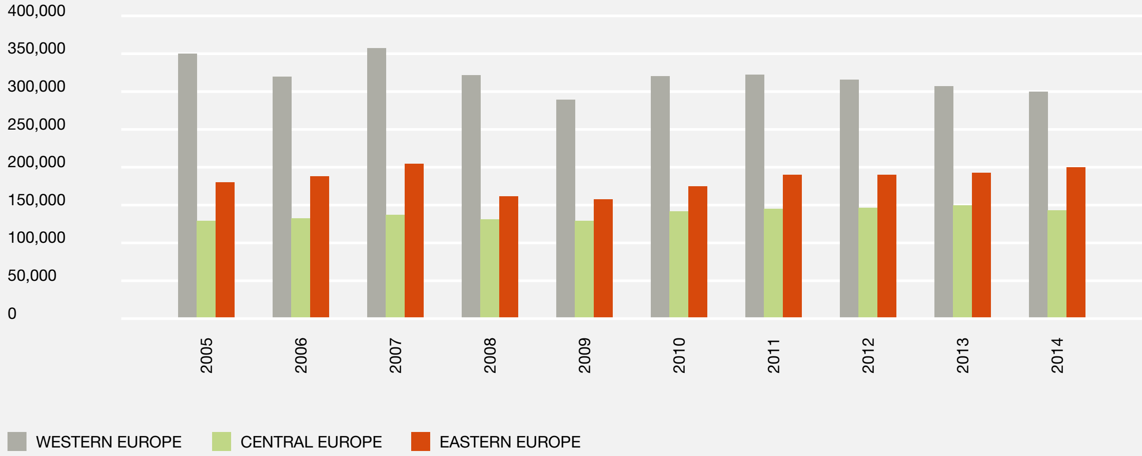
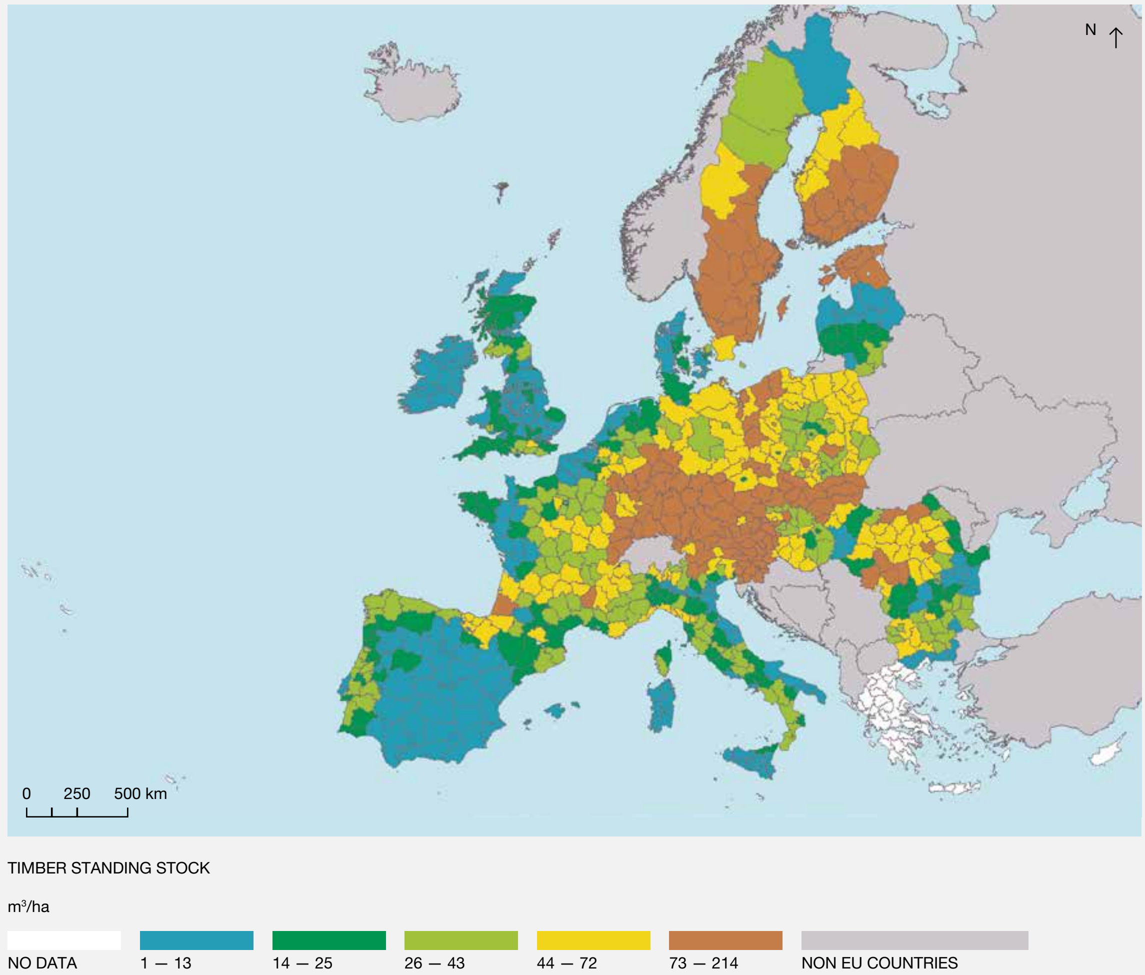


Figure 2 32 **Density of timber stock (all uses) in European Union (EU) countries. Source: European Commission (2011).**



2.2.2.3 Materials and assistance

Nature contributes to people's quality of life by providing materials for construction, clothing, ornamental purposes, or assistance for herding, guidance and guarding (IPBES, 2017a). For most of these materials, comprehensive national or sub-national level data do not exist, with the exception of wood. Here, we present the status and trends of this contribution from nature to people in Europe and Central Asia associated with the provision of wood, cotton, and other vegetal materials, materials from marine systems and the assistance of dogs in guarding and protecting livestock.

2.2.2.3.1 Provision of wood

Roundwood is defined as all wood removed with or without bark, including wood removed in its round form or in other forms (FAO, 2015a). Roundwood can be subdivided into industrial roundwood, used mainly for construction and in processed timber products, and woodfuel (see Section 2.2.2.2.1). Total production of roundwood has remained stable in Europe and Central Asia (FAO, 2015a), with a major impact by the fall of the iron curtain **(Figure 2.30)** and a slight decline for the period 2005-2014 in Western Europe **(Figure 2.31)**. Timber standing stock, regardless of use or degree of management, are largest in some regions of Western and Central Europe: forests of Central Europe, Scandinavia and the Alps **(Figure 2.32)**.

2.2.2.3.2 Cotton and other vegetal materials

During the period 1961-2014 cotton lint was mostly produced in Central Asia and Turkey. Production in Central Asia has fluctuated without a clear trend **(Figure 2.33)**, masking marked technological, economic and political transformations of the cotton industry (Kandiyoti, 2007).

Reed has traditionally been used in many regions for thatching, but it can be also be utilized in a number of other ways, including in construction and gardening, in paper, textile and plastic production, and as fodder and fertilizer (Köbbing *et al.*, 2013). Reed is grown and harvested throughout the subregions (Köbbing *et al.*, 2013). Mediterranean countries of Europe play an important role in the provision of cork, as they produce 87% of cork globally, especially the Iberian Peninsula, which is home to the majority of cork oak (*Quercus suber*) forests in the world (Acácio & Holmgren, 2014; APCOR, 2011) and, therefore, also cork extraction **(Figure 2.34)**. About 70% of harvested cork is used for the production of bottle stoppers. Other products include flooring, insulation material, clothes and accessories, and decorative objects (Bugalho *et al.*, 2011).

Rosins are solid forms of resins obtained from pine trees and some other conifers. They are extracted by tapping the tree (Mitchell *et al.*, 2016). Historically used to waterproof ships, they are now used in the production of chemicals, paints, inks, varnishes, floor coverings and soaps. Sources of rosins in Europe and Central Asia are *Pinus pinaster* (Portugal), *P. sylvestris* (former Soviet Union), *P. halepensis* (Greece) and *P. brutia* (Turkey) (FAO, 1995).

Only a few countries in Europe and Central Asia produce turpentine and resin, with decreasing trends due to the high costs of labour. Portugal accounts for the majority of world trade in gum turpentine, but production fell from an average of 110,000 tonnes per year during 1978-1987 to 30,000 tonnes by 1992 (FAO, 1995). Minor production is

Figure 2 33 **Annual production of cotton lint in Central Asia, 1992–2014, in tonnes. Source: FAO (2017).**

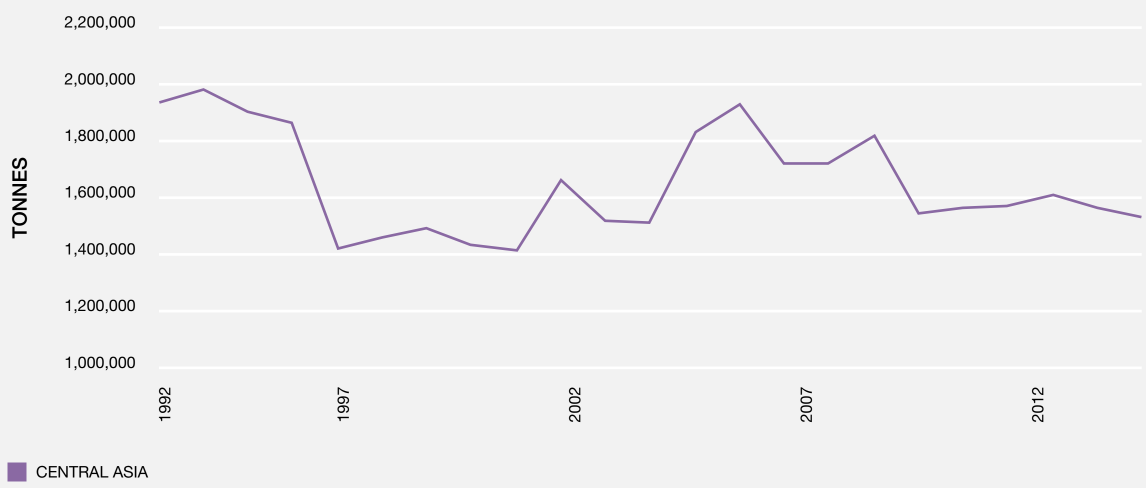
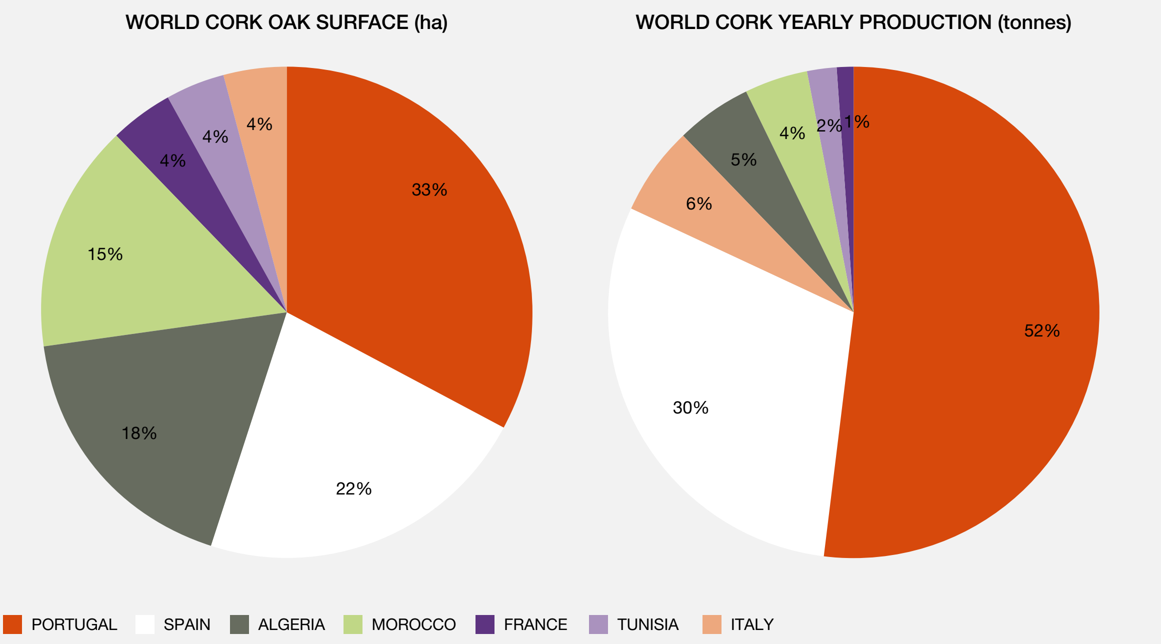


Figure 2 34 **Cork oak distribution and production in the western Mediterranean. Source: APCOR (2009).**



also reported in Central and Eastern Europe (FAO, 1995). Recently, new uses of pine resin in polymers have emerged (Wilbon *et al.*, 2013).

2.2.2.3.3 Materials from marine ecosystems

Marine ecosystems provide a wide range of materials for different uses, including algae maerl, seaweed fishmeal, fish oil (used in textile production, metallurgy, production of detergents, paints and resins), shellfish and molluscs for ornamental purposes (Murillas-Maza *et al.*, 2011). Seaweed and kelp species are used in various ways in Western Europe **(Figure 2.35)**. Kelp is now particularly used for extraction of alginates, which are used in the food processing industry, as well as in the production of textiles and pharmaceuticals (Netalgae, 2012; Smale *et al.*, 2013). France and Norway are the main producers of kelp in Western Europe with annual production of about 50,000 tonnes of *Laminaria digitata* in France and about 200,000 tonnes of *L. hyperborea* in Norway (Smale *et al.*, 2013). In Western Europe, production of macroalgae has decreased in the last 10 years (Bioforsk, 2012).

Maerl is a collective term for various species of non-jointed coralline red algae (family Corallinophycidae) that live unattached to the seabed. Maerl has been dredged in the European Union for use as an agricultural soil conditioner and for use in animal and human food additives, water filtration systems, and pharmaceutical and cosmetic products. By the 1970s extraction peaked with about 600,000 tonnes per year in France[14]; however, due to their very slow growth, maerl beds have declined throughout the North East Atlantic and are classified as vulnerable on the European Union Red List (Gubbay *et al.*, 2016a).

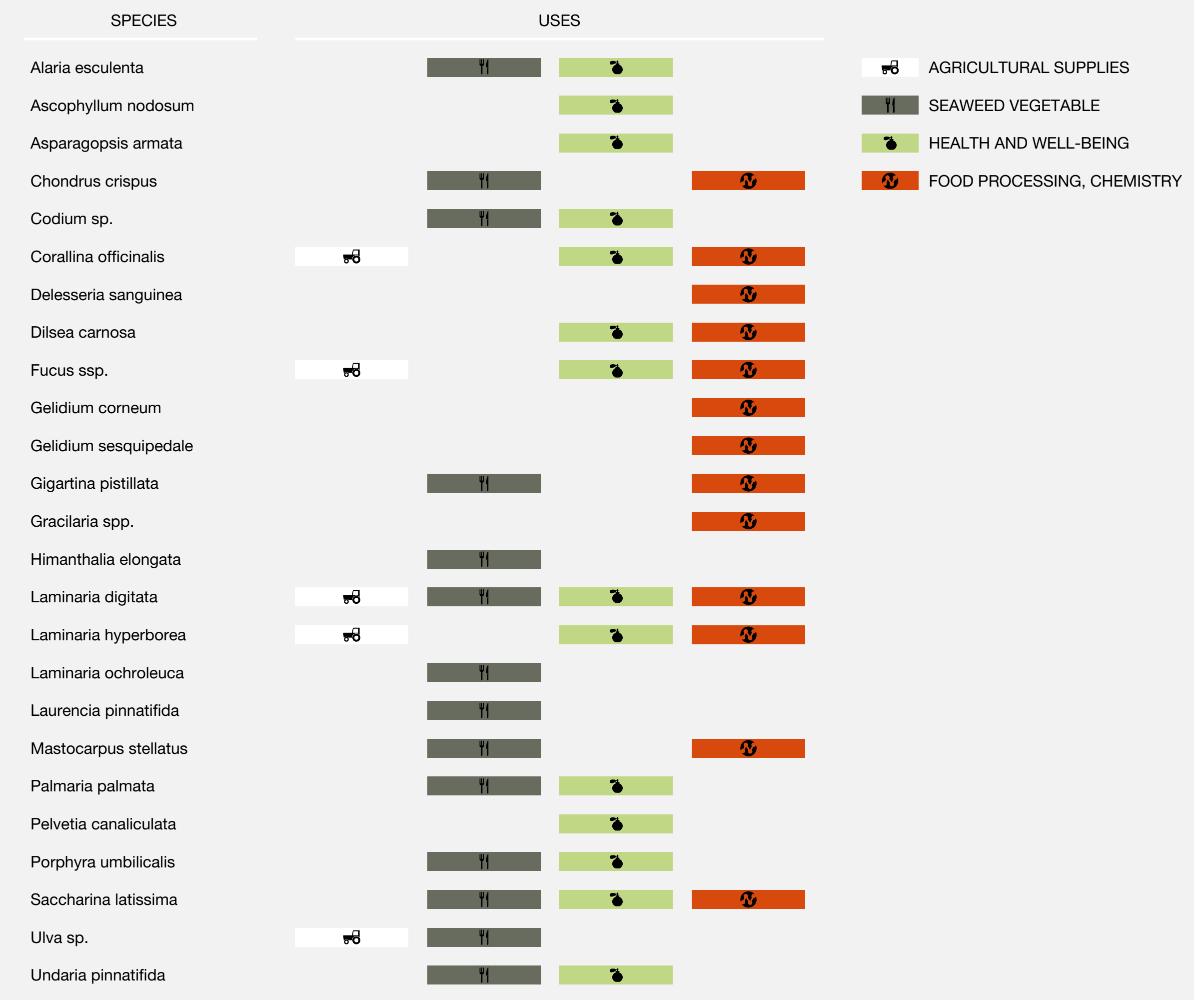
2.2.2.3.4 Assistance of livestock protection and guard dogs

For centuries guard dogs have helped shepherds protect their livestock from predators, specifically brown bears (*Ursus arctos*) and wolves (*Canis lupus*), in Central Europe and Central Asia (Gehring *et al.*, 2010; Linnell & Lescureux, 2015). With the decimation of these predators in Western Europe and the collectivization of agricultural policy under communist regimes, much of the indigenous and local knowledge about the use of guard dogs was lost (Gehring *et al.*, 2010; Linnell & Lescureux, 2015). However, with the recent recovery of large carnivores in continental Europe (Chapron *et al.*, 2014), guard dog use is being suggested as a means of facilitating human-carnivore coexistence (Linnell & Lescureux, 2015). Indeed, more than 1,000 dogs are now used in the Alps for this purpose (Gehring *et al.*, 2010). Indigenous peoples and local communities value them, as a herder explains: "*No, the beasts are no real problem for us, we have our dogs and sticks, we are not afraid of wolves and bears*" (herder; Ivascu & Rakosy, 2017) (see supporting material Appendix 2.2[15]). Guard dogs in Europe and Central Asia hold substantial

14. http://forum.eionet.europa.eu/european-red-list-habitats/

15. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

Figure 2 35 **Main uses of macroalgae in Europe. Source: Netalagae (2012).**



identity value among shepherds and breeds are closely linked to specific areas **(Figure 2.36)** (Linnell & Lescureux, 2015).

2.2.2.4 Provision of medicinal resources

The value of biodiversity as a resource for the production of medicines is one of the clearest examples of the relationships between nature and human health. Numerous species of plants, animals and fungi have been used to produce traditional therapies since ancient times, and wild flora and fauna continue to support the development of modern pharmaceutical products. This section considers medicinal plants in Europe and Central Asia, which form part of traditional and local medicinal practices, as well as medicinal plant products, which are sold commercially, and their use in modern pharmaceutical development. It covers plants, which are harvested directly from the wild, as well as those that are grown in home gardens or cultivated commercially. For the assessment of this contribution from nature to people, in addition to the literature review undertaken in this chapter (supporting material Appendix 2.1[16]), we also conducted an expert[17] elicitation on the basis of several key messages. The original key messages and the results of the expert elicitation are provided in supporting material Appendix 2.5[18].

Nature's capacity to provide medicinal plant resources depends on the species richness of medicinal plants. Several areas in Europe and Central Asia are characterized by high medicinal plant species richness, including the

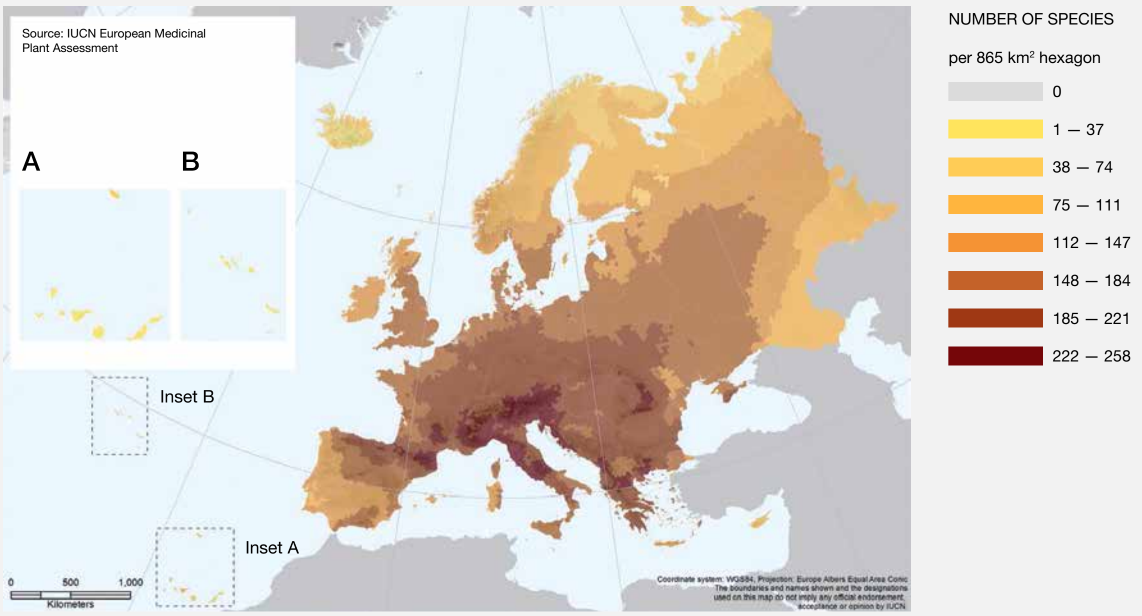
16. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.1_protocol_of_the_systematic_review_used_for_chapter_2_of_the_eca_assessment.pdf

17. Eighteen experts from the different biodiversity and health networks (such as the Belgian Community of Practice Biodiversity & Health (COPBH) and its international connections, Co-operation on Health and Biodiversity (COHAB), ESP thematic working group on health, Network for Evaluation of One Health (NEOH) and contact authors of publications found in the literature review conducted for this contribution from nature to people).

18. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.5_medicinal_plants.pdf

Figure 2 36 **Breeds of guard dogs identified in Europe and Central Asia. Source: Linnell & Lescureux (2015).**

Figure 2 37 **Species richness of selected medicinal plants in the European Union. Source: Allen *et al.* (2014).**



Mediterranean region, the Alps and the Pyrenees, the Massif Central in France, the Balkan Peninsula, the Crimean Peninsula and the Carpathian Mountains **(Figure 2.37)** (Allen *et al.*, 2014). However, some of these medicinal plants are threatened due to unsustainable patterns of exploitation (Allen *et al.*, 2014). Land development and land use change are the next greatest threats, with residential and commercial development and agricultural practices also having important impacts. In Central Asia, intensified agricultural practices, loss of indigenous knowledge, and climate change have also been identified as significant threats to medicinal plant diversity (e.g. Bocharnikov *et al.*, 2012; Breckle & Wucherer, 2006; Haslinger *et al.*, 2007) (see supporting material Appendix 2.5[19]). Consequently, collection of plants from the wild and loss of habitat due to

19. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.5_medicinal_plants.pdf

physical development and land use change are the most significant threats affecting medicinal plants in the region.

Indigenous and local knowledge plays an essential role in creating greater understanding of the potential contributions of many plant species to human health. The importance of biodiversity-derived medicines has been widely noted, with a significant number of commercially available pharmaceutical products being derived from compounds identified in biodiversity (e.g. Bernstein, 2015). The World Health Organization estimates that 70-80% of the global population depend on some form of indigenous and local medicinal knowledge for their primary health care (Ekor, 2014). In addition, indigenous and local knowledge has been a source of interest and inspiration for modern drug development for several decades (see also Section 2.2.3.4); at the same time, various ethical issues associated with bioprospecting and biopiracy have been raised. These issues appear to be less significant in Europe (Efferth *et al.*, 2016) (supporting material Appendix 2.5[19]).

Despite the importance of indigenous and local knowledge, there is a rapid rate of decline of traditional medical knowledge in Europe and Central Asia. In our fast-changing environment, especially related to increasing urbanization and changing agricultural practices, many traditions are disappearing from rural areas, with a profound loss of indigenous and local knowledge, particularly among the younger generations (see Section 2.2.3.1). This decline has been highlighted by several scientific studies (e.g. Quave *et al.*, 2012; Sánchez-Mata *et al.*, 2016). In some regions of Western and Central Europe, direct links have been identified between disappearing traditional farming systems and the decline in biodiversity of medicinal plants. On the other hand, there has been renewed interest in preserving traditional forms of knowledge about medicinal plants in the face of societal change and globalization as a form of cultural heritage (Pardo-de-Santayana *et al.*, 2010).

Recent decades have also seen an increase in the use of medicinal plants as complementary, non-conventional or alternative forms of medicine (Barata *et al.*, 2016; Roberti di Sarsina, 2007). Reasons cited for this increased attention have included public desire for affordable health remedies, and a perception that "natural" products are somehow safer and more effective than mainstream medicines. These factors have stimulated a rapid expansion of commercial markets for these remedies (FAO, 2005; Leonti & Verpoorte, 2017). The commercialization of traditional medicines and medicinal indigenous and local knowledge has seen many of these remedies moving from traditional practices to health and other markets.

Migrant populations moving into Europe and Central Asia from other regions have also brought their own traditional knowledge and related medicinal practices with them. Evidence suggests that these communities rely largely on plants and plant products imported from their home countries rather than alternatives that occur naturally in their new home regions (Pieroni *et al.*, 2013; Quave *et al.*, 2012) (supporting material Appendix 2.5[19]). This raises a number of further issues for conservation and public health, including those related to the collection, importation, sale and use of plants across borders outside of normal regulatory frameworks. While it appears that migrants prefer medicinal plants and related products imported from their home regions to local native alternatives, increasing demand may see alternative plant species being sought in migrants' new home environments, presenting a further challenge for the sustainable exploitation of living resources. Therefore, because of increasing migration into Europe and Central Asia from other regions, there is an urgent need to increase the understanding of traditional medicinal practices within national public health care systems.

In addition to their potential role in supporting public health, traditional medicines may provide other social and economic benefits. Research in Tajikistan and Afghanistan has indicated that the use of medicinal plant species contributed significantly to local health sovereignty and security (see Section 2.3.2), which was particularly important during a period of social and political instability (Kassam *et al.*, 2010). From a public health perspective, it appears important to ensure that traditional medicinal practices, which do not use marketed products but instead rely directly on harvested plants, are recorded and assessed, and to engage with practitioners to explore and communicate on issues of safety and efficacy.

2.2.3 Status and trends of nature's non-material contributions to people

2.2.3.1 Learning and knowledge generation

2.2.3.1.1 Formal learning and knowledge generation

Nature benefits people by contributing to learning processes that inspire people and allow them to acquire knowledge and to develop skills. These benefits can occur through formal institutions, informal learning and at all levels of education (Angelstam *et al.*, 2013; Anić *et al.*, 2012; Mocior & Kruse, 2016). There are contrasting trends across these benefits. Formal learning linked to nature has increased recently, partly as a result of new learning and knowledge development processes linked to sustainable environmental management. Informal learning that draws on nature has also expanded due to the increases in recreation and tourism (see Section 2.2.3.2), especially in protected areas promoting education and learning (Angelstam *et al.*, 2013; Smrekar *et al.*, 2016; Zedler, 2017). Some informal forms of learning and knowledge generation based on nature are in decline, particularly linguistic diversity which has traditionally been shaped by biodiversity and features of the natural environment (Section 2.1.1.1.2 Gorenflo *et al*., 2012; Maffi, 2005). The interactions between language and nature mean that a decline in linguistic diversity will be accompanied by a reduction in the variety of ways people communicate about aspects of nature and biodiversity (Harmon & Loh, 2010).

Formal learning in outdoor spaces has grown as national education systems have expanded. Formal learning provides additional benefits for learners and teachers in terms of cognitive outcomes, critical thinking, inspiration, observation skills and engagement with nature (Bizikova *et al.*, 2012; Mocior & Kruse, 2016; Schlegel *et al.*, 2015). Adults who have learned about sustainable development at school, or informally through activities such as gardening, may perceive their living space in a manner that is conducive to more sustainable lifestyles (Bendt *et al.*, 2013; Breuste & Artmann, 2015; Fridl *et al.*, 2009).

People using natural environments for recreational experiences also learn from each other. For example, a survey of 1,300 marine divers and recreational anglers in the UK showed that the sharing of knowledge and experience with others was a valued cultural ecosystem service (Jobstvogt *et al.*, 2014). Learning benefits linked to inspiration from nature were also found in a survey of 291 people in Turkey (Fletcher *et al.*, 2014). In Spain a survey of 1,400 people revealed that environmental education was a preferred ecosystem service for a large proportion of respondents and environmental education was viewed as a more important cultural ecosystem service than aesthetic values and recreational hunting (Martin-Lopez *et al.*, 2012). Also in Spain, a survey of 198 beneficiaries of the largest park in Barcelona found that environmental learning was a perceived benefit of the park of low monetary value, but of high non-monetary value (Langemeyer *et al.*, 2015).

2.2.3.1.2 Indigenous and local knowledge

Local ecological knowledge has been increasingly documented in Western, Central and Eastern Europe, particularly around its role in sustainable management of nature's contributions to people, its contribution to ecosystem restoration and its role in building social-ecological resilience (Carvalho & Frazão-Moreira, 2011; Hernández-Morcillo *et al.*, 2014; Molnár *et al.*, 2016). Overall, local ecological knowledge in Western, Central and Eastern Europe has eroded in recent decades, something acknowledged in the scientific literature as well as by the indigenous and local knowledge holders (see supporting material Appendix 2.2[20]). Significant losses of indigenous and local knowledge were found in Western Europe in agrobiodiversity management (Iniesta-Arandia *et al.*, 2014; Kizos *et al.*, 2013; Reyes-García *et al.*, 2015), in forest management (Johann, 2007; Rotherham, 2007), and in pastoralist systems (Fernández-Giménez & Fillat Estaque, 2012; Oteros-Rozas *et al.*, 2013b). Evidence of erosion of indigenous and local knowledge was also found in Central Europe, associated with agrobiodiversity management (Šmid Hribar & Urbanc, 2016), pastoralism (Lozej, 2013; Otčenášek, 2013) and medicinal plants and wild food plants (Łuczaj *et al.*, 2012; Pardo-de-Santayana *et al.*, 2010; Pieroni *et al.*, 2013). However, some research has found stable patterns in indigenous and local knowledge associated with wild food plants and mushrooms in Central Europe (Łuczaj *et al.*, 2015; Pieroni *et al.*, 2013). In Eastern Europe, a decline in indigenous and local knowledge has been found in wood-pastures (Varga & Molnár, 2014), pastoralist systems (Kikvidze & Tevzadze, 2015; Lavrillier *et al.*, 2016), and the indigenous and local knowledge associated with wild food (Łuczaj *et al.*, 2013).

The erosion of indigenous and local knowledge also involves the loss of linguistic diversity as indigenous and local languages represent the reservoirs of considerable knowledge about non-human species and their relationships with the environment (Nabhan, 2001). The endangerment level of indigenous and local languages in Europe and Central Asia is critical (see **Figure 2.38**). While a large number of these languages are extinct[21] (12% of total languages) or critically endangered[22] (11%), 14% still remain alive as most children speak the language (vulnerable category). The level of endangerment varies across subregions (see **Figure 2.38**). While Central Asia has no languages under the categories of extinct and critically endangered, 31% and 24% of languages in Eastern Europe and Central Europe, respectively, are classified as extinct or critically endangered. Despite this level of threat, it is noticeable that the trends of the Index of Linguistic Diversity for indigenous languages in Eurasia between 1970 and 2005 is rather stable (with a slight decline from 1990) (see **Figure 2.39**) because Western and Central Europe might have lost the majority of its linguistic diversity prior to 1970 (Harmon & Loh, 2010).

The general loss of indigenous and local knowledge is mainly attributed to the transition from an agriculturally-based and subsistence-oriented economy to a market-oriented economy (Carvalho & Morales, 2010; Hernández-Morcillo *et al.*, 2014; Pardo-de-Santayana *et al.*, 2010). Changes in culture that affect shared beliefs, meanings

20. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

21. Extinct: There are not speakers

22. Critically endangered: The youngest speakers are grandparents and older, and they speak the language partially and infrequently

and practices regarding plants and animals or other contributions from nature to people, are also responsible for the lack of value associated with indigenous and local knowledge among younger generations, which consider these traditional practices and knowledge as symbols of poverty or backwardness (Christanell *et al.*, 2010; Hernández-Morcillo *et al.*, 2014; Pardo-de-Santayana *et al.*, 2010). Gender relations are of special interest in Western Europe, where women and men have had differentiated roles in preserving indigenous and local knowledge (Pardo-de-Santayana *et al.*, 2010; Reyes-García *et al.*, 2010). Demographic changes, such as ageing of indigenous and local knowledge holders, rural abandonment and outmigration of women and younger generations from rural areas, have also led to a marked decline in generational transmission of indigenous and local knowledge (Fernández-Giménez & Fillat Estaque, 2012; Molnár, 2014; Oteros-Rozas *et al.*, 2013b). These factors are also acknowledged by indigenous and local knowledge holders as powerful drivers of erosion of their knowledge (see also supporting material Appendix 2.2[20]).

Some governmental policies can also support the maintenance of indigenous and local knowledge. For example, the Common Agricultural Policy reform legislation offers support for "high nature value" farming, which is characterized by long-established, low-intensity and holistic farming systems highly adapted to local environmental conditions (Keenleyside *et al.*, 2014). In this sense, high natural value farming is not only essential if the European Union is to meet its 2020 biodiversity targets, but also to counteract the decline in indigenous and local knowledge.

There is a proven gap in documentation of indigenous and local knowledge in Central Asia and therefore more studies are needed on how traditional practices and indigenous and local knowledge associated with nature could bring important insights into biocultural diversity conservation in

Figure 2 38 **Level of endangerment of languages in Europe and Central Asia A and level of endangerment by subregion B Source: Own representation based on Moseley (2010); UNESCO (n.d.). Overseas territories in other regions are not included.**

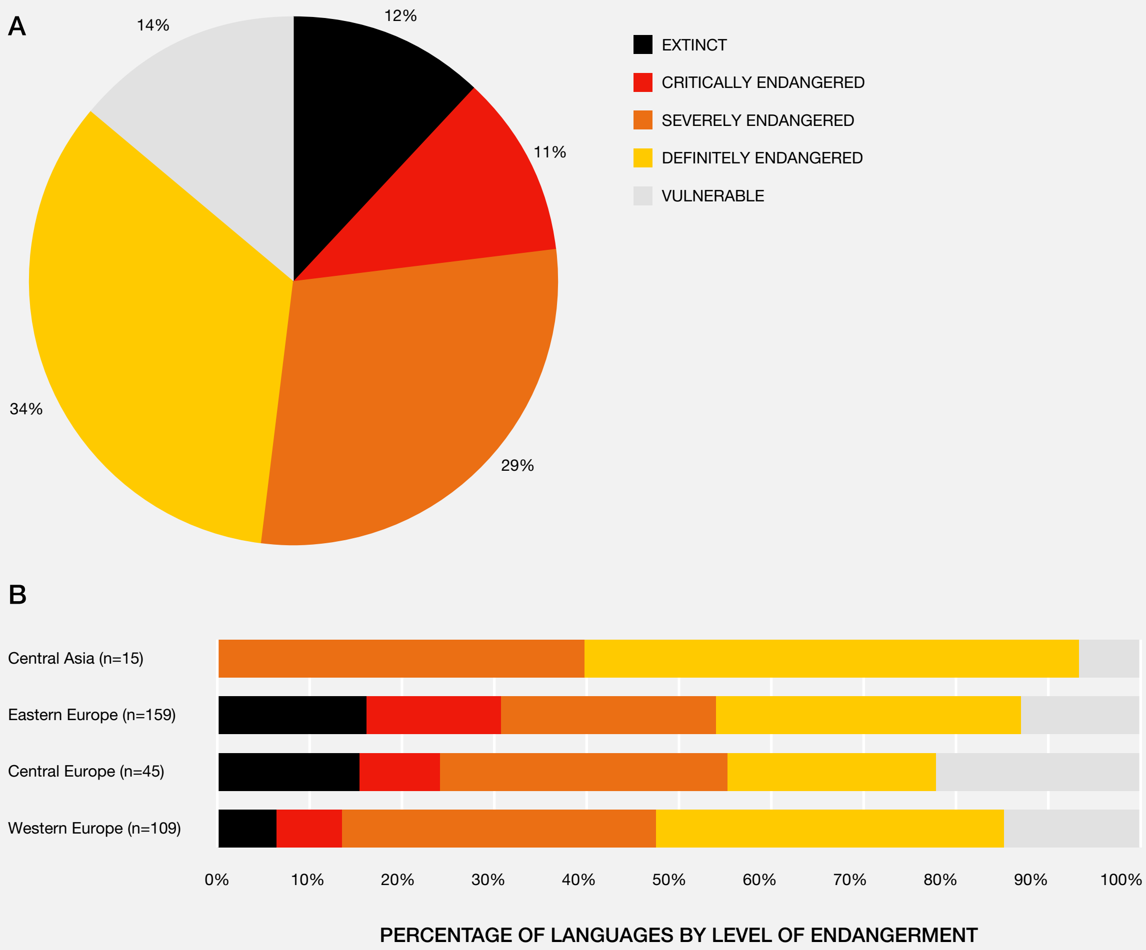
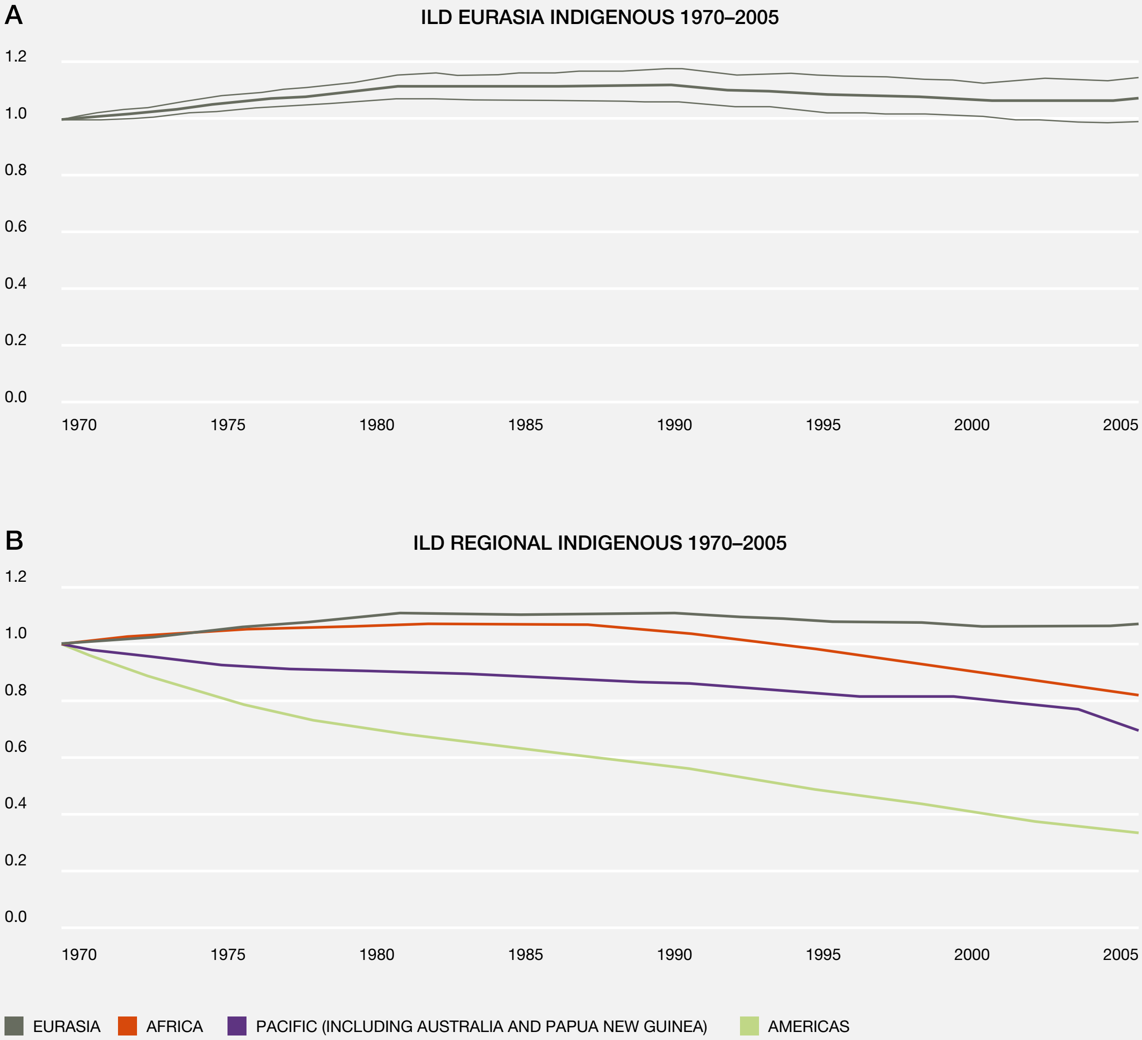


Figure 2 39 **Trends of the Index of Linguistic Diversity (ILD) in Eurasia A and in the different regions of the world B Source: Harmon & Loh (2010).**



the subregion (Pawera *et al.*, 2016). In addition, although there is some evidence about the role of indigenous and local knowledge in marine systems (Maynou *et al.*, 2011; Moore, 2003), more research is needed to report on the status and trends of this knowledge in that context.

2.2.3.2 Physical and psychological experiences

2.2.3.2.1 Recreational experiences

Nature in Europe and Central Asia provides opportunities for recreation such as hiking, trekking, climbing, running, mountain biking, horseback riding, camping, picnicking, sailing, boating, swimming, snorkeling or diving, skiing and green care, as well as activities related to species, such as wildlife-watching, particularly birdwatching. Nature also provides opportunities to perform extractive recreational activities, such as hunting, fishing and angling, mushroom gathering, berry and fruit picking (Bell *et al.*, 2007; Schulp *et al.*, 2014a; Seeland & Staniszewski, 2007). Thirty-eight per cent of the European Union is characterized by high outdoor recreation potential (Paracchini *et al.*, 2014), particularly coastal and freshwater systems and broadleaved woodlands (Hornigold *et al.*, 2016). Recreation is a well-recognized contribution from nature to people in broadleaved forests of Western and Central Europe (e.g. Grilli *et al.*, 2015; Mavsar *et al.*, 2013; Sténs *et al.*, 2016). In freshwater ecosystems, recreation is more common in rivers with clear water and high flows than rivers with mud, algae and litter (Eder & Arnberger, 2016; Vesterinen *et al.*, 2010). Marine and coastal systems also provide the basis for recreational activities, such as recreational fishing, birdwatching, whale-watching, swimming, diving and snorkeling or other water sports (Ahtiainen *et al.*, 2013; Beaumont *et al.*, 2007). In the last decades, the capacity for nature-based recreation in the aforementioned ecosystems has decreased because of land-use change (e.g. Liquete *et al.*, 2016b; Pietilä & Fagerholm, 2016; Roberge *et al.*, 2016).

Green spaces in urban areas provide multiple physical and psychological experiences (Bolund & Hunhammar, 1999; Kabisch *et al.*, 2016), such as sense of peacefulness and tranquility (Chiesura, 2004) or hiking and walking (Baró *et al.*, 2016; Smrekar *et al.*, 2016). While an overall increase in urban green spaces was identified in Western Europe from 2000 to 2006, most of the cities of Central and Eastern Europe experienced a decline in the same period (Kabisch & Haase, 2013). The recreational experience in urban green spaces depends on different elements, such as the presence of forests

Figure 2 40 **Demand for nature-based recreation in the European Union.**

Trends of percentage of people in the European Union with nature (i.e. ecosystems or landscapes) and other related-nature (beach and sport-related activities, e.g. scuba-diving, cycling, etc.) motivations as the main reasons for going on holiday. Source: Own representation based on European Commission (2016b).

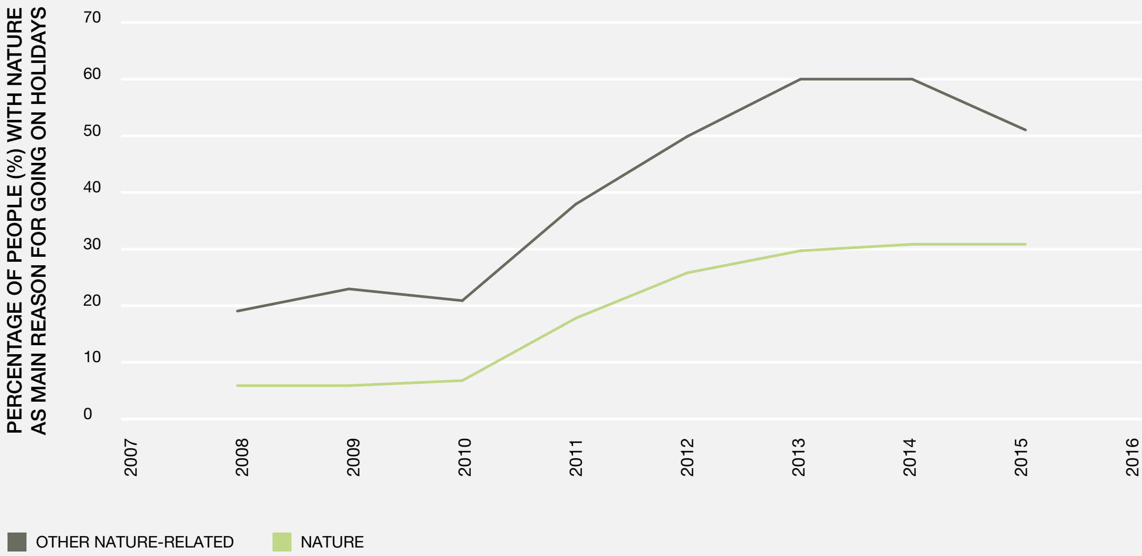
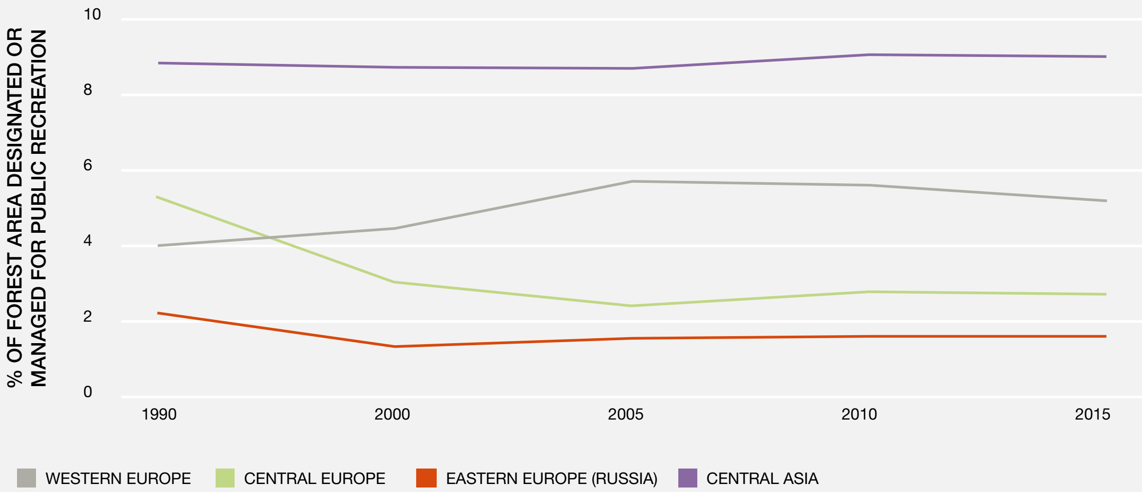


Figure 2 41 **Distribution of recreational options in Europe and Central Asia: Temporal trends of the forest surface managed or designated for recreational purposes in the four subregions. Source: Own representation based on http://www.fao.org/forest-resources-assessment/en/.**



and wetlands or riparian systems (Baró *et al.*, 2016) or high species richness (Fuller *et al.*, 2007). Urban gardens are increasingly recognized among these elements in Western and Central Europe (Bell, 2016; Breuste & Artmann, 2015; Camps-Calvet *et al.*, 2015).

Nature-based recreation is in high demand in Europe and Central Asia (e.g. Agbenyega *et al.*, 2009; García-Llorente *et al.*, 2012; Sténs *et al.*, 2016). For example, 31% of people surveyed in the European Union gave nature as their main reason for going on holiday. Other reasons were nature related, such as beach and sport-related activities (e.g. cycling, boating or diving), which were mentioned by 51% of people surveyed in the European Union (European Commission, 2016a). In the last decade, nature as the main reason for holidays has increased in the European Union **(Figure 2.40**). Participation in nature-based recreation is not equally distributed between countries due to differences in the number of protected areas **(Table 2.5)**, forest areas designated for recreational purposes **(Figure 2.41)**, or accessibility to natural areas (Bell *et al*., 2007).

Nature's capacity to provide extractive outdoor experiences relies on a variety of species. In the European Union, 97 species are hunted, while 152 species and 12 genera of mushrooms and 592 edible plant species are reported as being collected (Schulp *et al.*, 2014b). However, this estimation is incomplete because studies in Turkey showed that at least 2,000 species of mushrooms are edible (Çağlarirmak, 2011; Kizmaz, 2003). The highest richness of game species is reported in Central Europe, southern Scandinavia and the Baltic countries, while for edible mushroom and plant species it is the forested and mountainous areas of Western Europe **(Figure 2.42)** (Schulp *et al.*, 2014a).

Hunters as a percentage of the European Union population in 2010 varied between 0.17% (Netherlands) and 12.4% (Italy) (Schulp *et al.*, 2014a). In Central Asia, the flourishing of sport hunting (Kronenberg, 2014) and the presence of body parts of particular animals (e.g. snow leopard (*Uncia uncia*), Asiatic Bear (*Ursus arctos isabellinus*)) in markets suggest both legal and illegal hunting (Cunha, 1997; Haslinger *et al.,* 2007). Recreational fishing is a growing phenomenon in Western Europe (Toivonen *et al.*, 2004). Collection of mushrooms, truffles, berries, fruits and edible nuts is more prevalent in Western Europe than Central Europe and Eastern Europe **(Figure 2.43)** (MCPFE *et al.*, 2007). However, the diversity of wild plants collected has suffered a decline in recent decades in Western and Central Europe (Łuczaj *et al.*, 2012; Reyes-García *et al.*, 2015; Rzadkowski & Kalinowski, 2013). This decline coincides with urbanization and loss of natural habitats, rural abandonment, cultural change, the erosion of indigenous and local knowledge, and industrialization of food production (Łuczaj *et al.*, 2012; Reyes-García *et al.*, 2015). By contrast, some uses of wild edible plants are preserved due to a revival of traditions linked with "traditional" cuisine (Reyes-García *et al.*, 2015; Schulp, *et al.*, 2014b).

Figure 2 42 **Species richness of the 38 common game species in the European Union A, 27 common edible mushroom species in the European Union B, and 81 common wild food vascular plant species in the European Union C. Source: Schulp *et al.* (2014b).**

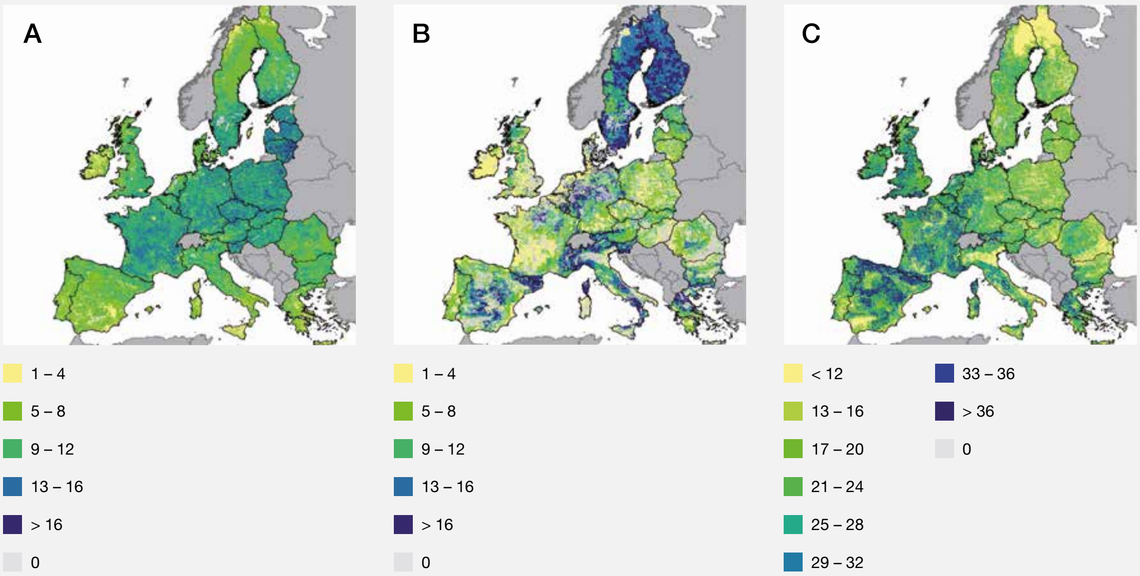
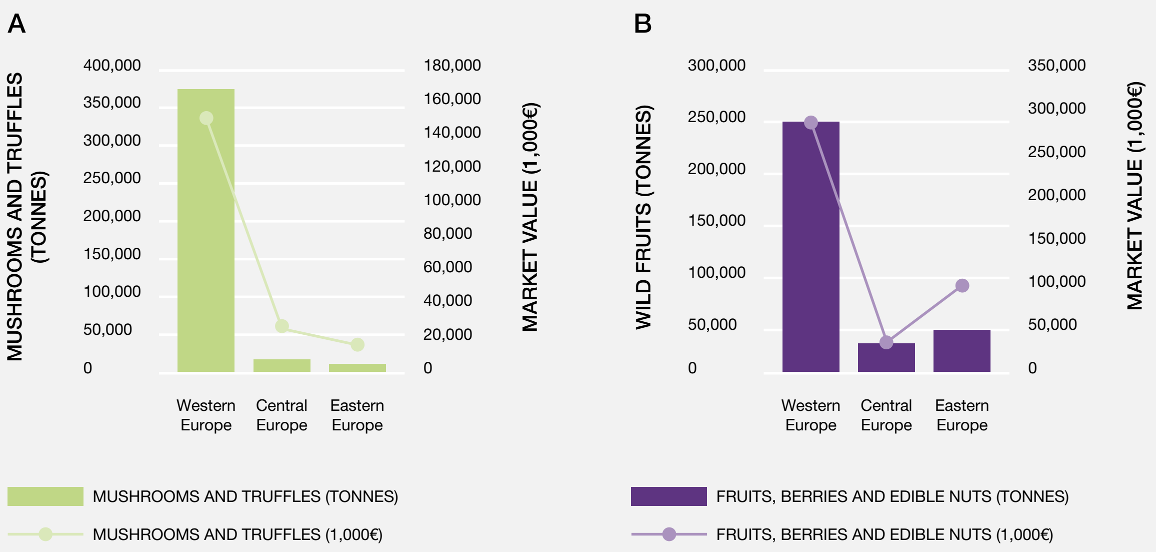


Figure 2 43 **Distribution of the amount and market value of A mushrooms and B berries, fruits and edible nuts picked in forests in Western, Central and Eastern Europe. Source: Own representation based on MCPFE *et al.* (2007).**



2.2.3.2.2 Aesthetic experiences

Nature is a source of aesthetic experiences for people in Europe and Central Asia (e.g. Daniel, 2001; Kaplan & Kaplan, 1989; Ode *et al.*, 2009; Schirpke *et al.*, 2013). Aesthetic enjoyment is dependent on perceived naturalness (e.g. Arriaza, 2004; Van den Berg & Koole, 2006), landscape heterogeneity (e.g. Dramstad *et al.*, 2006; Frank *et al.*, 2013; Schirpke *et al.*, 2013; Sevenant & Antrop, 2009), and high levels of biodiversity (e.g. Casalegno *et al.*, 2013; Lindemann-Matthies *et al.*, 2010; Tribot *et al.*, 2016).

People in Western and Central Europe prefer natural areas with verdant vegetation over arid landscapes and urban landscapes (García-Llorente *et al.*, 2012; Sevenant & Antrop, 2009). Landscape configurations like open forests (Gundersen & Frivold, 2008; Hansen & Malmaeus, 2016) or wood-pastures are most preferred among verdant natural areas (e.g. Plieninger *et al.*, 2015; Surová *et al.*, 2013; Van Zanten *et al.*, 2014). However, mosaic landscapes were considered to have higher aesthetic value than landscapes dominated by forest in Western and Central Europe (e.g. García-Llorente *et al.*, 2012; Howley, 2011; Howley *et al.*, 2012; Schirpke *et al.*, 2013). Mountains and coastal systems also provide aesthetic enjoyment, expressed by high numbers of related geotagged photographs (Oteros-Rozas *et al.*, in press; Van Zanten *et al.*, 2016). Water features also contribute to aesthetic pleasure (e.g. Kaltenborn & Bjerke, 2002; Tveit *et al.*, 2006; Van Zanten *et al.*, 2016).

The capacity of landscapes to provide aesthetic experience has declined because of urbanization, land-use intensification, rural abandonment, disappearance of common lands and water pollution (see Chapter 4) (Šmid Hribar *et al.*, 2015; Hunziker *et al.*, 2008; Ruskule *et al.*, 2013).

2.2.3.3 Supporting identities

Individuals derive a good quality of life from knowing of the mere existence of particular species, ecosystems or a landscapes, independent of their actual use (Krutilla, 1967; Reyers *et al.*, 2012), but also from their sense of place, cultural heritage, and from spiritual experiences. In contrast to physical and experiential values (see Section 2.2.3.2), this contribution from nature to people relates to virtues and principles (Chan *et al.*, 2012).

2.2.3.3.1 Protected areas

Protected areas indicate where societies have expressed their will to protect species and ecosystems. Protected areas can take many forms, as distinguished by (IUCN, 2017). Some categories of protected areas contain core zones, where natural dynamics can take place and which are largely inaccessible to the public. These categories are: "Ia Strict Nature Reserve", "Ib Wilderness Area", "II National Park" and "IV Habitat/species management area". The status of these protected areas in Europe and Central Asia, as reported in the World Database on Protected Areas (UNEP-WCMC & IUCN, 2016), was used as an indicator for "supporting identities" (see **Figure 2.44** and **Table 2.5**). Globally, there has been an increase in protected areas

Figure 2 44 **Terrestrial and marine protected areas in Europe and Central Asia. The map displays strong protection categories (Ia, Ib, II and IV). Source: World Database on Protected Areas (UNEP-WCMC & IUCN, 2016).**

Table 2 5 **Proportion of protected areas in Europe and Central Asia. The table displays strong protection categories (Ia, Ib, II and IV) in the four subregions. Source: World Database on Protected Areas (UNEP-WCMC & IUCN, 2016).**

Region	Ia Strict nature reserve [% of land area]	Ib Wilderness area [% of land area]	II National Park [% of land area]	IV Habitat/species management area [% of land area]	Total area (in km²) of categories Ia, Ib, II and IV
Central Europe	0.00	0.27	0.87	0.93	92,284
Western Europe	0.48	2.70	3.16	1.60	1,077,634
Eastern Europe	1.91	0.00	1.02	5.20	6,930,197
Central Asia	0.68	0.00	0.65	1.04	196,475

(all IUCN categories) from about 8% in 1990 to 14.7% in 2016 (UNEP-WCMC & IUCN, 2016). It should be noted that motivations to establish a protected area differ, so the chosen indicator does not necessarily reflect particularly important species and ecosystems (Joppa & Pfaff, 2009).

2.2.3.3.2 Emblematic, symbolic or iconic species or ecosystems

An existence value can be attributed to emblematic, symbolic or iconic species or ecosystems that are particularly appreciated for their existence, independent of their actual use for recreation (e.g., bird watching, game viewing). Certain so-called "flagship species" have drawn wide public interest (Barua, 2011). Many of these species' habitats occur outside Europe and Central Asia, for example the tiger (*Panthera tigris*), gorilla (*Gorilla gorilla*), giant panda (*Ailuropoda melanoleuca*), orangutan (*Pongo abelii*), as well as elephants and seahorses (Barua, 2011). The contribution from nature to people in these cases is not provided by ecosystems in Europe and Central Asia, but is valued by people within the region. There is currently a knowledge gap on how iconic and emblematic species that *are* native to Europe and Central Asia are perceived across the region. The wolf (*Canis lupus*), brown bear (*Ursus arctos*), wolverine (*Gulo gulo*), lynx (*Lynx lynx*) and wisent (*Bison bonasus*) have been framed as "Europe's big five" in collaboration with conservation experts (IUCN, 2014). A global meta-analysis found that species in forest and marine inland waters are particularly highly valued. Of these species, the moose (*Alces alces*) and the humpback whale (*Megaptera novaeangliae*) (Martín-López *et al.*, 2008) occur in Europe and Central Asia. Furthermore, there is country-specific evidence of people assigning particular existence values to species. For instance, people in Sweden value large carnivores, irrespective of having the possibility to view them (Karlsson & Sjöström, 2008). In Spain, the imperial eagle (*Aquila adalberti*) and the Iberian lynx (*Lynx pardinus*) were among the species for which people showed the highest preference and willingness-to-pay for their conservation (Martín-López *et al.*, 2007). In the UK, White *et al.* (2001) found high conservation interest for the otter (*Lutra lutra*), measured through high willingness-to-pay for their conservation. Preferences for the existence of species, such as willingness-to-pay for marine biodiversity, can differ across the region (Ressurreição *et al.*, 2012). Willingness-to-pay for conservation has also been shown to be more strongly influenced by certain marine iconic species that are actively experienced (seals, octopus, birds) than by species that do not directly have a use value (i.e. are only protected for their existence) (Jobstvogt, 2014).

2.2.3.3.3 Attitudes towards nature

Another indication of this contribution from nature to people is attitudes towards nature conservation. In the EU-28, 76% of the people totally agree with the statement "We have a responsibility to look after nature". This percentage differs regionally, ranging from 65% in Italy to 94% in Cyprus and Sweden (European Commission, 2015a). See also supporting material Appendix 2.2[23] with quotes recognizing a decreasing trend of appreciation of nature by young holders of indigenous and local knowledge.

23. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

2.2.3.3.4 Spiritual experiences

Ecosystems have traditionally served as areas for spiritual or religious rituals and experiences derived from nature (Groot *et al.*, 2005). Natural areas of special spiritual significance include areas recognized as sacred by indigenous and traditional peoples as well as by institutionalized religions or faiths as places for worship and remembrance (Verschuuren *et al.*, 2010). Sacred or holy natural places occur at a variety of scales in Europe and Central Asia, varying from rock formations or forest patches to mountains and islands. Supporting material Appendix 2.6[24] shows a selected list of natural areas considered as "sacred natural sites" based on IUCN's Task Force on Cultural and Spiritual Values of Protected Areas (Wild & McLeod, 2008) and the Delos Initiative (Mallarch & Papayannis, 2012). Five sites on this list are located in Central Europe, three in Eastern Europe, 17 in Western Europe and one in Central Asia. The importance of these sites and other natural areas of spiritual and cultural significance to the quality of life in Europe and Central Asia is elaborated on in Section 2.3.3**.**

2.2.3.4 Maintenance of options

The desire to maintain potential options or benefits provided by nature for future generations is an expression of how people value inter-generational justice (see Section 2.3.4). The capacity of supply of this contribution from nature to people is indicated by overall patterns in species-level biodiversity (see **Table 2.6**, Section 3.2.3). One measure of the unique contribution to this contribution is given by total number of endemic species, which is low for Europe and

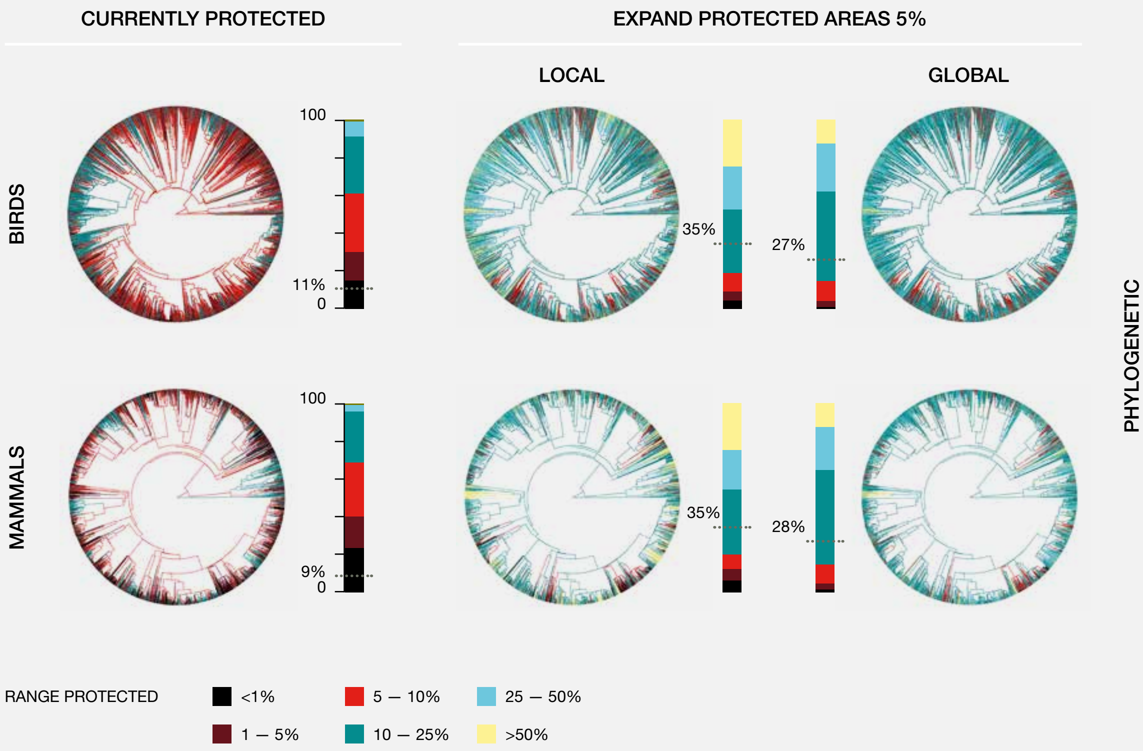
24. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.6_list_of_sacred_natural_sites.pdf

Table 2 6 **Numbers of classified, endemic and threatened species as proxy for the status of the maintenance of options of nature's contributions to people in Europe and Central Asia relative to the other three IPBES regions (the Americas, Asia and the Pacific, and Africa). Source: Brooks *et al.* (2016), data for taxonomic groups that have been comprehensively assessed using IUCN red list criteria. Total global number of assessed species, over all these assessed groups, = 32,790. Total number of these assessed species that are threatened = 6,539.**

	Europe and Central Asia	Average value over the other 3 IPBES regions
Number of assessed species, over all assessed groups, that are found in nominated IPBES region	2,487	11,840
Number of those species endemic to the region	332	9,681
Number of assessed species that are threatened and are found in nominated region	302	2,251
Number of those threatened species that are endemic to the region	83	2,036

Figure 2 45 **Status of protection of phylogenetic diversity shown on the phylogenetic trees for birds and mammals.**

Tree diagrams on the left show current protection levels, and tree diagrams on the right use colours to show potential conservation gains for a 5 per cent increase in protected areas. For each branch of each tree, degree of protection is defined as the percentage of the total branch occurrences that is protected (percentage of "range protected"). Source: Pollock *et al.* (2017). Reprinted by permission from Macmillan Publishers Ltd.



Central Asia relatively to Africa, Asia and Pacific and America regions (see **Table 2.6**). Phylogenetic diversity (Faith, 1992) over multiple taxonomic groups is also an informative metric of the capacity of biodiversity to deliver maintenance of options (Faith, 2016) (also see Chapter 3). An assessment of the phylogenetic diversity of birds and mammals (see **Figure 2.45**) (Pollock *et al.*, 2017) identified many high priority areas, such as in southern Croatia, the Odessa region of Ukraine, and north-western Kazakhstan, for their better conservation.

The maintenance of options from biodiversity in Europe and Central Asia (and from outside the region) can be assessed through the valuation of genetic diversity by pharmaceutical companies (see Section 2.2.2.4). After a period of reduced interest there is a shift back towards natural products, supported by improved methods to explore species' DNA to search for useful compounds (Piper, 2017). The appreciation for this contribution from nature to people is also found in the greater awareness of recent unanticipated benefits from biodiversity. The State of the World's Plants (Willis, 2017) provides examples of benefits from genetic variation. For example, the ash tree (*Fraxinus excelsior*) is suffering dieback across northern parts of Western Europe from a fungus; however, whole genome sequencing has helped characterize the genetic diversity, so that resistant individuals can be identified.

Medicines derived from medicinal plants (see Section 2.2.2.4) and from marine organisms also raise awareness of biodiversity option values. However, benefits of this contribution from nature to people also may include other products. For example, it has been found that honeycomb moth caterpillars can eat through plastic (Bombelli *et al.*, 2017). The caterpillars are beewax-eating pests, but enzymes from the caterpillars provide an un-expected global benefit. Another example is the recent published role of golden jackals (*C. aureus*), long regarded as a pest, as a remover of domestic animal carcasses, which is saving about two million euros in those countries west of Black Sea with estimated jackal population size >100 individuals –i.e. Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Hungary, Romania and Serbia- (Ćirović *et al.*, 2016). The appreciation and value of this contribution from nature to people can also be estimated through the ongoing reporting of surprising discoveries in the popular press. For example, the golden jackals' example was widely communicated through a New Scientist article[25]. Such examples can reinforce people's relational value, linking biodiversity to future generations' quality of life (Faith, 2016). The Millennium Ecosystem Assessment (2005) concluded that "*the value individuals place on keeping biodiversity for future generations— the option value— can be significant*". Recently, a consortium of IUCN and global conservation NGOs argued for the value of biodiversity in maintaining options, providing many examples of past surprising benefits from biodiversity (Gascon *et al.*, 2015).

2.2.4 Interregional flows of nature's contributions to people: dependency of Europe and Central Asia on ecosystems of other regions

2.2.4.1 Introduction: interregional flows of nature's contributions to people

Nature's contributions to people being used in Europe and Central Asia are provided by ecosystems both within and outside the region. Through interregional flows of nature's contributions to people, i.e. the active or passive transport of energy, matter or information, differences between the provision and actual consumption of ecosystem services can be balanced (Liu *et al.*, 2016). Flows of nature's contributions to people happen both between subregions of Europe and Central Asia, and between the region and other parts of the world. Interregional flows of nature's contributions to people involve telecoupling, i.e. socioeconomic and environmental interactions over distances (Liu *et al.*, 2016), and have several consequences. Ecosystem service use in one location can have impacts on ecosystems in other locations, such as degradation and connected loss of biodiversity (Mayer *et al.*, 2005). For example, deforestation embodied in final consumption of the EU-27 equated to 732,000 ha (2004). In other words, 10% of the world's annual deforestation (7,290,000 ha per year) was the result of consumption by the EU-27 (see **Figure 2.46**) (European Commission, 2013).

Furthermore, interregional flows can have effects on quality of life, such as distributional equity, as discussed in the context of land grabbing (see Section 2.3.1.1) (Rulli *et al.*, 2013). On the other hand, interregional flows of nature's material contributions to people can lead to overall lower costs of food (Schmitz *et al.*, 2012). Additionally, access to goods from outside the region through trade contributes to food security (see Section 2.3.1.1) as well as supporting livelihoods in the producing country.

25. https://www.newscientist.com/article/2090451-invasive-trash-eating-jackals-save-europe-e2-million-a-year/

Figure 2 46 **Consumption of nature's contributions to people associated with global deforestation allocated by sector for the EU-27 (2004).**

Brazil, Argentina, Paraguay, Indonesia and Malaysia, among others, have been identified as important sources of embodied deforestation. Source: European Commission (2013b).

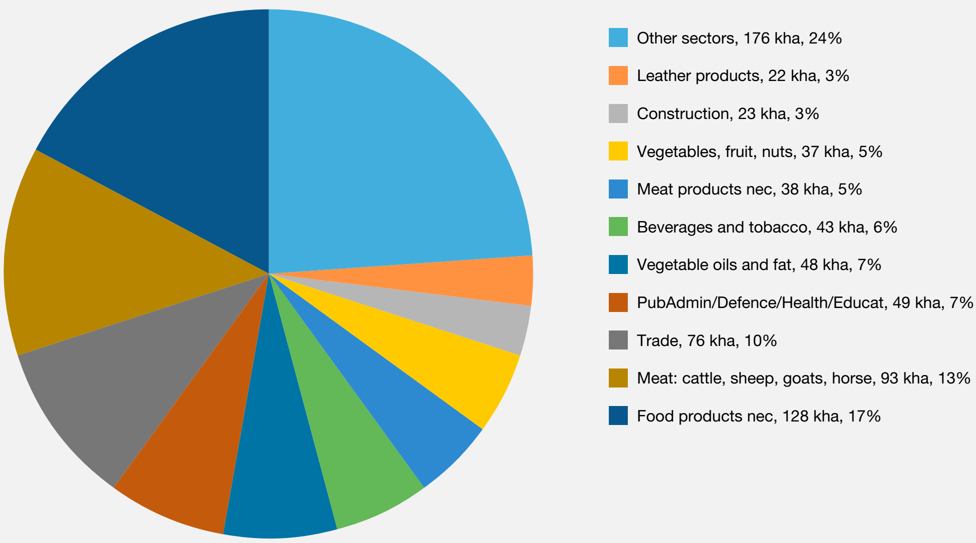
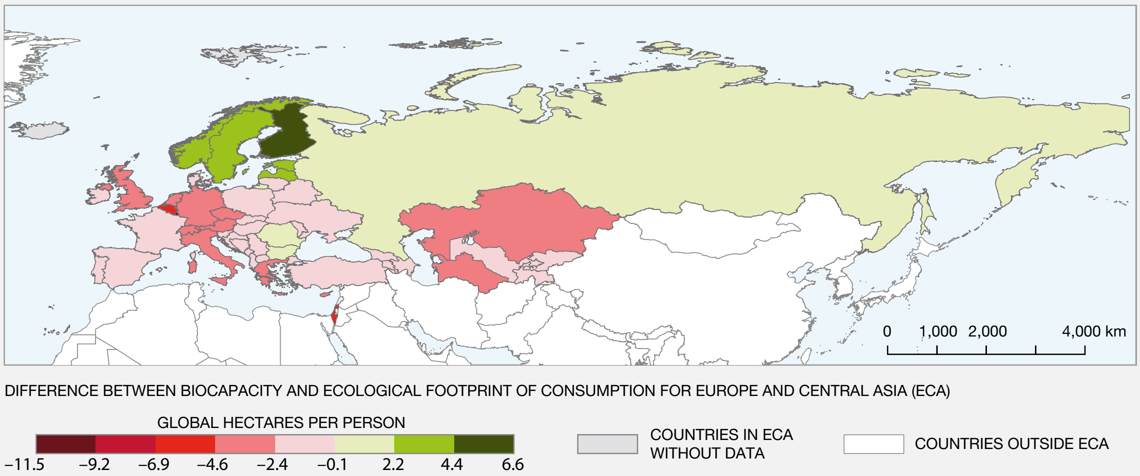


Figure 2 47 **Difference between biocapacity and ecological footprint (consumption) in global hectares per person for Europe and Central Asia (ECA).**

A positive value (green) indicates a biocapacity reserve; a negative value (red) indicates a deficit. A deficit derives from the overuse of local renewable resources or the net import of renewable resources for consumption. Countries shaded in green have high biocapacity, so they have a reserve despite having a higher ecological footprint than many other countries. Source: Own representation based on Global Footprint Network (2017).



2.2.4.2 Ecological footprint

Ecological footprint is a composite indicator for use of nature's contributions to people (Borucke *et al.*, 2013; Kitzes & Wackernagel, 2009) that quantifies the area needed to provide certain material or regulating contributions and expresses consumption in an area in terms of the area needed to renewably provide those contributions (Kitzes & Wackernagel, 2009). Ecological footprint includes proxies for nature's contributions to people such as crops, grazing land, fish, timber, and carbon sequestration (Borucke *et al.*, 2013). Biocapacity is another proxy for ecosystem productivity. Specifically, biocapacity refers to the capacity of a certain area to generate an ongoing supply of renewable resources and thus is a proxy for ecosystem productivity. Data on the ecological footprint of consumption and on biocapacity (in global hectares per person) are available for most of the countries within Europe and Central Asia (missing: Andorra, Iceland, Liechtenstein, Monaco, San Marino). For Europe and Central Asia in 2013, the ecological footprint (consumption) was 4.6 ha and biocapacity only 2.9 ha (based on 49 countries) (Global Footprint Network, 2017). This indicates that the region either overuses or net imports renewable natural resources. Both ecological footprint and biocapacity differ regionally, and so does the difference between the two measures **(Figure 2.47)**. For Western Europe (data for 19 of 24 countries), the footprint was 5.1 ha, vs. 2.2 ha biocapacity; for Central Europe (all 18 countries) the footprint was 3.6 ha, vs. 2.1 ha biocapacity, for Eastern Europe (all seven countries) the footprint was 4.8 ha, vs. 5.3 ha biocapacity; and for Central Asia (all five countries) the footprint was 3.4 ha, vs. 1.7 ha biocapacity. This means that Western and Central Europe and Central Asia have a deficit, while Eastern Europe has a reserve, in terms of biocapacity. A deficit can be ascribed to overuse of local renewable resources or net import (interregional flows) of renewable resources for consumption. In **Figure 2.47** countries shaded green have high biocapacity, so they have a reserve despite some also having large ecological footprints.

2.2.4.3 Status and trends of interregional flows for selected nature's contributions to people

Human appropriation of net primary productivity (HANPP) is a measure that includes biomass extraction from ecosystems for food, fodder, fibres and bioenergy. For large parts of Western Europe, HANPP appropriated is lower than HANPP embodied in consumption. For Central and Eastern Europe and Central Asia, HANPP of the region is about the same as or slightly higher than HANPP embodied in consumption (Erb *et al.*, 2009a, 2009b). European Union imports embodied HANPP to an increasing extent, in particular from South America (Kastner *et al.*, 2015) (see **Figure 2.48**).

Central and Western Europe depend on land elsewhere for crop production to a large degree; Eastern Europe and Central Asia to a lesser degree. Main sources are Brazil, Argentina, China and the USA (Yu *et al.*, 2013). In 2008 Western Europe showed relatively low levels of self-sufficiency in terms of crop production and consumption,

Figure 2 48 **Human appropriation of net primary productivity (HANPP) (Mt dm/yr) embodied in trade between the European Union and ten world regions. Arrows indicate the largest flows (red=import, black=export). Source: Kastner *et al.* (2015).**

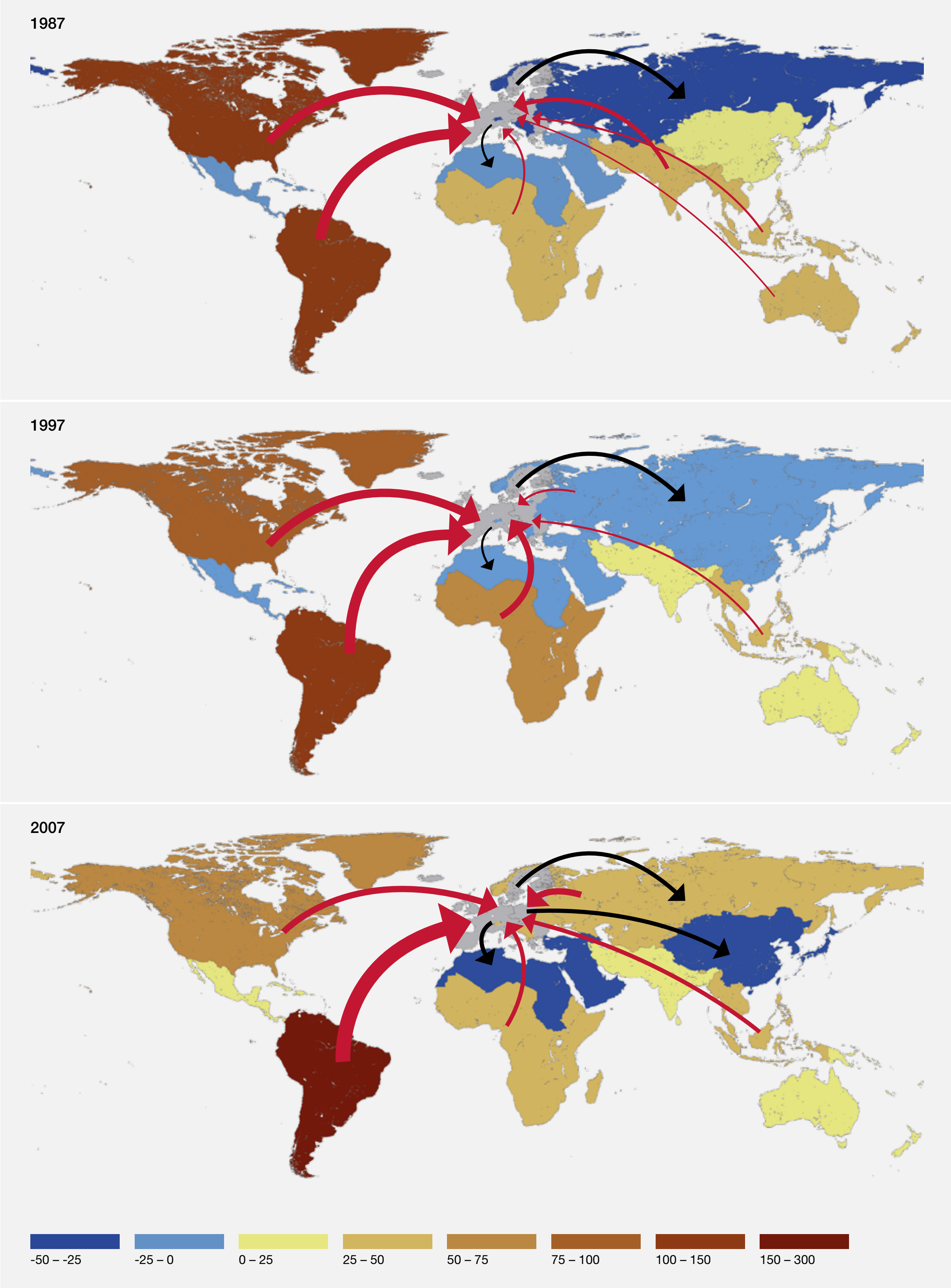
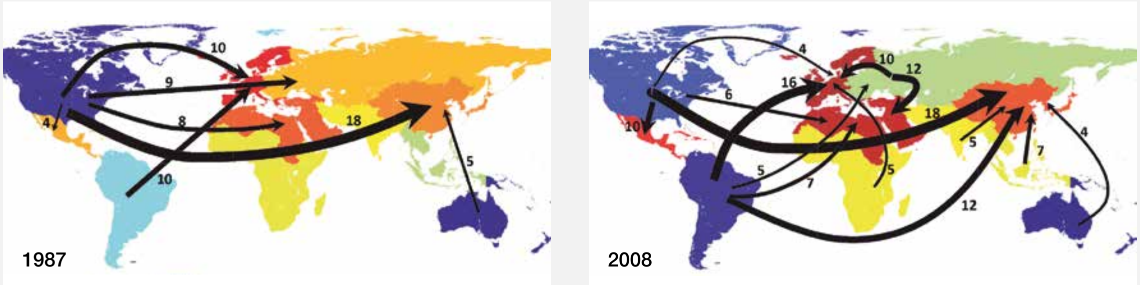


Figure 2 49 **Croplands (million ha harvested per year) related to import and export of crops. Source: Kastner *et al.* (2014).**



SELF-SUFFICIENCY RATIO (PRODUCTION / CONSUMPTION)

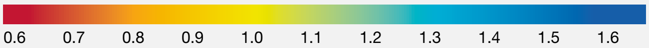
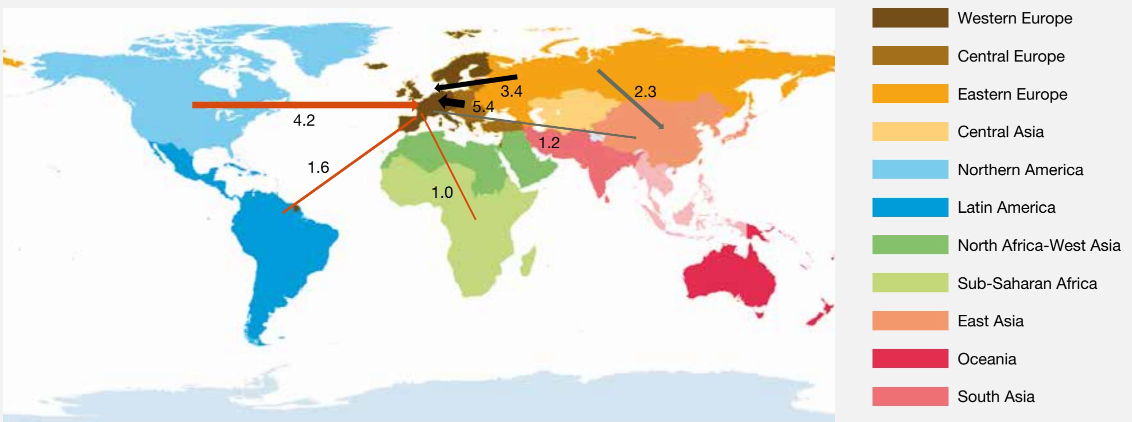


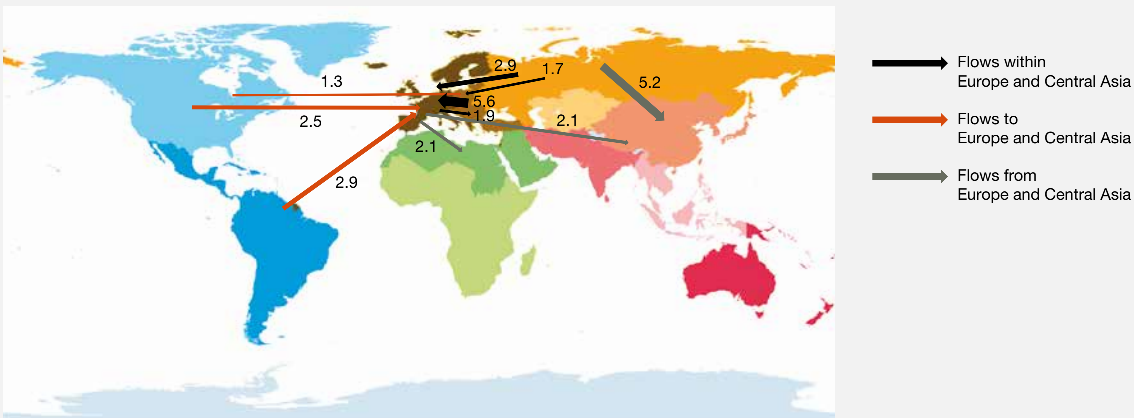
Figure 2 50 **Flows of traded wood and wood products (million tonnes of C), within, to and from Europe and Central Asia for 1997 and 2012.**

Only flows above 1 million t C are indicated with arrows. Source: Based on data from Henders *et al.* (2015); Kastner *et al.* (2011).

1997



2012



while Central and Eastern Europe as well as Central Asia showed higher production than consumption levels (i.e. self-sufficiency ratio larger than 1) (see **Figure 2.49**) (Kastner *et al.*, 2014). **Figure 2.49** indicates Central and Western Europe depended in 2008 on food and feed imports equivalent to the annual harvest of 35 million hectares of cropland, a land area the size of Germany. See Section 2.3.1.1 on food security.

Worldwide median minimum distance from fishing source to place of consumption has increased from about 500 km in 1950 to about 2,500 km in 2011 (Watson *et al.*, 2015b). Seafood exports from Europe and Central Asia increased over the period 1976-2009, with Russia, Norway and Spain being the main exporters. Per capita consumption also increased, with Norway, Iceland, Spain, Portugal and Lithuania being the countries with the highest per capita consumption (Watson *et al.*, 2015a) (See Section 2.2.2.1).

Interregional flows of roundwood and wood products (t C per year) have changed patterns between 1997 and 2012 **(Figure 2.50)**. The largest flows within Europe and Central Asia are exports from Central and Eastern Europe to Western Europe (stable between 1997 and 2012). Eastern Europe increased exports to South Asia. Flows from North America to Western Europe decreased, flows from Latin America to Western Europe increased.

Interregional flows take place also for carbon sequestration. There is evidence that terrestrial ecosystems only sequester a small fraction of anthropogenic carbon emissions in Europe (defined here as the landmass between the Atlantic Ocean and the Urals, excluding Turkey and the Mediterranean isles) (Janssens *et al.*, 2003). The rest is sequestered by terrestrial ecosystems in other parts of the world, by oceans, or adds to the atmospheric carbon stock.

2.2.5 Summary of trends of nature's contributions to people

The contributions to people from ecosystems in Europe and Central Asia have changed markedly since the 1950s, promoting changes in the quality of life of its societies (see Section 2.3). Although the ecosystems of the region are currently delivering multiple contributions to people, there has been evidence of negative trends in the provision of regulating and some non-material contributions since the 1960s (see **Figure 2.51**). Overall, 58% of publications provide evidence of negative trends of nature's contributions to people provided between 1960 and 2016, while 28% reported positive trends (see supporting material Appendix 2.7[26] for the whole list of references reporting increasing, constant, decreasing and mixed trends per contribution). This pattern, however, is not consistent across contributions: while 59% and 66% of the scientific publications reviewed provide evidence of declining trends in regulating and non-material contributions, respectively, only 39% of the studies show negative trends in the delivery of material contributions **(Figure 2.51)**. In fact, of the range of nature's contributions to people delivered in Europe and Central Asia, about 44% have been assessed as declining, particularly regulating and some non-material contributions, such as learning derived from indigenous and local knowledge. The decreasing trends of learning derived from indigenous and local knowledge also have consequences for other contributions from nature to people, such as the use of medicinal plants (Section 2.2.2.4), wild food gathering (Section 2.2.3.2.1), the use of guard dogs for protecting livestock (Section 2.2.2.3.4) and the cultural identity of peasants, herders and shepherds (Section 2.3.3, supporting material Appendix 2.2[27]), which have also declined over the assessed period.

Intensification of management practices, technology, manufactured capital and market forces have promoted increasing trends in the provision of particular material contributions from nature to people, including food, biomass-based energy and materials **(Figure 2.51)**. The increasing trends in the delivery of specific material contributions have come at the expense of the long-term deterioration of regulating contributions. Some key regulating contributions, such as habitat maintenance, pollination, regulation of freshwater quantity and quality, formation and protection of soils, and regulation of floods, have been negatively affected since the 1960s by intensified management practices that seek to increase production of crops, livestock, aquaculture, woodfuels and cotton. In addition, the increasing demand in Western and Central Europe for nature's material contributions to people, such as food and biofuels, is straining the capacity of ecosystems and nature's contributions to people in other regions of the world (Sections 2.2.2.3 and 2.2.4).

The improvement found for some of nature's regulating contributions to people in the last decade in Western and Central Europe (see **Figure 2.51**), such as regulation of water quality, protection of soils and removal of animal carcasses by scavengers, can be explained by the successful implementation of European Union policies, such as the Nitrates and Water Framework Directives (see Section 2.2.1.7) and the Common Agricultural Policy (see Section 2.2.1.8), the implementation of different nature-based solutions for water quality (see Section 2.2.1.7), as well as different conservation programmes for vertebrates (see Section 2.2.1.10). In addition, it is worth noting that water-based regulating contributions from

26. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.7_assessment_references_synthetic_table.pdf

27. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

Figure 2.51 **Assessment of each of nature's contributions to people (NCP) based on published literature for each subregion and for Europe and Central Asia as a whole.**

The bottom row of the panel shows the trends of all contributions. The bar indicates the proportion of papers that provide evidence of decreasing, constant, increasing or mixed trends for each contribution, representing the level of agreement. The intensity of the colour represents the total number of publications identified and used in this assessment (i.e., solid colours indicate many papers, whereas faded colours indicate few, and blank space indicates zero studies), thus, representing the quantity of evidence. The degree of confidence is also represented by indicating the level of agreement (i.e. the strongest agreement is presented when only one colour is shown) and the quantity of evidence (i.e. the most robust evidence is presented when the assessment is validated by more than 31 multiple independent papers, which is represented by dark solid colours). Colours can also vary for the same contribution when trends of contribution subtypes differ. See supporting material Appendix 2.7* for the list of references reporting trends in contributions across subregions of Europe and Central Asia. Source: Own representation.

* Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.7_assessment_references_synthetic_table.pdf

nature to people have improved in Western Europe since the 1990s due to changing patterns in societal behaviour driven by European Union policies, but not because of an enhancement in ecosystems' capacity to provide them. For example, although water quality is improving due to the aforementioned Union policies and pollution reduction, ecosystems' capacity to regulate water quality has been jeopardized by a reduction in the areal extent of wetlands and floodplains (see Section 2.2.1.7). The abstraction and use of freshwater have decreased since the 1990s; however, water availability per capita has also decreased by 15% since 1990 (see Sections 2.2.1.6, 2.3.1.3). Similarly, the increasing trends of physical and psychological experiences (see **Figure 2.51**) can be explained by the fact that people in the European Union have increasingly demanded nature for recreational activities, although land-use change has threatened the ecosystems highly valued by people for these experiences (see Section 2.2.3.2.1).

The pattern of trends in nature's contributions to people is consistent across the subregions of Europe and Central Asia **(Figure 2.51)**. Declining trends of these contributions are reported in Central Europe (61% of the scientific evidence), Western Europe (55%), Eastern Europe (54%) and Central Asia (48%); while increasing trends are mostly reported for Western Europe (35% of scientific evidence). Nevertheless, it should be noted that more scientific research (in English language-journals) on nature's contributions to people has been conducted in Western and Central Europe than in Eastern Europe and Central Asia (Boerema *et al.*, 2017), with implications for the levels of confidence about status and trends of nature's contributions to people across subregions **(Figure 2.51)**.

2.2.6 Future trends in nature's contributions to people

This section examines the potential impacts of individual drivers on future trends in nature's contributions to people, with trends in direct and indirect drivers covered in Chapter 4 and the impacts of combined drivers and trade-offs between contributions discussed in Chapter 5, Sections 5.2 and 5.3. A semi-structured literature review (see Section 2.2) was undertaken, with information extracted into a template to enable comparison across nature's contributions to people and to facilitate integration with Chapter 5's analysis of the impacts of multiple drivers on the status and trends of contributions (see Section 5.3.3 and 5.3.4). In the allotted time, this search process could only be fully applied to food and feed, air and climate regulation, and learning and inspiration. Even the targeted semi-structured literature review yielded comparatively few articles, except for Western Europe. Thus, it was not possible to estimate robustly future trends in nature's contributions to people in Europe and Central Asia. As in Chapter 4, the most frequently identified driver of trends in contributions was climate change, followed by land use, land-use change and forestry (LULCC).

2.2.6.1 Regulating contributions

Nature's regulating contributions to people are likely to show mixed responses to climate change across Europe and Central Asia (Kovats *et al.*, 2014). Few studies have examined future trends in *pollination or pollinators*, but both qualitative and quantitative modelling studies suggest that climate change is likely to lead to pollinator decline. Modelling shifts in bumblebee distribution showed that, by 2100, up to 36% are projected to be at high risk from climate change (losing >80% of their current range), with 41% at risk (losing 50-80% of their current range), depending on the scenario (Kerr *et al.*, 2015).

Little literature was found for the *air regulation* as a contribution from nature to people. Tallis *et al.* (2011) estimated that the planned increase in tree cover, from 20% to 30% in the Greater London Authority area, could increase particulate matter (PM_{10}) removal by 18% by 2050, assuming no change in tree cover types. Papers on past and present trends in urban air quality comment on the importance of trees and green space in the future (e.g., Baró *et al.*, 2014).

Climate regulation may become more important as countries seek to meet their greenhouse gas commitments under the Paris Agreement. For example, the Tajikistan government has a national programme on carbon sequestration (2014-2024), which includes plans for afforestation and reforestation (Mustaeva *et al.*, 2015). For future carbon budgets, climate and land use, land-use change and forestry (LULCC) were the most frequently analyzed drivers, with the net balance of their effects depending on their impact on vegetation, soil storage and decomposition. In the Arctic, global mean temperature increases could decrease carbon storage in permafrost soils by 2100, despite increased uptake of carbon by vegetation. In northern parts of Western and Eastern Europe, warming could increase tree carbon storage (Olchev *et al.*, 2009; Shanin *et al.*, 2011), although it would decrease if precipitation declines (Olchev *et al.*, 2009), especially in southern areas of the European Union (Lavalle *et al.*, 2009). Also, forest disturbance from wind, bark beetles and wildfires are projected to decrease the carbon storage potential of forests in Western and Central Europe by 503.4 TgC between 2021–2030 (Seidl, 2014).

Land use change and fire could have mixed effects on future *carbon budgets* (Kuemmerle *et al.*, 2011; Verkerk *et al.*, 2014). Unmanaged woodlands in Western Europe should continue to be a carbon sink (Allen *et al.*, 2016), while in central Russian forests, fire and management could have a greater influence than climate on future vegetation and soil carbon stocks, with forests becoming a carbon source rather than a sink (Shanin *et al.*, 2011). There are similar mixed responses to land use change and management on formerly abandoned lands in Eastern Europe and Central Asia (Causarano *et al.*, 2011), with afforestation increasing carbon storage, while for biofuel production, using low intensity/high density grass-legume pastures, it depends on the timing of cultivation, tillage and climate change, and soil carbon sequestration would increase unless climate change were to decrease vegetation net primary productivity (Vuichard *et al.*, 2008).

Artificialization and soil sealing are rapidly increasing in the European Union (FAO, 2015b; Jones *et al.*, 2012) and might affect the *formation and protection of soils* as a contribution from nature to people in the near future, while this is not yet a problem in Central Asia due to the vast extent of land (UNEP & UNECE, 2016). Hence, the supply of erosion control in the coming decades will mainly depend on the farming practices and land-use policies implemented.

Changes in climate will affect the demand for, and supply of, *hazard regulation*. Greater demand could result from increased glacier melt (Hagg *et al.*, 2006; Sorg *et al.*, 2012; Stoffel & Huggel, 2012); flooding due to heavy precipitation events in parts of Western and Central Europe (Kovats *et al.*, 2014); and fire frequency and severity, especially in parts of

Russia (Gauthier *et al.*, 2015) and southern Western Europe, where the annual burned area could increase by a factor of three to five by 2100 under the IPCC A2 emission scenario (Dury *et al.*, 2011).

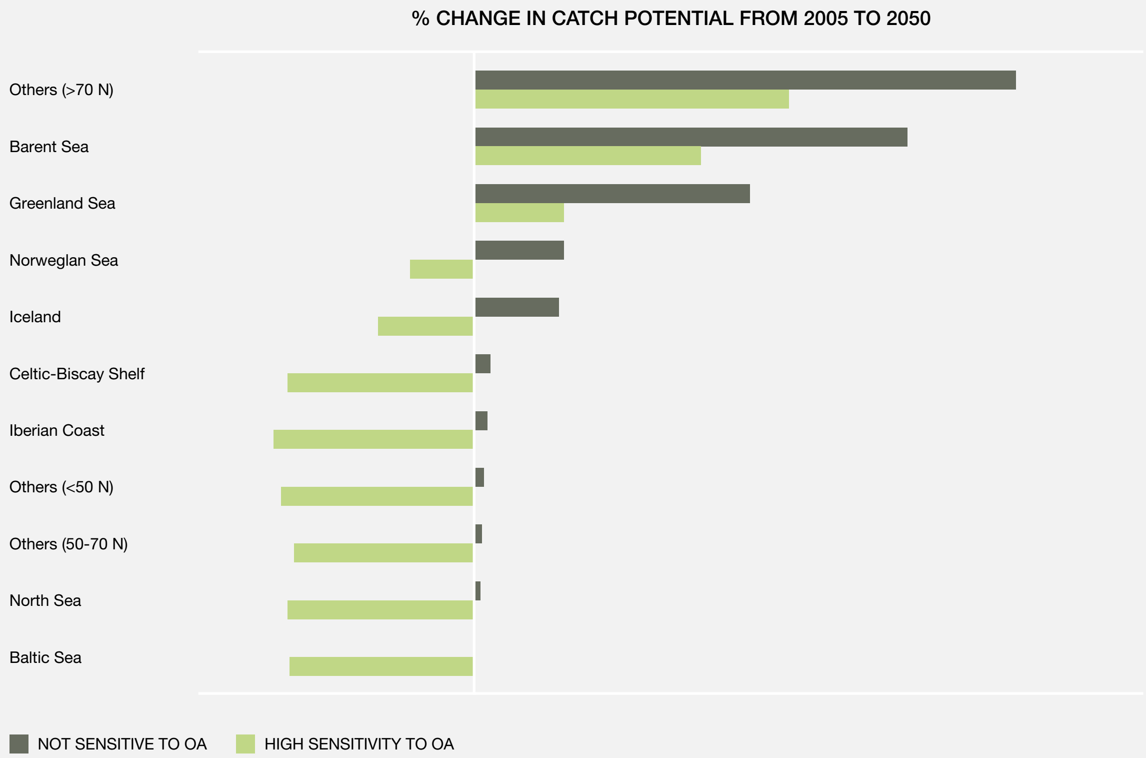
2.2.6.2 Material contributions from nature to people

Changes in seasonal, and extremes of, temperature and precipitation, as well as CO_2, can affect *food and feed* provision, which show mixed trends in yield, depending on the scenario, region and crop. Global modelling of cereal production in 2050 shows increases in countries in the Organization for Economic Co-operation and Development and in countries emerging from the former Soviet Union, partly as a result of an enhanced CO_2 fertilization effect, with cereal consumption possibly increasing in the former, and increasing in the latter depending on scenario (Alcamo *et al.*, 2005). Zabel *et al.* (2014) also suggest that climate change will increase the extent of agriculturally suitable land and food production in Russia. Food, livestock and fibre production, however, are projected to decrease in parts of Western and Central Europe, but to increase in the northern parts of these regions (Kovats *et al.*, 2014). Climate change is projected to cause increased yields of rainfed maize, while rainfed wheat shows a mixed response across Europe and Central Asia, depending on the climate scenario (Nelson *et al.*, 2010). It could lead to an overall decrease in daily per capita calories available (Nelson *et al.*, 2009) and in fodder quality (Quetier *et al.*, 2007). In Eastern Europe and Central Asia, by 2050, yields of many irrigated crops show a mixed response, but water shortages mean that irrigation is unlikely to be able to continue at current levels, so yields could decrease by 50% or more (Sutton *et al.*, 2013). Other studies project decreases in agricultural production from combined effects of climate change and deteriorating land use practices in the Czech Republic (Lorencova *et al.*, 2013) and across Western Europe (Haines-Young *et al.*, 2012).

Timber production may decrease in many parts of Central Europe, but with increases predicted in northern parts of Western Europe. In Finland, forest stand models, in which tree growth is converted into site and then regional forest growth, calculate that, under an Intergovernmental Platform on Climate Change SRES B2 scenario (based on

Figure 2 52 **Projected changes in maximum catch potential by 2050 relative to 2005 under the SRES A1B scenario, with assumptions about sensitivity to ocean acidification (OA).**

Projections are made using a dynamic bioclimatic envelope model with physical and biogeochemical outputs from the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory Earth System model (TOPAZ). Source: Cheung *et al.* (2012).

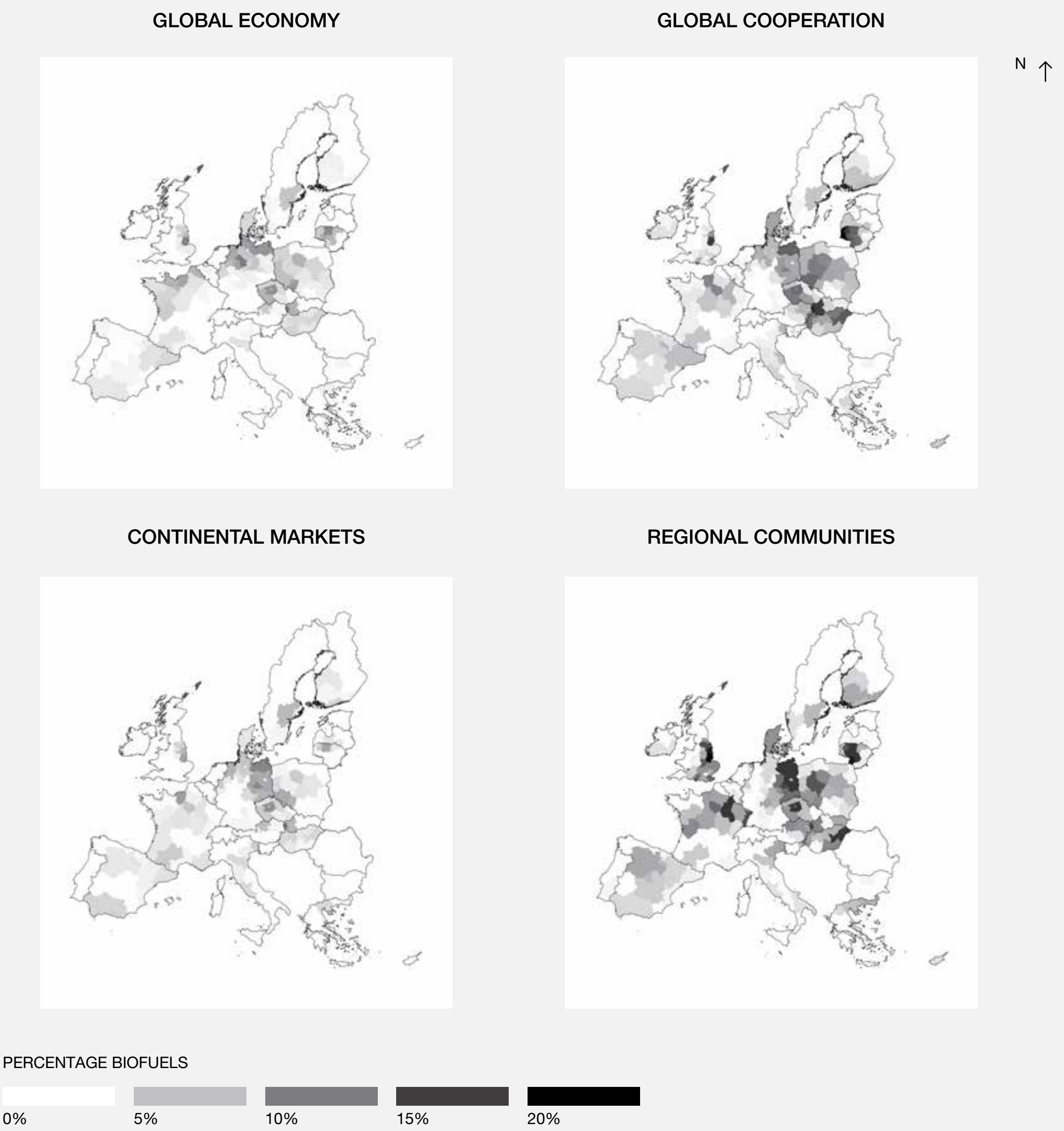


the Special Report on Emissions Scenarios (SRES)), pine growth in southern Finland could increase by 16% and in Lapland by 31%, while under a higher (SRES A2) emissions scenario these figures are 40% and 80% respectively (Forsius *et al.*, 2013).

In the EU-27, demand for *biomass-based wood for energy*, and wood products are both projected to increase from 2010 to 2030 under a *global markets* scenario (Verkerk *et al.*, 2014), but the production and consumption of wood products is lower and could slow under the *regional sustainability* scenario (Jonsson, 2013), with Eastern Europe accounting for a greater proportion of production and consumption of solid wood, pulp and paper products. The increasing demand, especially for wood-based energy, means that EU-27 supply may not meet the future demand for raw wood materials.

For fish production, the maximum catch potential could increase in Western Europe, especially in high latitude seas (>50ºN), with an average yield increase of 30-70% **(Figure 2.52)**, depending on assumptions about the effects of ocean acidification on fish ecophysiology (Cheung *et al.*, 2012).

Figure 2 53 **Biodiesel and ethanol production in the European Union (EU-27) by 2030 under different scenarios combining drivers such as globalization and regionalization, import levels, processing facilities and infrastructural arrangements, subsidy levels, and nature conservation policies. Source: Hellmann & Verburg (2011).**



Within Europe and Central Asia, the main biodiesel and bioethanol producers and consumers are within the European Union. Based on the Special Report on Emission Scenarios (Nakicenovic & Swart, 2000), the scenarios for the spatial allocation of *biofuel crops* within the EU-27 region showed that by 2030, for different storylines with various political and economic circumstances, some regions are projected to have a higher share of biofuel crops (Hellmann & Verburg, 2010) **(Figure 2.53)**.

For 2050 under a *business-as-usual* scenario, biofuel potential amounts annually to 3.6 EJ (Western Europe), 6.3 EJ (Central Europe), and 7.9 EJ (Central Asia and Russian Federation) (Haberl *et al.*, 2011). **Figure 2.53** shows that current biofuel production in the subregions is strongly below the future potential. Western Europe has the lowest potential, but the significantly highest biofuel production. However, these biofuel potentials do not take changes in population, diets, and climate into account. The highest unused potentials for biofuels are in Central Asia and Russia.

2.2.6.3 Nature's non-material contributions to people

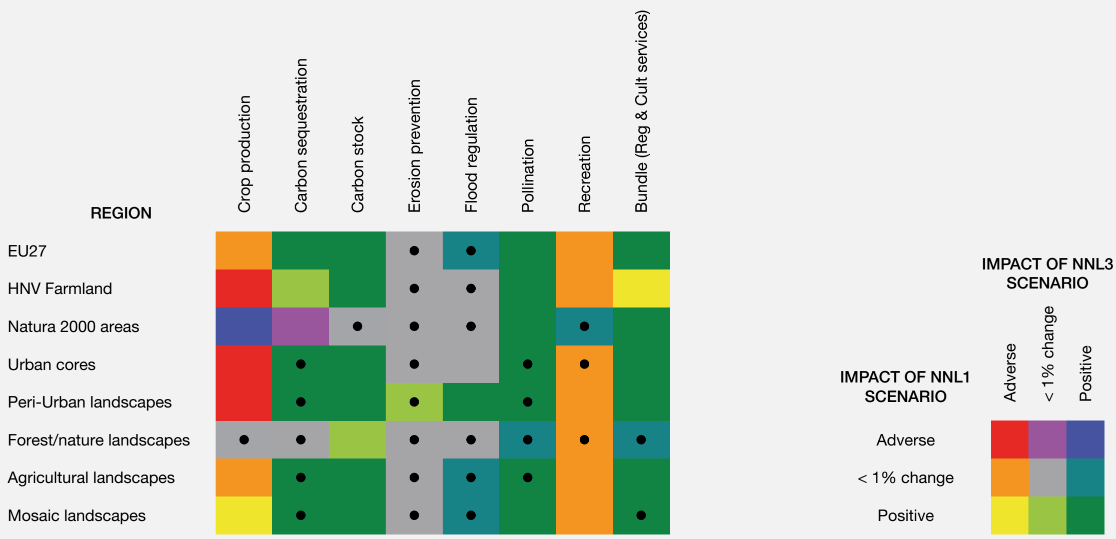
There are fewer studies on the future of nature's non-material contributions to people and most of them relate to learning and inspiration and physical and psychological experiences linked to outdoor recreation and tourism. In northern Scandinavia and north-western Russia, tourism and recreation could decrease in winter due to climate change, but increase in summer, while cultural ties to the landscape and species unique to northern areas could decline (Forsius *et al.*, 2013; Jansson *et al.*, 2015).

Verkerk *et al.* (2014) showed that recreational attractiveness (an expert-based index (1–10) of the preference value for different forest stands for recreation) did not change in Western or Central Europe in either a reference (*business-as-usual*) scenario or wood energy scenario (see above). The biodiversity scenario, however, could lead to an improvement in the recreational attractiveness index by 0.5 points (+ 9.4%; range between countries: + 0.2 to +1.0 points). Overall, the changes were quite small as the index depends on broad age classes of people, which changed relatively slowly between 2010 and 2030.

No clear evidence of future trends in learning and inspiration from nature can be identified, but knowledge of urban habitats can contribute to future urban greening policy and scenario development (Camps-Calvet *et al.*, 2015; Colding *et al.*, 2013; Mortberg *et al.*, 2013). Scientific and indigenous and local knowledge of a range of nature's contributions to

Figure 2 54 **A comparison of changes in nature's contributions to people in different landscape types under a *no net loss* scenario with better implementation of existing biodiversity conservation measures (NNL1) and a *no net loss* scenario with offsetting of residual impacts on areas of high biodiversity and ecosystem service value (NNL3), compared to *business-as-usual*.**

• Indicates no net loss of the contributions from nature to people compared to baseline under the NNL3 scenario.
Source: Schulp *et al.* (2016).



people is a key component of scenario development used to consider future strategies and options for environmental and conservation management, such as for transhumance networks in Spain (Oteros-Rozas *et al.*, 2013a), forests in Poland and Sweden (Carlsson *et al.*, 2015; Chmura *et al.*, 2010) and protected areas in Europe (Mattsson & Vacik, 2017). Emerging forms of learning, using virtual tools to develop environmental awareness amongst adults and young people will also rely on knowledge of biodiversity and drivers of change (Harwood *et al.*, 2015; Ulbrich *et al.*, 2015).

For many of nature's contributions to people, policies can also affect the future demand and supply. Simulations of how land use changes in the EU-27 could affect a range of contributions under a *business-as-usual* scenario and three biodiversity *no net loss* scenarios were undertaken by Schulp *et al.* (2016). The simulations found that while *no net loss* policies generally led to an improvement in most of nature's contributions to people, especially climate regulation and pollination, such policies would not totally address the loss of biodiversity and of nature's contributions to people because of the continued demand for land for human use **(Figure 2.54)**. Food provisioning could also be negatively affected under *no net loss* policies, while some of nature's regulating contributions to people and recreation could be little affected.

This, and other studies which consider a number of nature's contributions to people together (e.g. Kain *et al.*, 2016), highlight that trade-offs between contributions need to be taken into account when considering both current and future trends (Section 2.3.4.2).

2.3 EFFECTS OF TRENDS IN NATURE'S CONTRIBUTIONS ON QUALITY OF LIFE IN EUROPE AND CENTRAL ASIA

2.3.1 Contributions to food-energy-water security

Food, energy and water are essential for human well-being, poverty alleviation and sustainable development (FAO, 2014b). Food security, water security and energy security represent Sustainable Development Goals number 2, 6 and 7, respectively (see Section 2.4).

2.3.1.1 Food security

Food security is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 2014b). A condition for the full realization of the right to food is "food sovereignty" (De Schutter, 2014), defined as "the right of nations and peoples to control their own food systems, including their own markets, production modes, food cultures and environments" (Wittman *et al.*, 2010). The situation and trends of food security and sovereignty in Europe and Central Asia have been mixed in the last century and vary greatly between and within subregions, with the best situation in Western Europe, and Central Asia showing the largest challenges (all data retrieved from FAOSTAT).

Food availability is adequate across Europe and Central Asia, where the average dietary energy supply adequacy ranges from 137% in Western Europe to 121% in Central Asia (see **Figure 2.55**). Food accessibility and utilization varies between subregions. The domestic food price level showed stability between 2001 and 2014, but also large inequalities within the region with the lowest price levels in Western Europe, intermediate levels and decreasing in Central Europe, and three times higher levels and increasing in Eastern Europe. Undernourishment has been very low in recent decades in Central and Western Europe; in Eastern Europe, although currently stable around 7%, it reached almost 45% in the early 1990s; and in Central Asia, it has fluctuated and currently reaches 20%. The percentage of adults who are underweight increased to almost 4% in Central and Western Europe from the late 1990s to the end of the century. During the recession of 2007-2009 daily nutritional intake and the consumption of nutritious food declined in Eastern and Central Europe, so that after 2008 the percentage of households with children unable to afford a meal with meat, chicken, fish, or a vegetable equivalent every second day more than doubled in some countries reaching up to 18% in Greece in 2012 (UNICEF, 2014). Overall food stability is improving: domestic food price volatility is quite low and relatively stable in the last decades, except for a peak in Eastern Europe in 2005. However, the food production variability per capita is increasing since 2010, particularly in Eastern Europe, which might be considered a threat to food security. A global nutrition transition is affecting the quality of diet in Europe and Central Asia (see **Figure 2.56**), with rapid increases in the rates of obesity and overweight (Popkin *et al.*, 2011), which is linked to inefficiencies and waste in the global food system. In fact, the average fat supply and protein supply are increasing and the former is almost double in Western Europe than in Central Asia and Eastern Europe, which instead show the largest index of diet diversification **(see Figure 2.56)**. The prevalence of food over-acquisition is almost 50% in Western Europe and, although it is lower in the other subregions, it is increasing for these.

Figure 2 55 **Trends in indicators of food security for Europe and Central Asia. Source: Own representation based on data from FAO (2017).**

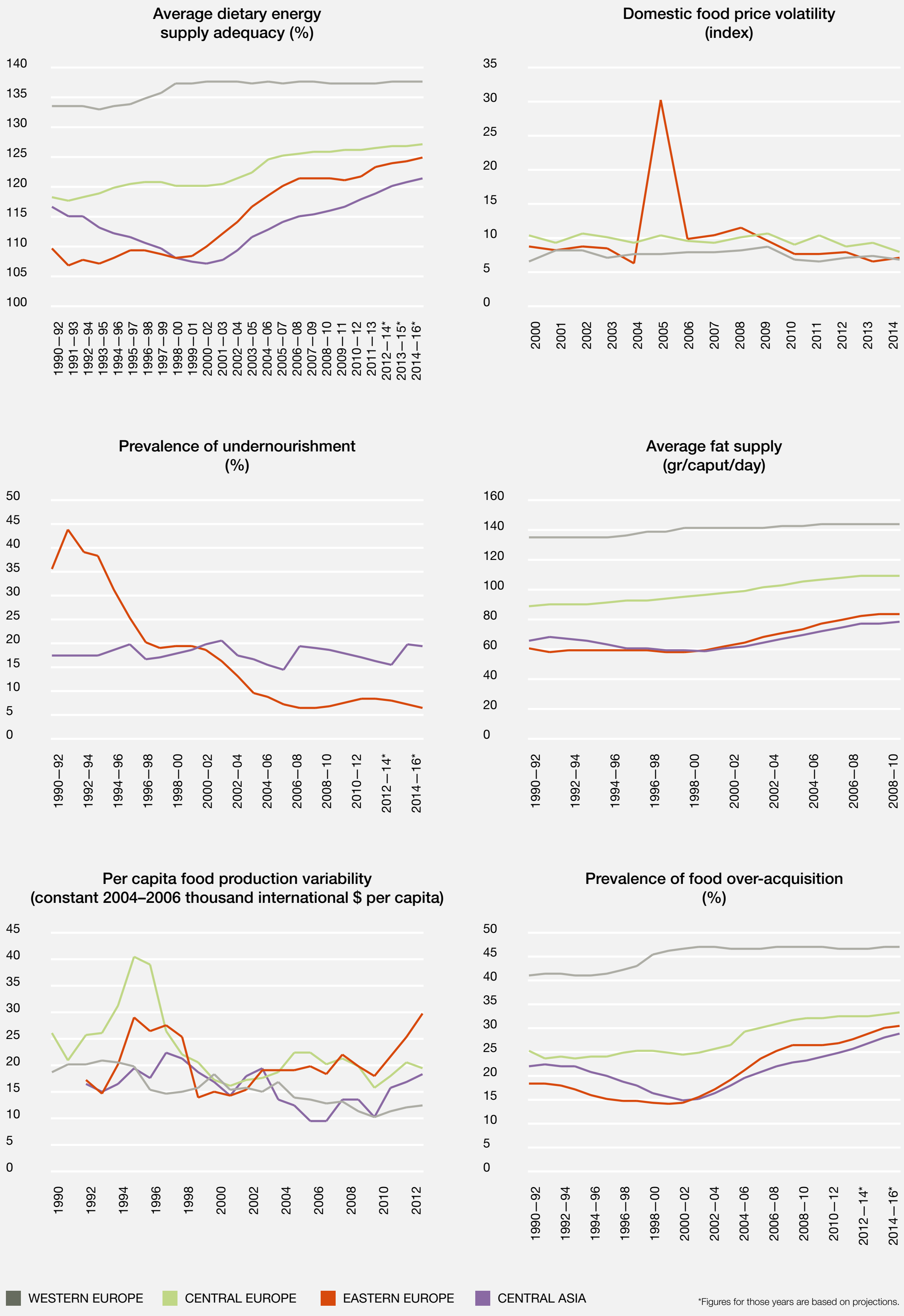
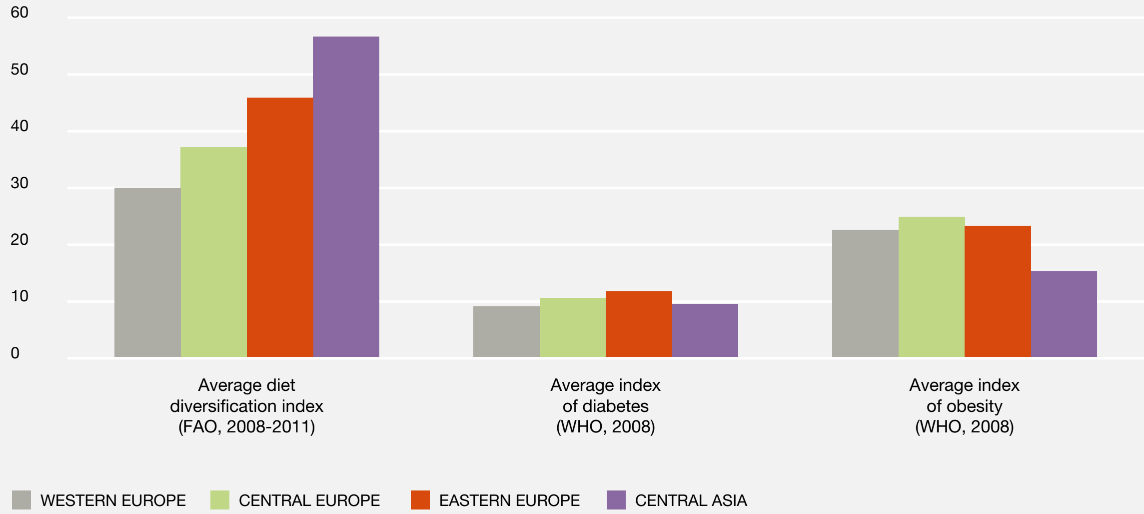


Figure 2 56 **Average indices of the quality of the diet and its impacts on health in subregions of Europe and Central Asia. Source: Own representation based on data from WHO (2008a, 2008b) and FAO (2017).**



Food security and food sovereignty are threatened by large-scale control of extended tracts of land by large investment companies (land deals or land grabs) (van der Ploeg *et al.*, 2015). In 2012 there were 51 documented cases in Europe and Central Asia occupying a total area of 4.4 million ha (see **Figure 2.57**): Russia, Ukraine and Romania are the countries with the largest land-grabbed areas (GRAIN, 2016). Countries from the region are also grabbing land abroad (0.63% of worldwide croplands), particularly Western Europe countries (0.57% of worldwide croplands). However, official statistics do not capture the real dimensions of the phenomenon, which leads to crop production being intensified and oriented to distant markets other than local needs (TNI, 2016). Finally, both food security and sovereignty are challenged by the loss of agri-food related indigenous and local knowledge and agrobiodiversity (see Chapter 3 and **Box 2.2**).

2.3.1.2 Energy security

Energy security has been defined by the United Nations as "access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses" and by the International Energy Agency as "uninterrupted physical availability (of energy) at a price which is affordable, while respecting environment concerns". Energy production was highest in Eastern Europe and lowest in Central Europe in 2014 (see **Figure 2.58**). For heating, "energy poverty" affects at least 10% of the population and is more likely for low-income groups in the European Union (see **Figure 2.60**). Energy poverty is more pronounced in Eastern Europe (Dubois & Meier, 2016).

The highest share of bioenergy (biofuels and waste) relative to the total production in the region is produced in Western and Central Europe. The highest share of hydropower relative to total production is produced in Western and Eastern Europe. Western Europe is a net importer of fossil energy carriers (coal, oil products, and natural gas), whereas Eastern Europe is the largest, and Central Asia the second largest exporter in the region. The net imports or exports by subregion are negligible for bioenergy (biofuels and waste) and other renewables compared with other energy carriers (see **Figure 2.59**).

At the country levels, the trade balance for biofuels in Central Asia and Eastern Europe are mostly equalized. Net exporters are mostly found in Western and Central Europe, the biggest being The Netherlands, Latvia and Germany. Similarly, Western European countries also strongly depend on imports (Italy, the United Kingdom, Denmark, Austria, and Belgium) (see **Figure 2.61**).

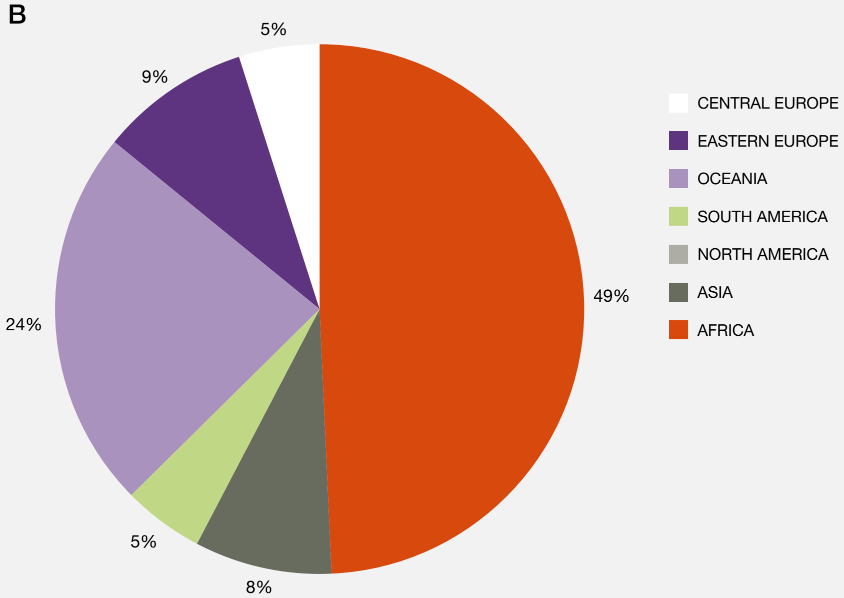
Currently, biomass supplies in the European Union are mostly based on domestic sources (4% of the biomass for bioenergy imported) (European Commission, 2014a). In scenarios for 2020 and 2030, biomass for bioenergy may even fill other supply shortages for industry, replacing coal power plants (Dafnomilis *et al.*, 2017).

In total, the actual contribution of bioenergy to energy security is weakly captured in existing research (Popp *et al.*, 2014) as the multitude of biomass sources, energy carriers, and conversion pathways impede tracking of this renewable energy source. In addition, there are not

Figure 2 57 **A A global map of the large-scale acquisitions of land (also known as land-grabbing) network: land-grabbed countries (green disks) are connected to their grabbers (red triangles) by a network link. Source: Rulli *et al.* (2013).**
B Percentage of surface grabbed by Western Europe in each subregion in Europe and Central Asia and world regions.

A

B



Box 2 2 **Custodians of food, seeds and traditions: biocultural diversity – the diversity exhibited collectively by natural and cultural systems - of people in the Pamir mountains of Tajikistan.**

"Lonely, desolate, and inhospitable as these mountains for the most part are, one may still find secluded valleys cut deep down into the mountain masses where some hardy hill-men till the ground and form villages."

The remote plains of the Pamir mountains are a challenging place to transform rock into life-giving soil, primarily rain-fed. Yet, that is what Pamiri people have done over millennia at between 2,000 and 4,000 metres, nurturing a centre of origin for grain and fruit varieties which have become staple crops all around the world, along with domesticated varieties of walnuts, apples, pears, apricots and mulberries.

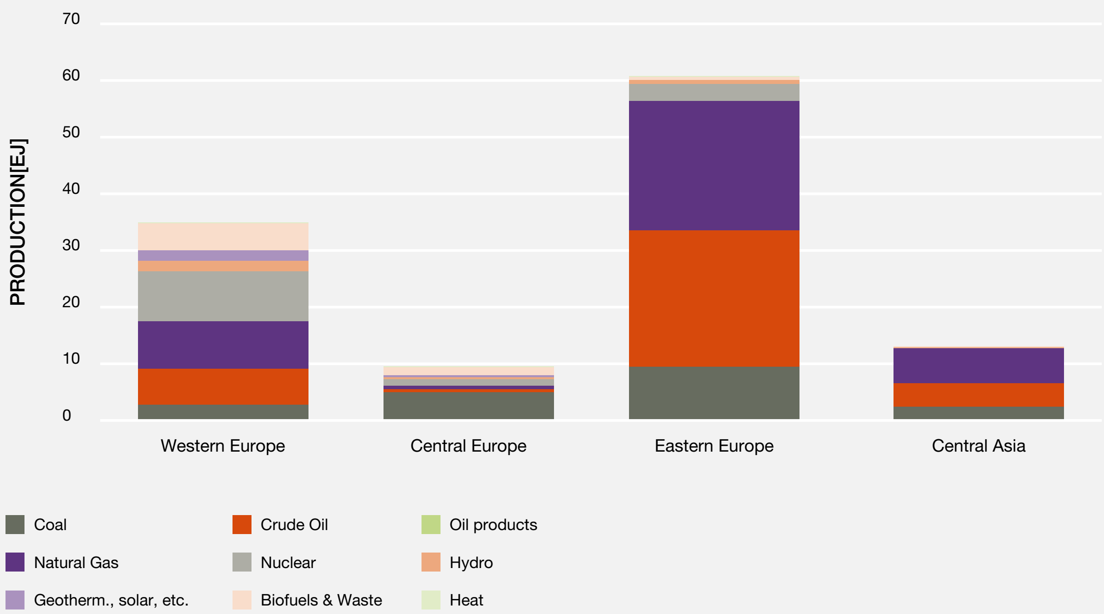
The rich agrobiodiversity of the Pamirs co-evolved with language, culture and spirituality, and as a result of local cooking traditions. Food embodies the interconnectedness of sustenance, health, spirituality, and ecosystem structure and function. *Baht,* a sweet festive porridge of flour and ice water, that is made in celebration of the new year, *Nawruz*, exemplifies these interconnections. The isolated Bartang Valley is well-known for the sweetest tasting *Baht*, because of a variety of wheat called *rush-kakht,* which is grown only in the upper reaches of the valley with the sole purpose to make *baht.* Women use small amounts of the flour of *rush-kakht* to bless the pillars of the house for a productive new year.

This text box is based on van Oudenhoven & Haider (2015).

Red wheat growing in Bartang valley. Photo: Judith Quax.

During *Nawruz*, little animals made of bread (Nazrak) are covered in Baht and provided as offerings. Photo: Judith Quax.

Figure 2 58 **Energy production (in exajoule) by energy source and region in Europe and Central Asia (2014). Source: Own representation based on IEA/OECD (2016).**



only rather novel bioenergy carriers such as biofuels, but also woodfuels, which are extensively used, but roughly estimated in statistics of the United Nations Food and Agriculture Organization. This is especially a problem for the numerous countries analyzed in Eastern Europe and Central Asia. The countries of Central Asia have a negligible share of bioenergy in their energy supply (see **Figure 2.58**). However, given the difficulties of affordable and reliable access, the use of biomass from traditional sources such as charcoal is weakly accounted for, which might be an indication that the figures underestimated nature's contributions to people from bioenergy (biofuels and waste) in this region (IEA/OECD, 2015).

2.3.1.3 Water security

Water security is assessed here as people's capacity to safeguard sustainable access to adequate quantities of water of acceptable quality (UN-Water, 2013). The indicators "percentage of population with access to improved drinking water sources" and "freshwater withdrawal as percentage of total renewable water resources" are used to describe general trends for water security in Europe and Central Asia. The former identifies adequate water availability of improved quality (World Bank, 2016), the latter reveals the extent to which long-term available water resources are exploited (FAO, 2016).

Overall, water security has increased in the region since the late 1980s (Animesh *et al.*, 2016; FAO, 2016; World Bank, 2016). Safe drinking water is secured for 95% of the Europe and Central Asian population, with higher percentages in Western Europe and Central Europe, while Eastern Europe (95%) and Central Asia (85%) have lower, but increasing access to improved drinking water since 1995 (see **Figure 2.62**). The trend in per capita water consumption has increased in all regions, due to increased population, except in Eastern Europe and Central Asia (Kummu *et al.*, 2016). On-going water pollution, especially in Eastern Europe and Central Asia, continues to threaten the availability of safe drinking water, while decreased water levels in natural reservoirs have led to increased water pollution (UN-Water, 2011). Freshwater extraction as a percentage of total renewable water resources decreased between 1993 and 2012 for the Europe and Central Asia region, most notably for Western Europe and Central Asia (see **Figure 2.62**). It coincides with a 15% decrease in water availability per capita since 1990 (see Section 2.2.1.5).

Although water is generally abundant in the European Union, droughts and over-exploitation have led to seasonal water scarcity in some water basins, especially in densely populated and agricultural areas (EEA, 2015e, 2016f; Karabulut *et al.*, 2016). Water stress in most countries of the European Union has decreased slightly since the 1990s, but many areas are considered close to being water scarce (EEA, 2011). In winter, around 6% of the European Union's population live under waterstressed conditions, while the figure is 14% in summer (EEA, 2016f). Around 20 river basin districts, including the Danube basin but mainly in the Mediterranean region, face structural water stress issues

Figure 2 59 **Net energy imports (in exajoules) by energy carrier and region in Europe and Central Asia (2014) (uncorrected for intra-regional trade). Source: Own representation based on IEA/OECD (2016).**

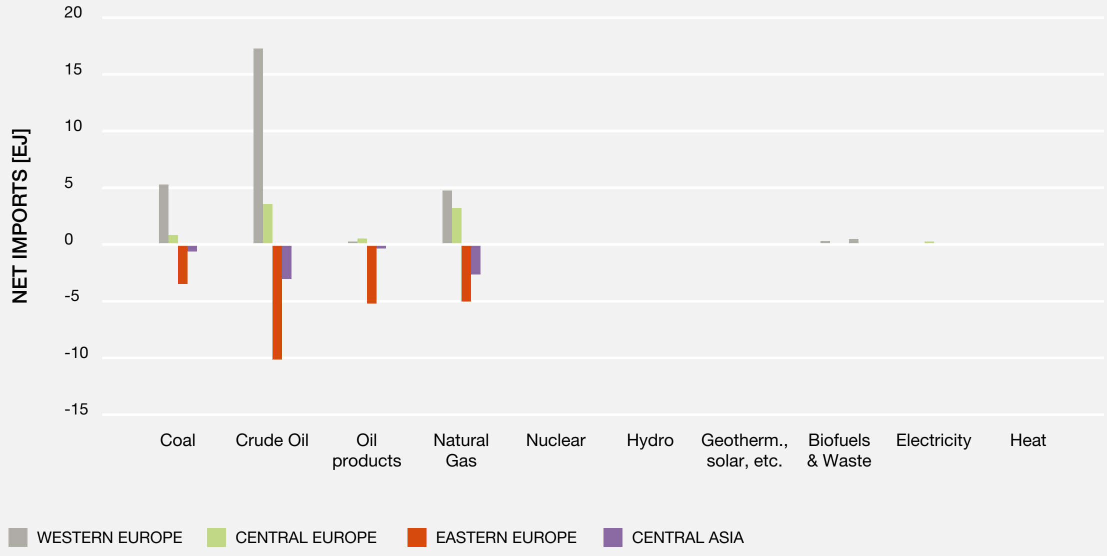
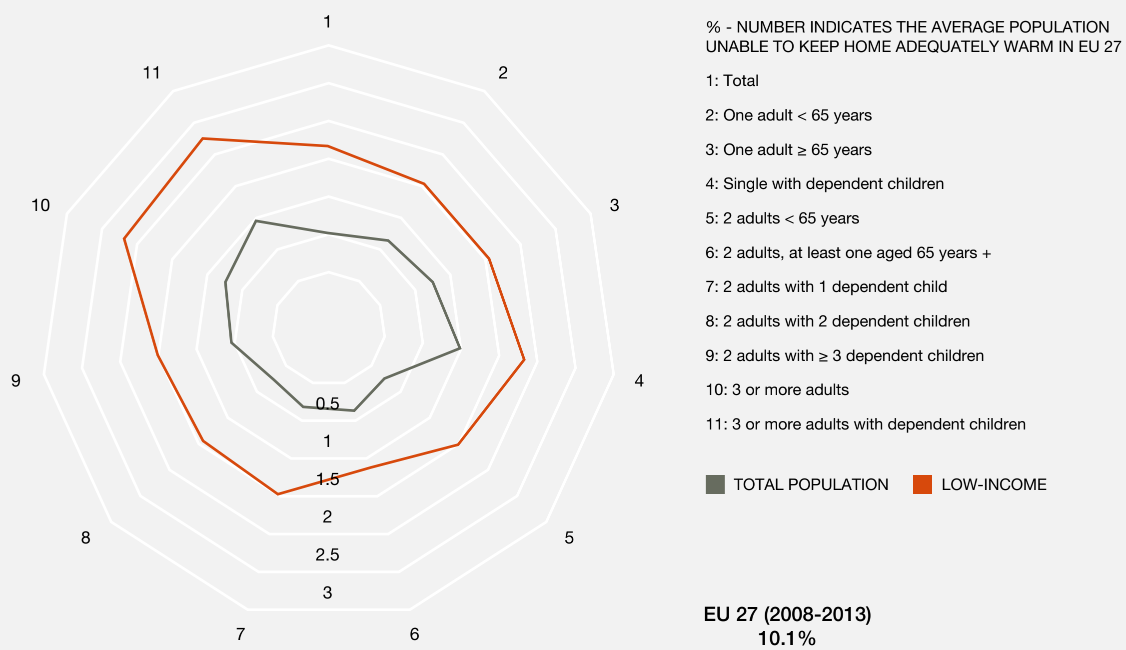


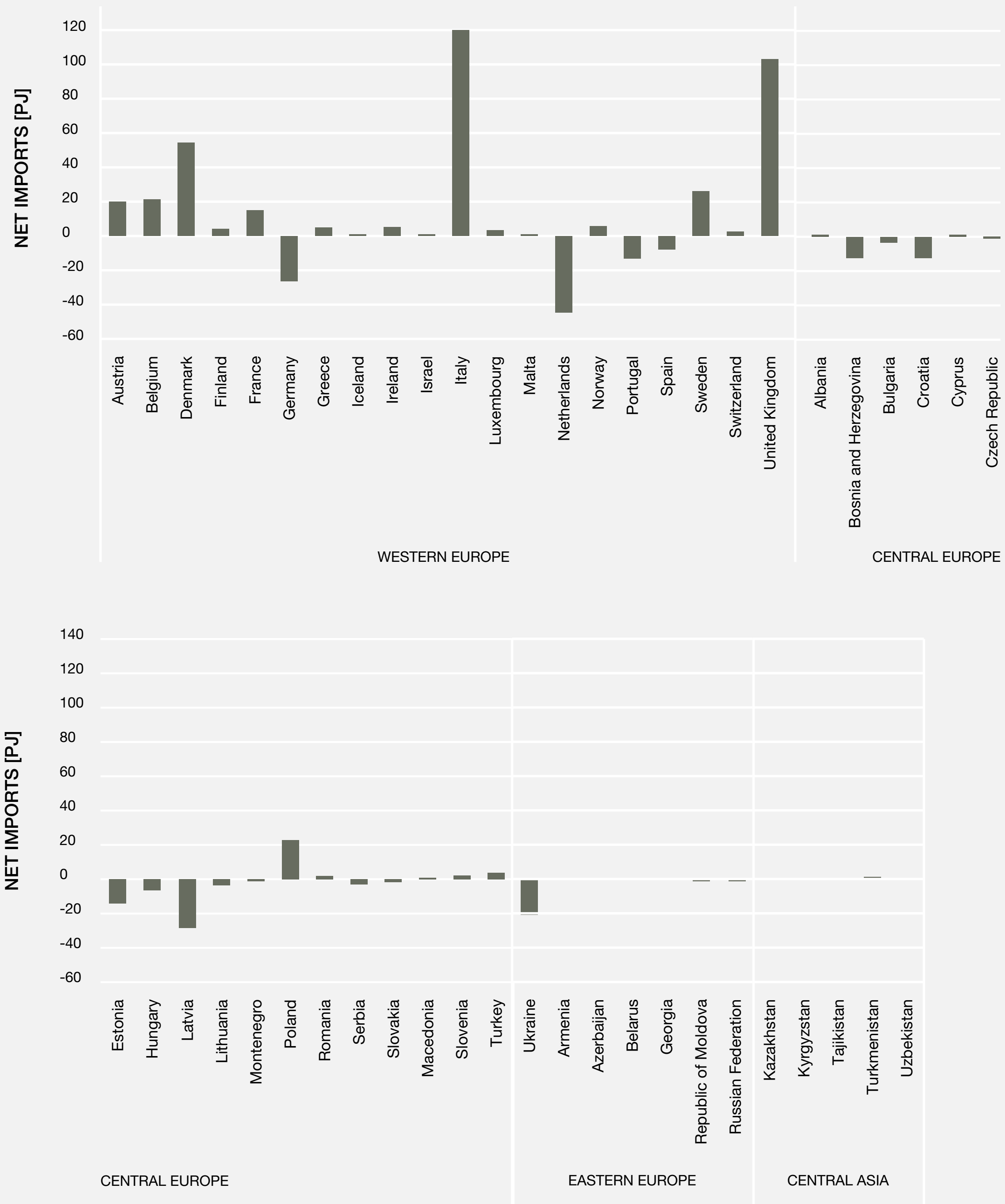
Figure 2 60 **Inequality in access to heating in the EU-27. Source: Dubois & Meier (2016).**



(EEA, 2016g), due to climate change and unsustainable water extraction (Skoulikidis *et al.*, 2017).
The spatial coverage of freshwater ecosystems in the European Union with a good ecological quality, which are crucial for providing clean water, has decreased from 42% to 32% (see Section 2.2.1.6).

Water security in Western Europe and Central Europe has remained stable since the late 1980s, despite a 40% and 5% decrease, respectively, in per capita freshwater availability since the 1960s (see Section 2.2.1.5) and a slight increase in water quality but on-going decrease in water quality regulation (see Section 2.2.1.6). Water security in

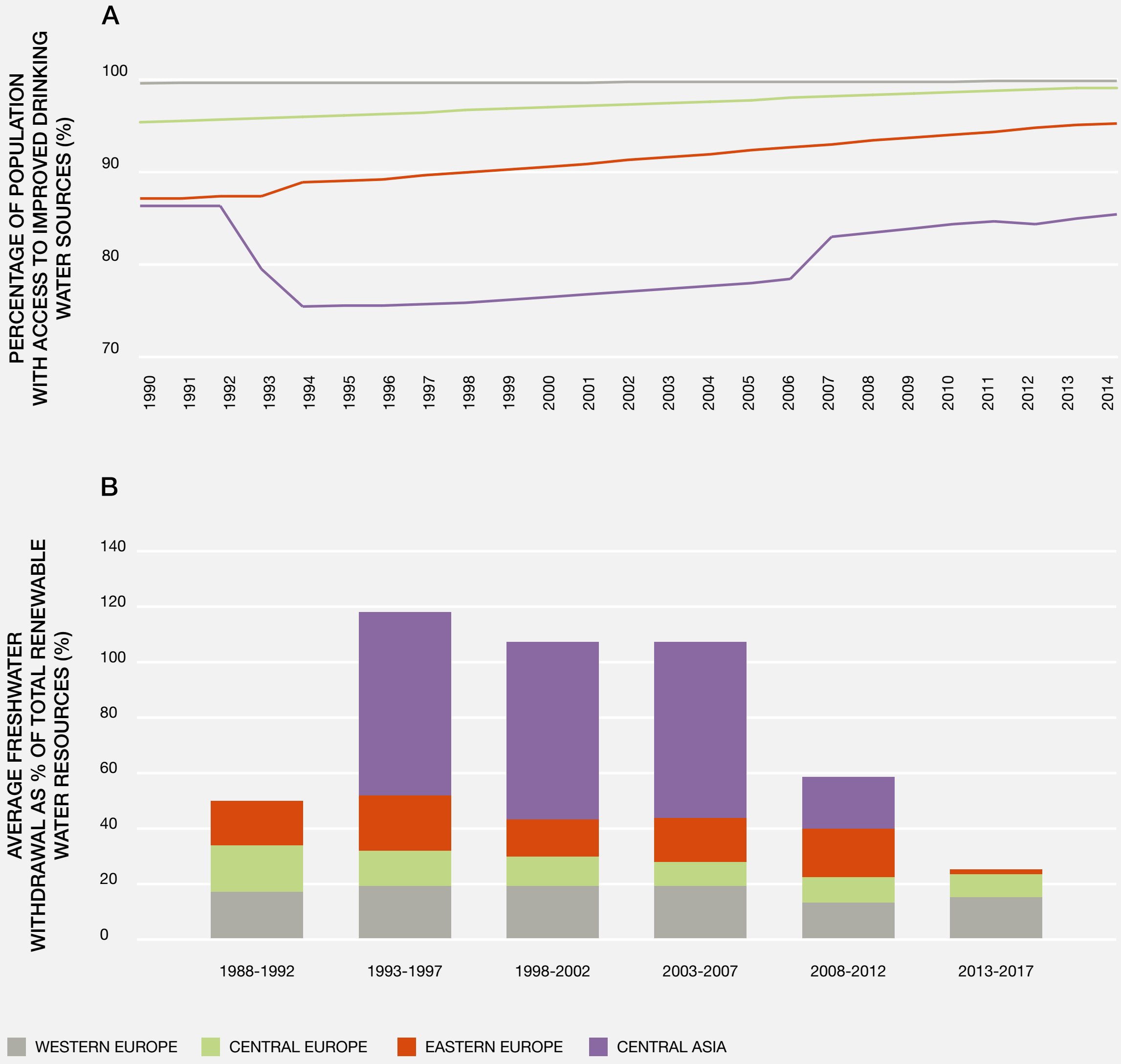
Figure 2 61 **Net imports of biofuels and waste by country (2014) (uncorrected for intra-regional trade). Source: Own representation based on IEA/OECD (2016).**



Eastern Europe shows mixed but generally increasing trends since the late 1980s, while per capita freshwater availability has increased by 10% since the 1990s. Several Danube river sub-basins in Eastern Europe were highlighted as being at risk of becoming waterscarce (Karabulut *et al.*, 2016).

Central Asia is considered to be facing water scarcity and shows mixed trends since the early 1990s (Animesh *et al.*, 2016; UNEP & UNECE, 2016). Access to safe drinking water has increased since 1994-2007, while recent trends for freshwater extraction as a percentage of available water are mixed and even decreasing (Alexander & West, 2011). This coincides with a mixed, but recent decrease in per capita freshwater availability since the 1990s (see Section 2.2.1.5). Ensuring water security in Central Asia depends on the distribution of, and access to, water resources,

Figure 2 62 Temporal trends in water security in Europe and Central Asia according to: A access to safe drinking water. Source: Own representation based on World Bank (2016); and B freshwater withdrawal as percentage of total renewable water resources. Source: Own representation based on FAO (2016). Note that information for 2013-2017 is incomplete.



especially between different countries (Abdolvand *et al.*, 2014; Conrad *et al.*, 2016; FLERMONECA, 2015).

2.3.1.4 Food-energy-water security nexus

Water, food and energy systems are characterized by complex interrelations. Energy is required to process and distribute water; water is central to nearly all forms of energy production; and both energy and water are key to any food enterprise (Harvey & Pilgrim, 2011; Hussey & Pittock, 2012; Karabulut *et al.*, 2016). Pursuing one particular security objective (either food or water or energy security) is sometimes achieved to the detriment of another, reflecting competing claims over limited natural resources and nature's contributions to people.

Agriculture intensification in Europe and Central Asia since the early 1950s has contributed significantly to an increase in the provision of food and feed (see Section 2.2.2.1) and to enhancing food security (see Section 2.3.1.1). However, it has had severe adverse effects on water security in many parts of the region (see the example of the Aral Sea in **Box 2.3**). Intensive agriculture has been one of the main causes of the pollution (eutrophication and contamination) and

Box 2 3 **The Aral Sea disaster.**

The Aral Sea provides clear evidence of how the pursuit of one security objective can be to the detriment of others. During the Soviet era, pressure on the water resource in the Aral Sea region was mainly due to the massive development of irrigation for rice and cotton production. After the dissolution of the Soviet Union, cotton production was reduced but remained key for generating currency revenues. Besides, irrigated winter wheat production grew rapidly to gain grain self-sufficiency (Jalilov *et al.*, 2016). In Central Asia as a whole, the areas under irrigation increased from 4.51 million ha in 1960 to 6.92 million ha in 1980, and to 7.85 million ha in 2000 (Rakhmatullaev *et al.*, 2010). Irrigation systems in the region are highly inefficient with almost half of the water diverted for irrigation lost before reaching the field. Over 50% of the irrigated soils of the region are salinized and waterlogged, due to long-term surface irrigation practices (Qi *et al.*, 2012). Changes in the hydrological cycle caused by the massive irrigation led to a significant decrease of river runoff, changes in the area of lakes, and rise of groundwater levels. Hydrological changes, including desiccation of the Aral Sea, basin-wide land-use and land-cover changes, as well as the degradation of the Aral Sea have strongly contributed to climate change in the region (Lioubimtseva, 2015; Micklin, 2007). Dust storms, with dust contaminated by fertilizers, pesticides, heavy metals, and other chemicals; water and wind erosion; widespread land degradation; water pollution; and frequent droughts have negatively impacted populations' health (Jensena *et al.*, 1997; Wiggs *et al.*, 2003), agricultural productivity and economic development in the area (Cai *et al.*, 2003; Lioubimtseva, 2015). In Central Asia as a whole, access to improved drinking water declined from 57% in 1990 to 50% in 2013 (Abdullaev & Rakhmatullaev, 2016). Cai and co-authors (2003) estimate that thirty-five million people have lost access to the lake's water, fish, reed beds, and transport functions.

overexploitation of freshwater bodies and the decrease in the extent of floodplains and wetlands (UNEP & UNECE, 2016). These trends have impaired water quality and quantity regulation (see Sections 2.2.1.6 and 2.2.1.7). In addition, many of nature's other regulating contributions to people, especially pollination, erosion, soil formation and functioning, regulation of flood control; and non-material contributions, such as traditional farming knowledge, have been negatively impacted by agriculture intensification. Another major trade-off associated with agricultural intensification concerns climate. Intensive agriculture is characterized by a loss of carbon in agricultural soil, which impairs its climate regulation capacity and other contributions from nature to people associated with soil (see Section 2.2.1.4 and Section 2.2.1.8). It also entails increasing emissions of fossil carbon used for mechanization and fertilizer production, and of greenhouse gases from cattle and nitrogenous fertilizers (see Section 2.2.1.3 and Section 2.2.1.4). However, over the last 25 years, agricultural intensification has triggered the abandonment, reforestation and afforestation of former agricultural land, especially in Western Europe (see Chapter 4). An increase in forest areas was the main cause of a net increase in greenhouse gas storage in ecosystems in Western, Eastern and Central Europe between 1990 and 2012 (see Section 2.2.1.4).

Biofuels also pose major potential trade-offs between security objectives. Over the past 15 years, the European Union policy for renewable energy and its biofuels blending target for transportation fuel (set at 10% by 2020 in the European Union Renewable Energy Directive (2009/28/EC)), have fostered the production and consumption of biofuel in Western and Central Europe (Sections 2.2.2.2.2 and 2.3.1.2). Biofuel production carries the risk of competing with food production, increasing food prices, intensifying agricultural land and water use, and harming biodiversity and other contributions from nature to people (De Fraiture *et al.*, 2008; Gerbens-Leenes *et al.*, 2012; Rulli *et al.*, 2013; Rulli *et al.*, 2016). Moreover, the potential of biofuels to reduce greenhouse gas emissions may be offset by the contribution of their production to emissions arising from fertilizers, machinery, and especially land conversion. Projected change in cropland area within the EU-28 caused by compliance with the 10% blending target mainly takes the form of less land abandonment (Valin *et al.*, 2015). Nevertheless, the adverse effects of biofuels vary spatially and depend on the choice of biofuel crop (de Vries *et al.*, 2010; Eggers *et al.*, 2009; Valin *et al.*, 2015). Biofuel derived from properly managed feedstocks with much lower life cycle greenhouse gas emissions than fossil fuels, and which do not compete with food production (mainly biofuel produced from ligno-cellulosic materials), do not entail negative impacts on land and water use, biodiversity, or greenhouse gas emissions (Havlík *et al.*, 2011; Tilman *et al.*, 2009). However, biofuel production in north-western Europe is currently mainly produced from wheat and maize (for bioethanol), and sugar beet and rapeseed (for biodiesel), which perform rather poorly for nearly all environmental indicators, as well as for greenhouse gas emissions (de Vries *et al.*, 2010). Moreover, the European Union 2020 biofuel mandate impacts ecosystems, water and food security globally through European Union imports. In the scenarios developed by Valin *et al.* (2015), most of the land use change resulting from the European Union 10% blending target occurs outside the EU-28, especially through conversion to oil palm in Southeast Asia.

2.3.2 Contributions to physical, mental and social dimensions of health

The recent state of knowledge review coordinated by the World Health Organization and the Convention on Biological Diversity (WHO & CBD, 2015) provides a detailed global assessment of the interlinkages between biodiversity and human health. The review explores the evidence base across three broad areas of human health outcomes – non-communicable diseases, communicable (i.e. infectious) diseases, and injury – and considers the value of biodiversity to medical science (WHO & CBD, 2015). The role of biodiversity and ecosystem services in supporting human health, and the health risks arising as a result of loss of biodiversity and ecosystem degradation are also highlighted by the review.

The linkages between nature and health are of increasing research and policy interest. While research efforts are increasingly interdisciplinary, there is still a need for greater integration of different fields of expertise and recognition of the importance of accounting for different forms of knowledge, as with other aspects of biodiversity policy (Pullin *et al.*, 2016). With this perspective in mind, in addition to following the literature review methodology of this chapter we also engaged in a process of IPBES-approved expert elicitation to strengthen the quality of the assessment and literature review. This also supports a key aim of IPBES, which is to build capacity in this rapidly growing field. The expert elicitation was based on the consideration of the World Health Organization and Convention on Biological Diversity literature review and key messages by an expert panel. Further details are provided in the supporting material Appendix 2.8[28].

The importance of biodiversity and ecosystem services to human health is well established in some areas of health research, for example with regards to the contribution of biodiversity to contemporary and traditional medicine (Heinrichs & Jäger, 2015; Payyappallimana & Subramanian, 2015), to food and nutrition security (Hillel & Rosenzweig, 2008; Hodgkin-Hunter, 2015), and through linkages to infectious disease risk (Karesh & Formenty, 2015). Traditional medicinal practice has long been based on preparations derived from wild or domesticated species, and the value of biodiversity is recognized in contemporary medicinal research, with the development of new pharmaceuticals supported by bioprospecting and often based on lessons from traditional knowledge (Newman & Cragg, 2016). The evidence regarding the contribution of biodiversity to food and nutrition security is also well established. Globally, diets rich in biodiversity (cultivated varieties as well as wild sources such as fish, fruit, fungi, invertebrates and bushmeat) help to support good nutrition, with many communities relying heavily on wild biodiversity as a primary source of energy, protein and micronutrients; for Europe and Central Asia data are limited, but some work has highlighted the cultural and economic significance of wild foods (Fuchs *et al.*, 2016; Łuczaj *et al.*, 2012; Schulp *et al.*, 2014b). Schulp *et al.* (2014b) identified 38 species of game, 27 species of mushrooms, and 81 species of vascular plants that are regularly hunted, collected and consumed in the European Union, with over 100 million European Union citizens consuming wild food each year, and argue for greater attention to be given to wild foods in ecosystem service assessments. There is evidence that dietary diversity may help to reduce the risks associated with certain non-communicable diseases, though this is moderated by effects of lifestyle and other socio-economic factors (Hunter-Burlingame-Remans, 2015; Johnston *et al.*, 2014).

Ecosystem change and degradation of natural habitats are identified as risk factors for disease emergence, though the precise contribution of biodiversity, or its loss, to risk of infectious disease outbreaks in wildlife, livestock or humans is generally less certain (Ostfeld & Keesing, 2012; Wood *et al.*, 2017). Biodiversity may reduce disease rise through a phenomenon known as the "dilution effect", whereby, in ecosystems where hosts of an infectious agent vary in their ability to transmit an infection, increased diversity of potential hosts may reduce the risk of disease outbreak. This concept remains controversial, and any such effect is likely to be highly specific to pathogen, location or geographic scale (e.g. Randolph & Dobson, 2012; Wood & Lafferty, 2013). Some evidence for the dilution effect in at least some local contexts has been presented from several studies, mostly from Western Europe (e.g. Bolzoni *et al.*, 2012; Kedem *et al.*, 2014; Khalil, 2016; Ruyts *et al.*, 2016).

Another area where the relationship between biodiversity and ecosystems and health may be highly variable is the impact which exposure to nature can have on mental and physical well-being (Horwitz & Kretsch, 2015; Lee & Maheswaran, 2011; Van Den Berg *et al.*, 2015). The ways in which health is affected by biodiversity and nature's contributions to people is determined by the nature of specific social-ecological systems, including the degree and types of interactions between people or their communities and the natural environment. This highlights the importance of social, economic and cultural factors in determining the strength and direction of linkages between health and biodiversity (Clark *et al.*, 2014; WHO, 2017; European Commission, 2016b).

Increased urbanization in Europe and Central Asia poses significant challenges for human health including a rise in non-communicable diseases associated with modern lifestyles, including obesity and diabetes, cardiovascular diseases, depression and anxiety disorders, and diseases

28. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.8_assessment_of_health.pdf

associated with pollution (Benziger *et al.*, 2016). Efforts to increase access of urban dwellers to green space and open countryside may help to address some of these health issues. Scientific review literature shows there are many potential pathways between exposure to nature or natural spaces and positive health status. However, these pathways do not necessarily exist for all persons within any given community, even where different social groups (differentiated by, for example, age, gender, ethnicity, income level, or education) have access to, or utilize, common areas of natural space (Hartig *et al.*, 2014; Jackson *et al.*, 2013; Myers & Patz, 2009). Again, several social, cultural and economic factors are likely to be at play, and more research is needed in this regard (Clark *et al.*, 2014).

Differentials in the ways in which some communities or groups within wider society (e.g., indigenous groups, refugees, women, the elderly or poor) experience and interact with biodiversity and ecosystems may result in differences in the influence of biodiversity and ecosystems on their health status. There is, thus, potential for group-specific or community-specific dependencies and risks (WHO, 2017; Horwitz & Kretsch, 2015; Jay *et al.*, 2012). Individual groups within a community (defined by, for example, gender, age, ethnicity, infirmity, engagement in cultural practices) may experience greater or lesser health benefits from biodiversity and ecosystem services, or be at greater or lesser risk of ill health associated with biodiversity loss and ecosystem change, than others, as a result of a range of moderating social, economic and cultural factors. Any relationships which can be drawn between health outcomes and biodiversity or ecosystem services are, therefore, likely to be dependent upon the ways in which groups or individuals understand, acknowledge or experience their relationship with the natural environment (Clark *et al.*, 2014).

There is well established evidence from multiple studies that a healthy immune system is supported by exposure to biodiversity (Rook & Knight, 2015). Exposure to environmental microbiota has been associated with reduced risks of allergy, chronic inflammation and certain other autoimmune diseases. A growing body of evidence suggests that interactions between wild microbes and the human microbiome – the diverse community of microbes present in the intestinal, respiratory and urogenital tracts, and on our skin – may be key to healthy immune function. Conversely, loss of diversity in human microbiota, which may be associated with decreased exposure to wild microbes, has been linked to increased risk of a range of non-communicable diseases, including inflammatory diseases, diabetes and allergies (Hanski *et al.*, 2012; Ruokolainen *et al.*, 2017).

With so many significant linkages identified between health and biodiversity, and with increased knowledge of the health risks posed by ecosystem change and biodiversity loss, numerous opportunities exist for development of integrated policies and practical strategies to realize benefits for both biodiversity and human health and well-being. Biodiversity conservation provides opportunities to secure and enhance those ecosystems and ecosystem services that are of particular relevance to human health outcomes (Romagosa *et al.*, 2015; ten Brink *et al.*, 2016). A review of national reports to the Convention on Biological Diversity (see supporting material Appendix 2.8[29]) examined the extent to which countries in Europe and Central Asia consider nature–human health linkages. Almost all countries involved in the analysis (covering 93% of those in the region) explicitly recognized the importance of nature–human health linkages. Only 8% mentioned these linkages in general terms, while the majority considered key details such as the diversity of linkages, local specificities, challenges, opportunities and actions. Some countries also mentioned local practice examples regarding application of health-relevant insights. Most (63%) mentioned both human health benefits and risks of nature-human linkages, while 6% mentioned only risks and 27.5% only benefits.

2.3.3 Cultural heritage, identity and stewardship

2.3.3.1 Value through use

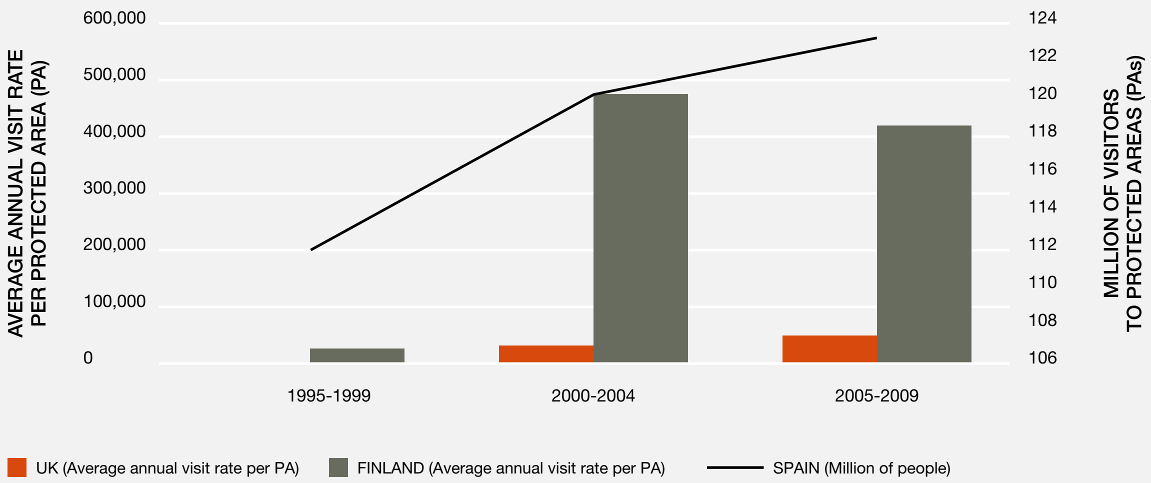
For different social groups in Europe and Central Asia, nature contributes to cultural heritage, identity and stewardship through providing opportunities for good quality of life beyond mere survival. It offers opportunities for leisure and tourism, maintaining indigenous and local knowledge, and being exposed to learning, inspiration and spiritual experiences. Evidence suggests that these contributions from nature to people show increasing trends (see Section 2.2.3).

Nature is in high demand for nature-based recreation activities by people in many parts of the region (see Section 2.2.3.2.1) (Hausner *et al.*, 2014; Martín-Lopez *et al.*, 2012; Rall *et al.*, 2017) and preferences for holidays of people in the European Union in the last decade, show an increasing interest in nature-based tourism (European Commission, 2016a). In addition, the number of visitors to protected areas increased between 1995 and 2009 in some Western European countries, such as Spain, Finland and the UK **(Figure 2.63)**.

Recreation and leisure are recognized by urban people as the most important benefits derived from urban green spaces. Other motivations to visit urban greenspaces

29. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.8_assessment_of_health.pdf

Figure 2 63 **Number of visitors to protected areas in the United Kingdom and Finland (measured as average annual visit rate per protected area) and Spain (measured as millions of visitors). Source: Own representation based on Balmford *et al.* (2015); Santos-Martín *et al.* (2013).**



include health, psychological well-being and emotional attachment to the site (Bolund & Hunhammar, 1999; Casado-Arzuaga *et al.*, 2013; Haase *et al.*, 2012). Green spaces and ecosystems are also used for formal learning by schools and universities in many countries in Europe and Central Asia, where outdoor learning provides additional value for learners and teachers in terms of knowledge and skill acquisition (Mocior & Kruse, 2016).

Indigenous and local knowledge has significant value for some local communities in Europe and Central Asia. A review of studies in Arctic regions argues that this knowledge plays an important role in land rights claims (Davis & Wagner, 2003). An in-depth study of resource-users and local organizations involved in a local fishery in Sweden shows how indigenous and local knowledge can contribute to fish management and conservation (Olsson & Folke, 2001). Co-production of knowledge by traditional herders and national park rangers for adaptive nature conservation management of wood-pastures and salt steppes can also lead to new occupations, like the so-called "conservation herders" (Molnár *et al.* 2016). Furthermore, the conservation of indigenous and local knowledge and related landscapes can support the economic development of rural areas by fostering tourism and consumption of local products, and contributing to the quality of life of people (Fernández-Giménez & Fillat Estaque, 2012; Parrotta & Agnoletti, 2007).

However, in many areas of Europe and Central Asia the value of local ecological knowledge has been eroded with a decline in indigenous and local knowledge. Studies comparing the UK to developing countries have argued that indigenous and local knowledge declines as nations become wealthier and ecological knowledge becomes less valued (Pilgrim *et al.*, 2008). Changes in culture are partly responsible for the devaluation of indigenous and local knowledge among younger generations, which consider these traditional practices and knowledge as symbols of poverty or backwardness.

The use of some of nature's material contributions to people is also strongly connected to values arising from non-material contributions, which contribute to cultural practices that enhance identity (see Sections 2.2.3.2 and 2.2.3.3). For example, in many Central and Western European countries, mushroom collecting is a part of culture and tradition (Hansen & Malmaeus, 2016; Martínez de Aragón *et al.*, 2011; Stoyneva-Gärtner, 2015). Recreational berry picking is also often a family and cultural tradition, which has been kept alive during recent decades (Schulp *et al.*, 2014b), mostly in Scandinavian countries (Kangas & Markkanen, 2001). It has been estimated that 56-58% of households in Scandinavian countries collect berries for domestic purposes (Jonsson *et al.*, 2002).

Belief systems are a fundamental aspect of people's culture that strongly influence their engagement with nature (Groot *et al.*, 2005). Religious or spiritual interactions with nature have been shaped over decades or centuries, and influence human endeavour directly or indirectly (IPBES, 2015). Many traditional knowledge systems in Europe and Central Asia depict ecosystems as fully alive, incorporating spirits of animals and other natural objects and spirits of human ancestors (Berkes *et al.*, 1998). Pre-monotheistic belief systems integrated elements of nature to give meaning to the world and humans' place in it (Verschuuren, 2006).

Similarly, myths and related rites have existed in Europe and Central Asia since the dawn of humanity (see **Box 2.4**). For a number of local and indigenous communities in Europe and Central Asia, especially those that have pagan, animistic or shamanistic roots, land is alive and full of various kinds of energies or life forces and nature's organizing principles are depicted as entities, spirits or natural law (UNEP, 1999).

2.3.3.2 Value through protection and beyond use

Different social groups indicate the value of their relationship with nature by expressing their desire to conserve and protect areas and iconic species that they do not use directly. People can express this form of value through willingness-to-pay and indications of other preferences for the protection of species irrespective of actual aesthetic or recreational use (see Section 2.2.3.4).

Protected areas are increasingly valued for their use and recreation potential. European Union people increasingly acknowledge their importance for eco-tourism and nature-related recreational experiences and 43% of European Union citizens identified this role of protected areas as very important (European Commission, 2015a). In addition, visitors to protected areas and UNESCO World Cultural Heritage Sites around Western and Central Europe have

Box 2 4 **The Cult of Hızır as an Expression of Revering Nature's cycles.**

Seasonal changes are important components of folk calendars throughout the world. In the Turkic world (including Yakuts, Mongols, Kalmyks, Buryats and Tungusic people in Central Asia), Hıdrellez (known as Ruz-ı Hızır or day of Hızır) is one of the most important seasonal celebrations and represents the revival of the warm and productive summer days (Uca, 2007). Based on folk calendar traditions, the year is divided into two, the summer known as "Days of Hızır" and the winter, known as "Days of Kasım". Hıdrellez Day falls on May 6 and is the day on which Prophets Hızır and Ilyas met on the seashore between dry land and water (Artun, 1990).

The awakening of nature is actively celebrated throughout the Turkic world on Hıdrellez day with rites that are dependent on water (Walker & Uysal, 1973). These ceremonies generally take place in nature, near sources of water, or near tombs and shrines. In rituals before sunrise on that day, Turks construct, in their gardens, models of the things they wish for most such as good health, or write their wishes on pieces of paper which are then either released into rivers and other water bodies or hung on trees (Walker & Uysal, 1973).

Tahtacı Turkmen villagers in the northern Aegean Kaz Mountains line up to wash their face in the early morning of Hıdrellez to receive health and bounty from the river waters.
Photo: Solmaz Karabaşa

expressed substantial willingness to pay to enjoy the recreational services provided (Martín-Lopez *et al.*, 2009), including in Turkey (Gürlük & Rehber, 2008) and Albania (Seidl, 2014).

A further value of tangible and intangible protected heritage associated with nature is that it helps to maintain cultural meanings and a sense of identity (Klinar & Geršič, 2014; Tengberg *et al.*, 2012). This can be based on the tangible material outcomes of cultural activities on landscapes (e.g., wood pastures, viticulture terraces) as well as individual species that are linked to intangible heritage such as through myths, legends, and religious practices (Daniel *et al.*, 2012).

Figure 2 64 **Distribution of the different types of protected areas among Europe and Central Asia subregions. Source: Own representation.**

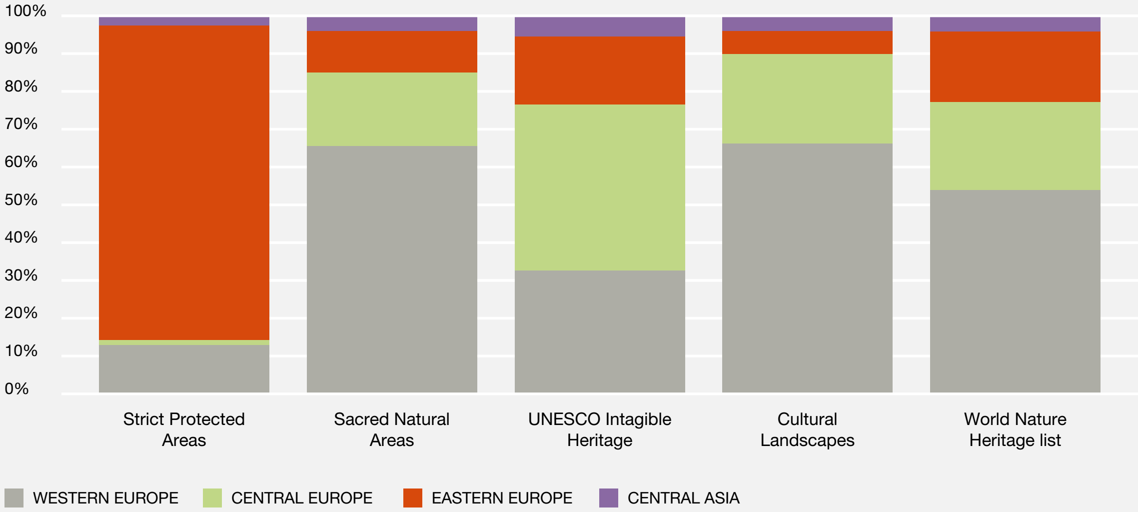
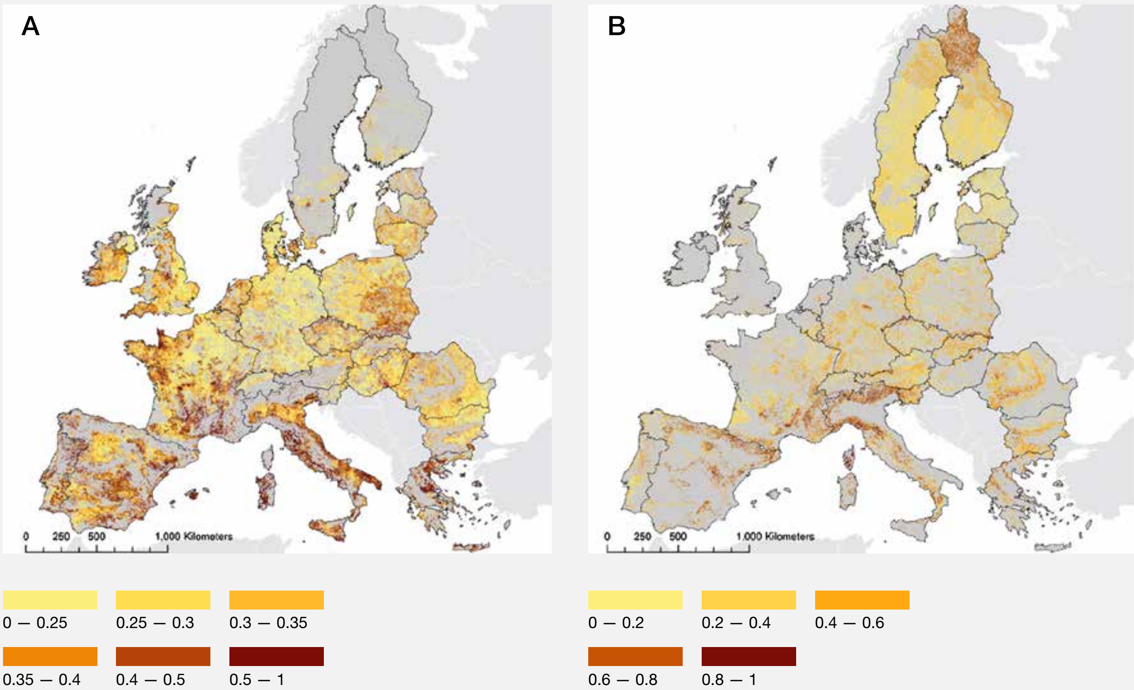


Figure 2 65 **Cultural Landscape Index (CLI) of Western and Central European A agricultural land and B forest that characterizes rural landscapes according to landscape structure, management intensity, and value and meaning. Source: Tieskens *et al.* (2017).**



The value placed on the protection of tangible heritage linked to nature is shown in UNESCO's World Heritage List in 2015, comprising 1,031 properties of which 22% were natural sites (Osipova *et al.*, 2014). Currently, 23.5% of these protected natural sites are located in Europe and Central Asia, with an unequal distribution among subregions (see **Figure 2.64**). Tangible heritage linked to cultural landscapes in Western, Central and Eastern Europe is also recognized in UNESCO's "list of cultural landscapes" (Besio, 2003). 51% of the landscapes in the UNESCO list (i.e. 49 landscapes) are situated in Europe and Central Asia, but again with uneven distribution among subregions (see **Figure 2.65**).

Yet, tangible heritage linked to European cultural landscapes is increasingly threatened by land-use intensification and abandonment (Tieskens *et al.*, 2017) that derive from cultural, political and economic drivers of change (see Chapter 4) (Plieninger *et al.*, 2016). The decreasing trends of the cultural and local identity associated with these landscapes, as well as the emotional attachment of Western and Central European people to these landscapes, is also acknowledged by indigenous and local knowledge holders (supporting material Appendix 2.2[30]).

The *Convention for the Safeguarding of the Intangible Cultural Heritage* is the international agreement that aims to acknowledge and protect intangible heritage. Out of 130 elements of intangible heritage from countries in Europe and Central Asia currently inscribed on the List of Intangible Cultural Heritage (UNESCO, 2003), 53 are directly linked to nature. They are linked to both the direct use of animals (e.g. falconry, and horse-riding games) and plants, or draw on the natural environment as a source of inspiration for songs, poetry and handicrafts.

Despite the value and protection of intangible and tangible heritage linked to nature, it continues to be threatened. In Western, Central and Eastern Europe, 30% of natural World Heritage sites are of significant concern (Osipova *et al.*, 2014) and five protected sacred natural sites in Europe and Central Asia are threatened (one in Central Europe, one in Eastern Europe, two in Western Europe and one in Central Asia).

2.3.4 Environmental equity and justice

2.3.4.1 Framing equity and justice

Aspects of equity and justice associated with nature's contributions to people relate to questions of who benefits from them (Daw *et al*., 2011; McDermott *et al.*, 2013), who bears the costs of a change in the provision of these contributions due to trade-offs (Bennett *et al.*, 2009; Howe *et al.*, 2014), who decides how societies influence the provision of the contributions (Berbés-Blázquez *et al.*, 2016), who is recognized in these decisions (Martin *et al.*, 2016; Zafra-Calvo *et al.*, 2017) and whose needs are fulfilled by nature's contributions to people (Chan *et al.*, 2012; Jax *et al.*, 2013). Equity is associated with fairness and justice (Konow, 2003; McDermott *et al.*, 2013; Pascual *et al.*, 2010). *Fairness* is often defined as the shared, dynamically constructed view of a given social group of distributive justice (Pascual *et al.*, 2010; Schokkaert & Devooght, 2003). The term *justice* refers here to fundamental moral rights and obligations. The term *equity* is used to evaluate comparatively the relationships between particular groups in society.

Distributive equity and justice focuses on the fair allocation, among individuals within a social group or among stakeholders, of costs (see **Box 2.5**) and benefits resulting from any management decision or action (McDermott *et al.*, 2013). *Procedural equity and justice*, in the context of the present assessment, relates to the procedural aspects of decisions on ecosystem management. It is assessed in terms of the degree of recognition, representation, involvement and inclusiveness in decision-making of different societal groups, determined e.g. by cultural identities, level of education and gender (Berbés-Blázquez *et al.*, 2016; McDermott *et al.*, 2013; Pascual *et al.*, 2010; Pascual *et al.*, 2014). Distributive justice and equity regarding the benefits derived from nature's contributions to people and harms from a loss of these contributions have a spatial component, as changes in ecosystems providing them will have uneven geographical impacts linked to where beneficiaries live (Liu *et al.*, 2016), see Section 2.1.2. There is also a temporal component (Jax *et al.*, 2013) as ecosystem service utilization today may destroy the basis for future service provision (Section 2.2.3.4).

2.3.4.2 Intra-generational distributive equity and justice

Nature's material contributions to people are often commodities traded in (global) markets. On the one hand, distributional equity and justice reflects the distribution of access to markets (UNEP, 2004). On the other hand, distributive equity and justice are influenced by global patterns in the distribution of benefits and costs from the production and consumption of nature's material contributions (such as biofuels, soy for animal feed, timber, pharmaceutical products from wild and domesticated biodiversity) (Section 2.2.4).

Whereas access to safe and adequate drinking water is generally well secured in Europe, people in Central Asia, especially children, bear disproportionate environmental

30. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

Box 2 5 **Human-wildlife conflicts (additional references can be found in supporting material Appendix 2.3*).**

Certain species cause human-wildlife conflicts and raise justice concerns in terms of the distribution of their damages (Jacobsen & Linnell, 2016). Human-wildlife conflicts in Europe and Central Asia are reported related to carnivores, mainly wolves (*Canis lupus*), brown bears (*Ursus arctos*) and European lynxes (*Lynx lynx*) (e.g. Imbert *et al.*, 2016; Knarrum *et al.*, 2006; Mattisson *et al.*, 2015; Rigg *et al.*, 2011), although conflicts with meso-carnivores (e.g. European badgers (*Meles meles*) and red foxes (*Vulpes vulpes*)) are also reported in Western Europe (Baker *et al.*, 2008; Delibes-Mateos *et al.*, 2013). The most frequent conflicts in Eastern, Central and Western Europe (no available data for Central Asia) are those related with damage to livestock and domestic animals (Kovařík *et al.*, 2014), damage to game species (Lozano *et al.*, 2013) and attacks on humans (Sahlén *et al.*, 2015). Other mammal species, such as moose (*Alces alces*) and wild boars (*Sus scrofa*), cause damage to agriculture and forest plantations (Horne & Petäjistö, 2003; Schley *et al.*, 2008). Many alien insect and mite species cause nuisances as pests of agriculture, horticulture, stored products and forestry (Kenis & Branco, 2010; Roques *et al.*, 2009).

* Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.3_extra-references.pdf

threats to their health due to a lack of access to safe drinking water – with the Aral Sea region and rural areas in Tajikistan being specific problem areas (see Section 2.3.1.3) (Carpenter *et al.*, 2006).

Urban green space can provide different regulating contributions such as prevention of urban heat islands, air quality regulation and noise reduction (Konijnendijk *et al.*, 2013). Its distribution has been shown to differ across a city resulting in lower access in residential areas with specific ethnic groups (Comber *et al.*, 2008) or a high proportion of immigrants (Kabisch & Haase, 2014).

Regarding flood regulation and flood protection measures (Section 2.2.1.6), a socio-economic investigation within the flood plains of England and Wales revealed significant inequalities in the distribution of flooding risk between the middle classes and less privileged groups (working classes, unemployed classes) – with inequality being especially influential in exposure to flooding risk within the tidal flood plains and in the Eastern regions of England (Benzie, 2014; Fielding, 2007, 2012; Walker & Burningham, 2011).

Nature's non-material contributions to people, in particular recreation, can be distributed unevenly across social groups. In the UK protected areas are largely enjoyed by older people and men, while minorities are underrepresented in the use of protected areas, and hence the more privileged people benefit (Booth *et al.*, 2010). Access to green space in cities provides opportunities for recreational experiences, but urban green space is distributed unequally within cities, leading to potential injustice (Comber *et al.*, 2008; Kabisch & Haase, 2014). Access to green space in cities differs across Europe, with more green space available to residents in cities in northern, western and central parts of the European Union than in cities in the south (Kabisch *et al.*, 2016). Access to green recreational areas reduced inequality in mental well-being in the Europe Union (Mitchell *et al.*, 2015). In Europe and Central Asia national reports to the Convention on Biological Diversity, several countries mention how health equality is influenced by human interactions with nature's contributions and biodiversity (see supporting material Appendix 2.8[31]).

In several countries in Europe and Central Asia, people have public access to forests that provide recreational experiences, but the uneven distribution of access raises justice issues. A high level (98-100%) of forests and wooded land were reported in 2010 as available for recreational purposes in Nordic and some Baltic countries as well as in several Central Europe countries including Bosnia and Herzegovina, Slovenia and Serbia. Lower levels of availability are found in some Western European countries such as UK (46%) and France (25%) (Forest Europe, 2015). The free use of some non-timber forest products is mostly allowed in Nordic countries as well as some other countries with high forest cover, and allowed to some extent in other countries. In some cases permission or payment is required (e.g. private forests in Croatia, France, UK, Turkey) (Bauer *et al.*, 2004).

2.3.4.3 Intergenerational distributive equity and justice

Intergenerational equity and justice require the maintenance of resilient and productive ecosystems for the future provision of nature's contributions to people (Davidson, 2012; Glotzbach & Baumgärtner, 2012; Jax *et al.*, 2013). This capacity of ecosystems, "maintenance of options", is considered an overarching contribution category. Regarding intergenerational equity there are philosophical and practical arguments for an absolute sufficientarian threshold (Page, 2007), which defines a minimum level of ecosystem services that every future person is presumed to need for good

31. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.8_assessment_of_health.pdf

quality of life. Regarding intergenerational equity in the distribution of beneficial contributions from nature to people, the sufficientarian threshold can be translated into a criterion for society to keep a constant stock of intact ecosystems (Ekins *et al.*, 2003) and a dynamic criterion of ecosystem resilience. The first criterion has been operationalized by general principles of sustainability (Daly, 1992) and specified principles, such as sufficiency, efficiency and persistence for the context of nature's contributions to people (Schröter *et al.*, 2017). The ecosystem resilience criterion captures the reliability of future provision of (life-sustaining) contributions. It has been operationalized into policy-relevant principles for enhancing the resilience of desired contributions, such as maintaining biodiversity and redundancy (Biggs *et al.*, 2012) and into the concept of safe operating space in the global context (Rockström *et al.*, 2009; Steffen *et al.*, 2015). An example of putting intergenerational equity into policy practice is the Swedish *generational goal* which was adopted by the Swedish Parliament in 2010 (Government of Sweden, 2014). The goal is to pass on to the next generation a society in which the major environmental problems have been solved, ensuring that ecosystems recover, biodiversity and the natural and cultural environment are preserved, promoted and used sustainably.

2.3.4.4 Procedural equity and justice

Distributive justice regarding nature's contributions to people and biodiversity is linked to historical injustices, i.e. historically determined unequitable distribution of property rights on which access rights to nature's contributions are frequently based (Berbés-Blázquez *et al.*, 2016). Historically, certain societal groups have been absent from decision-making arenas. Indigenous and local knowledge holders, such as farmers, indigenous communities, elders and women, are frequently among those whose participation is not sought or whose perceptions of nature-society relationships might differ from those who formulate and implement policy. This "procedural inequity" can result in trade-offs between nature's contributions to people that contribute to the well-being of some at the expense of others' (e.g. Daw *et al.*, 2015). The fact that certain social agents such as indigenous and local knowledge holders are not represented in decision-making can entail distributional inequity in the access and use of nature's contributions to people (Felipe-Lucia *et al.*, 2015) and can result in social conflicts (Kovács *et al.*, 2015).

The Aarhus convention on access to environmental information promotes public participation in decision-making and access to justice in environmental matters, which can be supportive to procedural empowerment granted to NGOs (De Santo, 2011). There are, however, large differences in terms of access to information and participation in decision-making, both nationally and regionally, with Western Europe being the most advanced (Mauerhofer, 2016). A UK case study shows the importance of early stakeholder participation: planning proposals not involving stakeholders at an early stage came to a halt and had to be changed due to stakeholder objections (Lange & Hehl-Lange, 2011).

Procedural justice is also influenced by levels of empowerment defined as "enhancing an individual's or group's capacity to make effective choices, effective in the sense of enabling them to transform those choices into desired actions and outcomes" (Alsop & Heinsohn, 2005). Key elements of empowerment are personal agency (the capacity to make meaningful choices) and opportunity structure (the formal and informal institutional contexts within which actors operate). Ecosystem management approaches have been shown to contribute to the empowerment of marginalized groups through increased knowledge and gaining a political voice (Charron, 2012). Deer management in Scotland through collaborative governance has the potential to help reconcile statutory obligations with stakeholder empowerment (Davies & White, 2012). In Poland the institutional context of urban greening has led to social empowerment failures: society perceives other issues as more pressing, trees are perceived as a problem, and there is a lack of knowledge on the possibilities of preventing tree damage (Kronenberg, 2015).

2.3.5 Valuing nature's contributions to people

The importance of nature's contributions to people can be measured from different value framings, including economic and socio-cultural value domains (Martín-López *et al.*, 2014; Pascual *et al.*, 2017). A range of valuation tools can be used to elicit the different aspects of the value of nature's contributions to people (Jacobs *et al.*, 2017). Economic approaches are capable of eliciting the monetary value of these contributions through market-based approaches (e.g. market pricing) and non-market approaches (e.g. travel cost method, hedonic pricing or stated preference methods). Other approaches avoid using monetary calculations and instead elicit both instrumental and relational values in socio-cultural metrics (e.g. preference assessment, narratives or time use method) (Jacobs *et al.*, 2017). While economic valuation is often framed in the so-called "total economic value" framework that captures use and non-use values (Pearce & Moran, 1994), social dominated valuation examines the importance, preferences or needs expressed by people towards nature (Chan *et al.*, 2012). IPBES adheres to value pluralism recognizing the multiple and often conflicting valuation languages to show the multiple ways nature contributes to human well-being (Gómez-Baggethun & Martín-López, 2015; IPBES 2016). Below, we provide a synthesis of the plurality of values of nature's contributions

Table 2 7 **Values for agriculture and forestry production.**

Land Use	Measure	Mean $ (2017) / ha	Min $ (2017) / ha	Max $ (2017) / ha
Cereals*	Net profit	233	5	759
Dairy*	Net profit	718	14	6,443
Mixed crop*	Net profit	916	243	2,870
Sheep and Goats*	Net profit	434	79	8,438
Specialist cattle*	Net profit	381	55	1,320
Forestry (wood supply)**	Gross value added	255	14	891

Notes:
* Source: Farm Accountancy Data Network (2017) http://www.farmbusinesssurvey.co.uk/benchmarking/Default.aspx?module=FADN. Original data were converted to $ (2017) using appropriate GDP deflators and the average £ to $ exchange rate (2015)

** Source: Eurostat (2016a). Forests, forestry and logging. http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Economic_indicators_for_forestry_and_logging,_2005_and_2013.png#file. Original data were converted to $ (2017) using appropriate GDP deflators and the average € to $ exchange rate (2013).

to people across Europe and Central Asia by reviewing value evidence published over the last decade. In doing so, we advocate a value assessment framework that extends beyond conventional market-based monetary approaches to also incorporate non-market monetary and non-monetary socio-cultural values.

2.3.5.1 Market-based monetary values

Market-based monetary values are predominantly focused on nature's material contributions to people, for which a value can usually be estimated based on market prices. For example, net profits from agricultural production (across EU-28 countries) range from $233 / ha / yr (cereals) to $916 / ha / yr (mix crop), while the annual gross value added from wood supply in forests was $255 / ha / yr **(Table 2.7)**. Other market-based monetary values include avoided costs, replacement costs, mitigation costs, which may also be used to assess a wider range of nature's contributions to people.

2.3.5.2 Non-market monetary values

Studies reporting the non-market monetary values of nature's contributions to people in Europe and Central Asia (supporting material Appendix 2.9[32]) are predominantly focused on Western Europe, with very little evidence found for Eastern Europe and Central Asia **(Figure 2.66)**. There was some evidence that people in Central Europe have higher (standardized Int $)[33] values for contributions from nature to people than those from Western Europe (supporting material Appendix 2.9[32]).

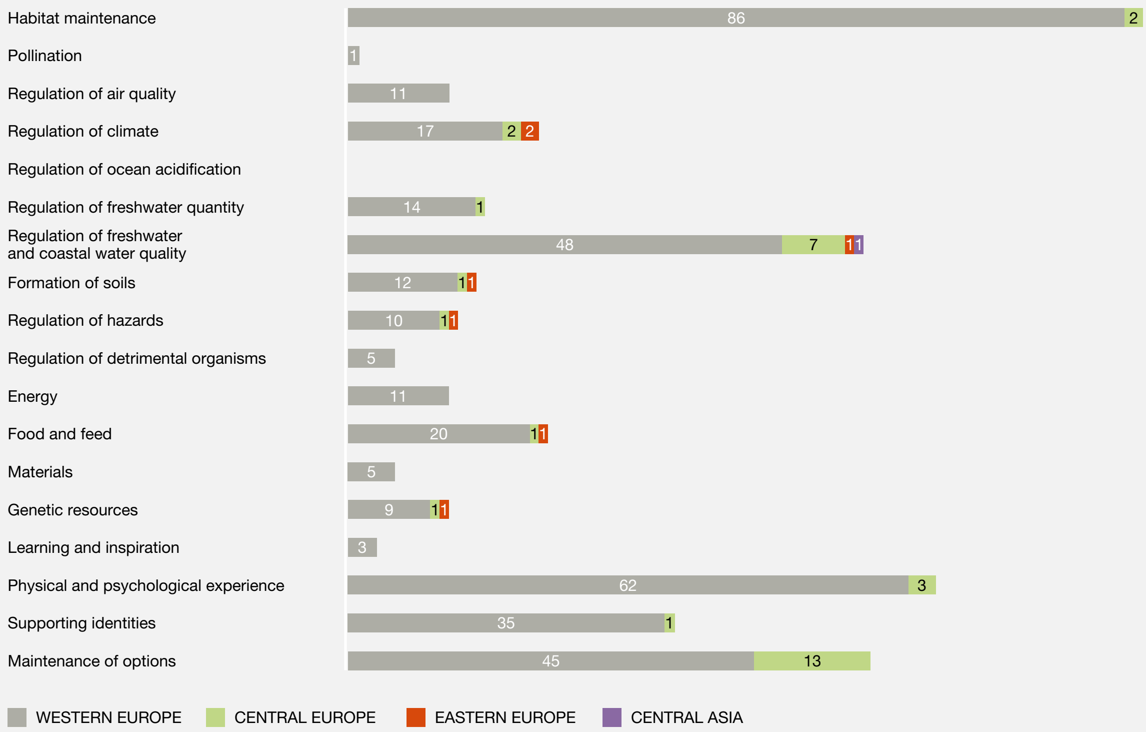
Across all countries in Europe and Central Asia, nature's regulating contributions to people were generally the most highly valued by people for their non-market benefits **(Table 2.8)**. Regulation of organisms detrimental to humans (median value = (2017) Int $149 / person / yr), regulation of air quality (2017 Int $127 / person / yr) and regulation of hazardous and extreme events (2017 Int $112 / person / yr) achieved the highest values. Material and non-material contributions tended to have lower non-market values, with the exception of material and assistance (2017 Int $171 / person / yr).

Analysis also explored non-market values on a per hectare basis **(Table 2.9)**, although fewer data were available for these. Again, the highest values were found for nature's regulating contributions to people. Regulation of freshwater and coastal water quality (2017 Int $1,965 / ha / yr) and habitat creation and maintenance (2017 Int $765 / ha / yr). Non-material contributions, such as physical and psychological experiences were also highly valued (2017 Int $1,117 / ha / yr). Across units of analysis, freshwater systems (2017 Int $867 / ha / yr) and mountains (2017 Int $603 / ha / yr) were most highly valued (supporting material Appendix 2.9[32]).

32. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.9_economic_values.pdf

33. Following the approach adopted by The Economics of Ecosystems and Biodiversity study (TEEB, 2010), we standardized NCP monetary values to a common currency and base year (International $ 2017). The standardization procedure adjusts values elicited in a particular currency and year to a standard currency and year using appropriate GDP deflators and purchasing power parity (PPP) exchange rates.

Figure 2 66 **Number of value data points (i.e. individual value estimates) found for each contribution from nature to people by subregion in Europe and Central Asia. Source: Own representation based on data sources shown in supporting material Appendix 2.9*.**



* Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.9_economic_values.pdf

It should be noted that there was a wide range in the non-market values found for each of nature's contributions to people (**Table 2.8** and **Table 2.9**). The range in values reflects differences in both the scope and size of the contribution evaluated and differences in the methods used to assess the values. Caution is therefore advised with respect to directly transferring the reported values to other policy contexts, particularly where the valuation is based on fewer than five observations.

2.3.5.3 Non-monetary values

Studies reporting social-cultural values of nature's contributions to people in Western Europe and Central Europe (see supporting material Appendix 2.7[34]) show that non-material contributions (including physical and psychological experiences and supporting identities) are considered among the most important contributions by people in Western and Central Europe in non-monetary terms. Food and feed, an important category of material contributions, is also highly valued in social terms. Among regulating contributions, habitat maintenance and regulation of freshwater quantity and quality are also important **(Figure 2.67)**. The highest proportion of research in social valuation of nature's contributions to people in Western and Central Europe was undertaken in mountain grassland areas, followed by urban and semi-urban areas, cultivated areas and Mediterranean and temperate forests.

2.3.5.4 Integrating values into policy

Nature in Europe and Central Asia is important for making a wide range of contributions to people, to which they attach value. These values are expressed in multiple dimensions. Conventionally, nature's material contributions to people have been valued through market prices. Evidence from Europe and Central Asia demonstrates that regulating contributions have significant non-market monetary values, while non-material contributions were demonstrated to be the most valued by people in social-cultural terms.

Assessments of nature's contributions to people (for example to meet the Aichi Biodiversity Targets, Sustainable

34. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.7_assessment_references_synthetic_table.pdf

Table 2 8 **Value per person of nature's contributions to people in Europe and Central Asia (2017 Int $ / person / year).**

		All of Europe and Central Asia	Mean	Median	Minimum	Maximum	N
REGULATING	1	Habitat creation and maintenance	114.17	41.56	1.88	913.58	59
	2	Pollination and dispersal of seeds and other propagules	53.23	53.23	53.23	53.23	1
	3	Regulation of air quality	112.94	127.50	30.37	189.86	9
	4	Regulation of climate	104.74	26.41	0.82	420.11	12
	5	Regulation of ocean acidification	-		-	-	0
	6	Regulation of freshwater quantity, location and timing	151.49	46.13	0.19	528.25	8
	7	Regulation of freshwater and coastal water quality	104.16	65.66	0.15	938.30	51
	8	Formation, protection and decontamination of soils and sediments	11.81	4.03	0.03	48.33	9
	9	Regulation of hazards and extreme events	121.63	112.34	15.07	304.58	8
	10	Regulation of organisms detrimental to humans	144.31	149.91	1.18	281.85	3
MATERIAL	11	Energy	165.02	75.29	0.78	614.08	10
	12	Food and feed	63.26	20.81	0.95	327.35	15
	13	Materials and assistance	280.13	171.41	0.31	777.37	4
	14	Medicinal, biochemical and genetic resources	138.24	33.88	4.45	844.96	11
NON-MATERIAL	15	Learning and inspiration	43.16	43.16	43.16	43.16	1
	16	Physical and psychological experience	111.44	13.57	1.35	1,314.79	51
	17	Supporting identities	127.07	53.09	1.06	1,399.60	32
	18	Maintenance of options	109.66	79.39	4.34	960.13	53

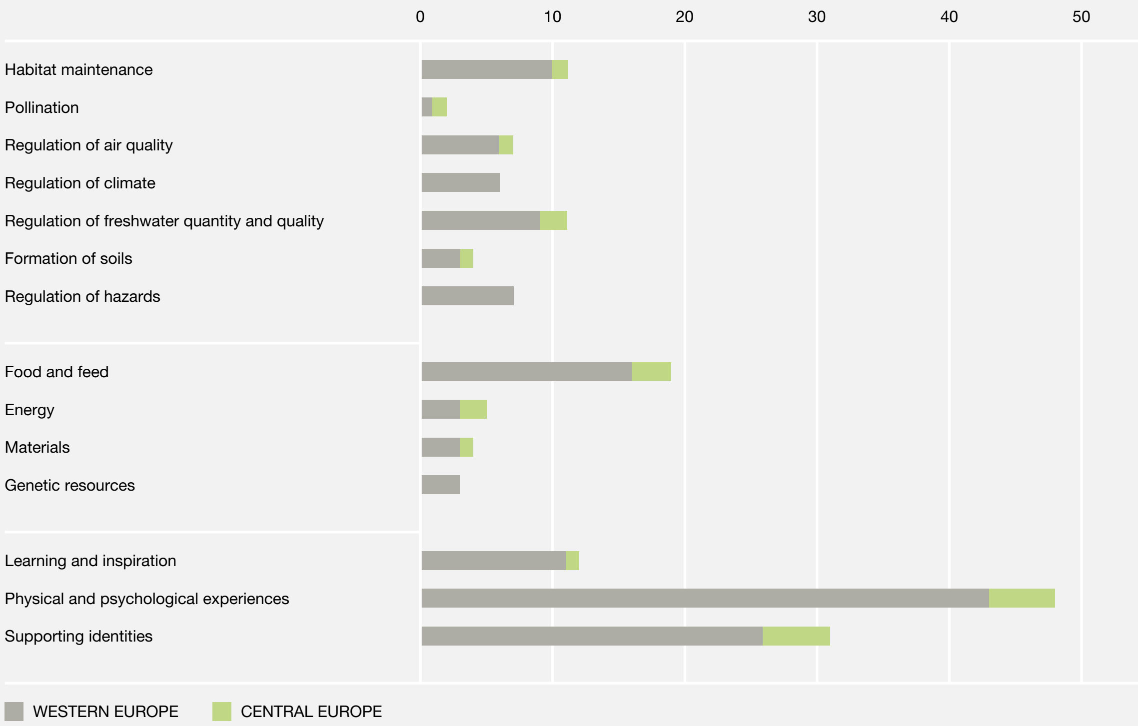
Supporting material Appendix 2.9 (available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.9_economic_values.pdf) provides a list of data sources.

Table 2 9 **Value per hectare of nature's contributions to people in Europe and Central Asia (2017 Int $ / ha / year).**

		All of Europe and Central Asia	Mean	Median	Minimum	Maximum	N
REGULATING	1	Habitat creation and maintenance	1,387.50	765.98	0.23	15,955.53	22
	2	Pollination and dispersal of seeds and other propagules	.	.	.	.	0
	3	Regulation of air quality	289.43	289.43	289.43	289.43	1
	4	Regulation of climate	464.53	464.53	61.67	867.38	2
	5	Regulation of ocean acidification					0
	6	Regulation of freshwater quantity, location and timing	27.13	30.71	10.50	40.18	3
	7	Regulation of freshwater and coastal water quality	3,202.54	1,965.22	1,546.62	6,095.77	3
	8	Formation, protection and decontamination of soils and sediments	32.32	32.32	4.75	59.89	2
	9	Regulation of hazards and extreme events	.	.	.	.	0
	10	Regulation of organisms detrimental to humans	.	.	.	.	0
MATERIAL	11	Energy	.	.	.	.	0
	12	Food and feed	112.84	9.63	1.53	327.35	3
	13	Materials and assistance	0.66	0.66	0.66	0.66	1
	14	Medicinal, biochemical and genetic resources	.	.	.	.	0
NON-MATERIAL	15	Learning and inspiration	7.47	7.47	4.62	10.31	2
	16	Physical and psychological experience	1,473.50	1,117.25	22.33	3,767.95	6
	17	Supporting identities	684	658.77	0.71	1,392.52	3
	18	Maintenance of options	0.80	0.80	0.65	0.95	2

Supporting material Appendix 2.9 (available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.9_economic_values.pdf) provides a list of data sources.

Figure 2 67 **Number of publications that found each contribution from nature to people among the five most valued by people in Western and Central Europe (no data were found for Eastern Europe and Central Asia). Source: Own representation based on data sources shown in supporting material Appendix 2.7*.**



* Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.7_assessment_references_synthetic_table.pdf

Development Goals) should account for this plurality of values. This conclusion goes beyond the recommendations of TEEB (2010), which focused on the inclusion of non-market monetary values and concurs with ideas developed in the UK NEA (2011) and IPBES, which highlight the need to include social, cultural and shared values in decision-making through, for example, deliberation with various stakeholders (Kenter *et al.*, 2015).

We demonstrate that alternative components of values of nature's contributions to people are expressed in different units, and therefore may not be directly compared through, for example, conventional benefit-cost analysis. Thus, researchers and policymakers require novel approaches to integrate value plurality into decision-making (Christie *et al.*, 2012; IPBES, 2016; Kenter *et al.*, 2016; UK NEA, 2011). One such approach is multi-stakeholder spatial decision analysis (Cerreta & Panaro, 2017).

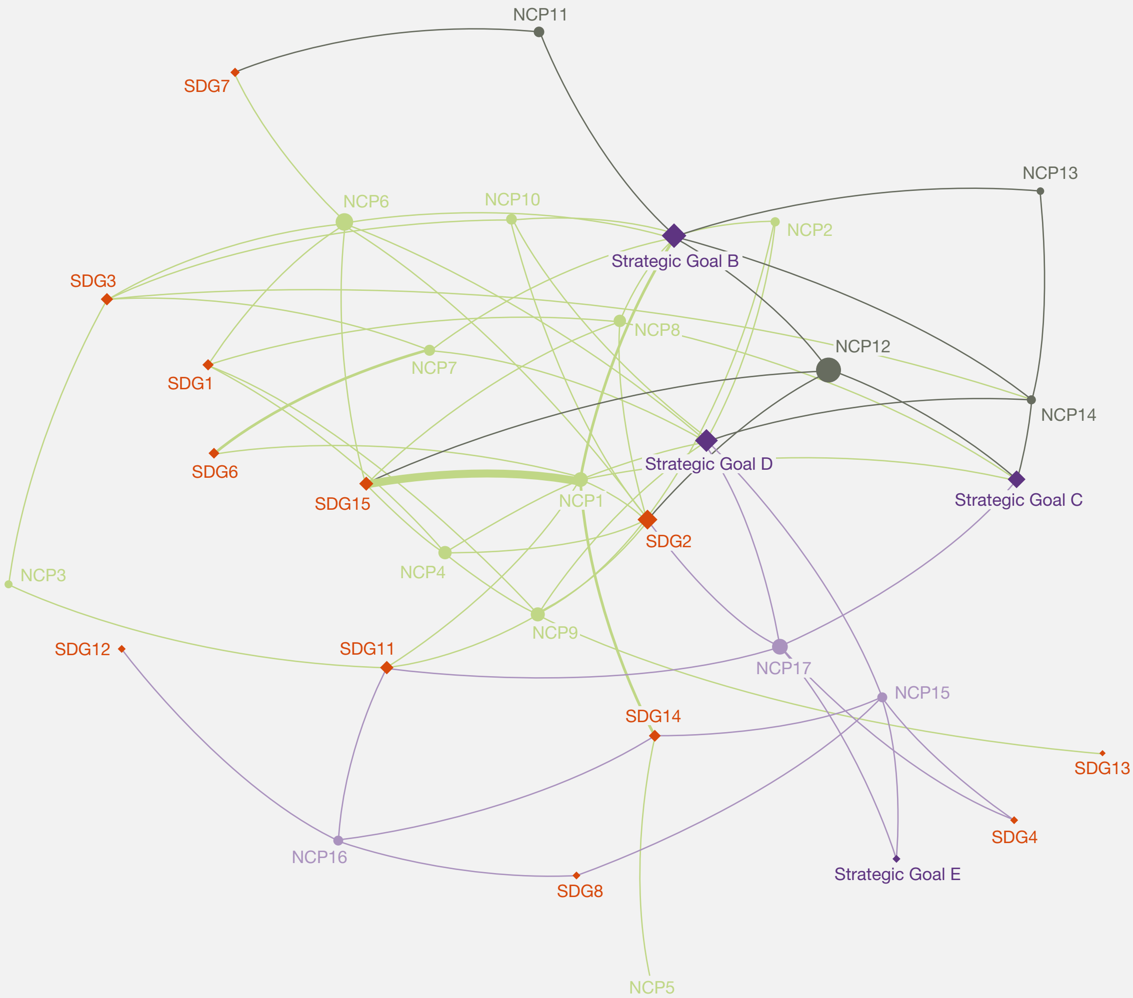
Good data on the plurality of values of nature's contributions to people exist for Western Europe, but are lacking for Central and Eastern Europe and Central Asia. There needs to be a greater focus on reporting more standardized per unit values for these contributions, where the units are clearly specified and can be compared across contributions, as this will facilitate (i) the assessment of the trade-offs of contributions between competing land uses, and (ii) the aggregation of values of contributions across the region.

2.4 RELEVANCE TO AICHI BIODIVERSITY TARGETS AND SUSTAINABLE DEVELOPMENT GOALS

Progress towards the Sustainable Development Goals (SDGs) and the Aichi Biodiversity Targets can be evaluated through the nature's contributions to people concept (Geijzendorffer *et al*., 2017). Considering the frequency with which specific contributions are mentioned in the strategies that contain these two sets of targets and goals, the direct relevance of all contributions is clear (see **Figure 2.68**). The top 25% most cited contributions across both strategies are the non-material contributions supporting identities (existence of species and ecosystems, and symbolic meaning of nature), the material contributions food and feed, and the regulating contributions habitat

Figure 2 68 **Relative importance of nature's contributions to people (NCP) for the Sustainable Development Goals (SDGs) and the Strategic Goals of the Strategic Plan for Biodiversity 2011–2020.**

The width of the lines indicates the frequency at which a certain contribution was mentioned in relation to a specific Sustainable Development Goal or Aichi Biodiversity Target (goals for which no relation to nature's contributions to people was found are not shown). The colour of the lines indicates whether the specific goal is connected with regulating (green), material (grey) or non-material (purple) contribution. The size of the nodes is proportional to the number of ties that a node has. Complete names of contributions are in Table 2.1. Source: Own representation.



creation and maintenance and regulation of water quality (see **Figure 2.68**) (Geijzendorffer *et al.*, 2017). For assessing progress towards policy goals and targets, especially Goal 2 (*zero hunger*) and Goal B of the Strategic Plan for Biodiversity 2011-2020 (*reduce the direct pressures on biodiversity and promote sustainable use*) information is required mainly on material contributions, with the latter also requiring information on regulating contributions. Information on non-material contributions are more equally needed over a range of goals and targets (Geijzendorffer *et al.*, 2017).

To interpret whether these sustainability goals are likely to be achieved, **Figure 2.68** combines the information depicted with the assessment of each contribution from nature to people (Section 2.2.5). According to this analysis, Europe and Central Asia is not advancing in *enhancing the benefits to all people from biodiversity and ecosystem services* (Strategic Goal D of the Strategic Plan for Biodiversity 2011-2020) because of the deteriorating status of many regulating and non-material contributions from nature to people (Section 2.2.5) and because the unequal access and distribution of contributions within the region (Section 2.3.4). Finally, because the practices and knowledge of indigenous peoples and local communities in Western and Central Europe have been eroded since the 1960s, the achievement of Strategic Goal E of the Strategic Plan for Biodiversity

2011-2020 (*enhance implementation through participatory planning, knowledge management and capacity building*) is threatened. However, it is worth noting that by including indigenous and local knowledge, the IPBES Regional Assessment for Europe and Central Asia respects, and thus contributes to, the achievement of Aichi Biodiversity Target 18 (*traditional knowledge respected*).

Regarding the interlinkages between the status and trends of nature's contributions to people and the achievement of the Sustainable Development Goals, it seems that some advances have been made to accomplish those related to environmental protection (Goals 13-15). Furthermore, the active contribution of multiple contributions from nature to health is supporting the achievement of Goal 3 (*good health and well-being*). However, the impact of biofuels and agriculture expansion on increasing land grabbing rates in other regions of the world and in Eastern Europe and Central Asia due to Western European consumption (Sections 2.2.4 and 2.3.1.1) jeopardizes the possibility of achieving Goal 2 (*zero hunger*), Goal 7 (*affordable and clean energy*) and Goal 12 (*responsible consumption and production*) in Europe and Central Asia. Further, future climate and land-use change are likely to exacerbate the decrease of water security (Goal 6). In fact, the number of water-stressed countries in Europe and Central Asia is projected to increase by 2030. Finally, the erosion of indigenous and local knowledge prevents some people from acquiring the relevant knowledge and skills needed to foster sustainable development and sustainable lifestyles and, thus, threatens the accomplishment of Goal 4 (*quality education*).

2.5 KNOWLEDGE GAPS

2.5.1 The unevenness of knowledge of nature's contributions to people in Europe and Central Asia

An important conclusion of this chapter's assessment of the status and trends of nature's contributions to people and their influence on quality of life is that, although there are thousands of publications and reports that are relevant to these contributions in Europe and Central Asia, a much smaller set of documents actually assess the status and trends of contributions. Furthermore, even fewer consider relationships between nature's contributions to people and good quality of life. The studies that do exist on the status and trends of nature's contributions to people are also uneven in their coverage of the different contributions. There are more accurate data on status and trends for material contributions, especially food and feed, than some regulating and non-material contributions. National ecosystem assessments often seek to analyze a range of contributions, but many publications and reports focus on individual ones. Western Europe has the most published literature on the status of nature's contributions to people and trends and their influence on the quality of life, contrasting with a very limited literature for Central Asia. Furthermore, very limited information on the status and trends in contributions is available for making comparisons between units of analysis since studies tend to focus on one or a small number of units of analysis. This conclusion, however, should be considered with caution as this chapter mostly reviewed English-language literature. *The uneven coverage in the existing literature of the different contributions for nature to people and subregions of Europe and Central Asia represents a key knowledge gap identified by the chapter.*

The limited availability of indicators for certain of nature's contributions to people in Europe and Central Asia is also a significant knowledge gap. Existing literature suggests indicator development for monitoring nature's contributions to people should cover the different components of these contributions (i.e. capacity, use and value; Section 2.1.2), provide data at multiple scales and address differences in contributions use based on societal characteristics (Balvanera *et al.*, 2017). However, according to existing studies the kind of information and indicators that are recommended for monitoring progress towards the Aichi Biodiversity Targets indicates a bias towards information related to capacity of nature's contributions to people (Geijzendorffer *et al.*, 2017). To implement regional and global assessment programmes of nature's contributions to people, existing studies highlight the need for indicator data at national scale for several contributions (Balvanera *et al.*, 2017). However, there are few indicators suitable and with available data to monitor contributions properly at the national scale (IPBES, 2017b). This chapter as a whole also confirms *there is a knowledge gap regarding indicators on the use of* nature's contributions to people*, demand and governance, which are less developed for the Europe and Central Asia region than capacity indicators*.

Even when data are available, *a further knowledge gap is that data and indicators focus on certain points in time, and evidence on long-term historical and future trends is missing for many of nature's contributions to people*. For example, for physical and psychological experiences of nature, little information exists on temporal trends of recreationists and visitors to the different ecosystems and their related recreational benefits, particularly in marine systems (Jobstvogt *et al.*, 2014; Ruiz-Frau *et al.*, 2011) and forests (Turtiainen & Nuutinen, 2012). To be able to establish future trends in nature's contributions to people, more work on quantitative (e.g. modelling) and qualitative projections of the impacts of different drivers is needed and a consistency of methods and scenarios would facilitate comparison, within and across Europe and Central Asia subregions (Section 2.2.6).

Existing analyses of monitoring and indicator development for nature's contributions to people identify that this should also take place at the local scale, but local indicators must be consistent with those at the regional and international scale in a manner that is integrated with efforts at higher levels (Balvanera *et al.*, 2017). For particular contributions, such as spiritual experiences or medicinal resources, methodological development and assessment may fit best to the local scale, due to the importance of local differences. This chapter has identified that at the local level indigenous and local knowledge on the interactions between nature's contributions to people and quality of life should be considered alongside scientific knowledge and used for setting future management policies. *There is a knowledge gap, however, relating to the recording of indigenous and local knowledge and such information needs to be collected before it disappears* (see Section 2.2.3.1) for its own value and because it has a role to play in guiding societies towards sustainability.

This chapter has also identified specific knowledge gaps in terms of the availability of indicator data for status and trends for the following aspects of nature's contributions to people:

- *Indicators of the trends in habitat creation and maintenance*; a number of indicators can be used to evaluate its current state such as some key migratory and breeding species and their habitat and indigenous and local knowledge can also be used to assess the status and trends of this contribution from nature to people (see supporting material Appendix 2.2[35]).
- *The relationship between water use and water availability*; indicator data for freshwater quantity for Eastern Europe and Central Asia is also lacking.
- *Soil quality;* encompassing its physical, chemical and biological components.
- *Carcass removal* by vertebrate and invertebrate scavengers and marine organisms (Donázar *et al.*, 2016; Martín-Vega & Baz, 2011; Moleón & Sánchez-Zapata, 2015).
- *The use of medicinal resources and plants;* ethnobotanical research is central to a better understanding of the medicinal potential of medicinal plants and national measures and indicators need to become comparable on an international scale, regarding health, ecological, cultural, legal or socio-economic aspects.
- *Wildlife-based tourism;* a data gap exists about accurate statistical information on the number of users developing recreational activities around wildlife (i.e. whale-watching, bird-watching).
- *Supporting identities;* there is a lack of consensus on suitable indicators but these could be developed using attitudes towards nature protection and species or ecosystem attributes or characteristics that are particularly valued for their existence (e.g. iconic, emblematic, symbolic species)
- *Interregional flows of nature's regulating and non-material* contributions to people; especially between Europe and Central Asia and other regions of the world.

This chapter also highlights some *significant knowledge gaps regarding the influence of nature's contributions to people on quality of life.* In particular, despite a large number of studies on the health aspects of nature's contributions to people in Western Europe, there are still *knowledge gaps on nature-human health linkages* in Europe and Central Asia and other regions. The current evidence base needs expanding to illuminate the scope and complexity of biodiversity-health relationships and their importance to health outcomes. More knowledge is needed on the degree to which social, cultural and economic factors influence the relationship between biodiversity, nature's contributions to people, and human health outcomes including the ways in which socio-economic status, age, gender and ethnicity can mediate health risks and benefits of nature. Such research can help to illuminate how health-biodiversity relationships are framed or understood by different communities or vulnerable groups.

The analysis of the relationships between nature's contributions to people and environmental equity and justice across Europe and Central Asia has to address the different understandings in countries and communities as to what constitutes equity and justice. Partly because of these differences there is *limited understanding of the plural values of nature's contributions to people endorsed by different societal groups and genders*. Moreover, there is even less empirical evidence about the inequities emerging from the different control over and access to these contributions (Bennett *et al.*, 2015). This knowledge is essential to understand fully how these contributions are likely to contribute to the quality of life of different societal groups and regions.

35. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.2_ilk_content_of_ncp.pdf

2.5.2 The challenges of knowledge generation on nature's contributions to people

This chapter has indicated that if status and trends in nature's contributions to people and their impact on quality of life are to be better understood across Europe and Central Asia, four key changes are required in approaches to knowledge generation on these contributions.

First, there is a need for agreed *methods that allow comparison of results and syntheses*. Each of nature's contributions to people is often studied and described in different ways and for different units of analysis, which makes it challenging to summarize status and trends for a region. For example, for the regulation of water quality, the large uncertainty in measurements and the absence of consensus on the most appropriate methods for its quantification make its assessment difficult (Clec'h *et al.*, 2016; Grizzetti *et al.*, 2012).

Second, there is a need for *integrative approaches that assess the multiple benefits derived from a particular contribution from nature to people*. For example, it is widely recognized that pollinators and animal-pollinated plants provide benefits not only as food and feed, but also through medicinal and symbolic plants, fibres (e.g. cotton), construction materials (e.g. some timbers), aesthetically significant landscapes (e.g. flower meadows), musical instruments (e.g. bees wax used for violins), and as sources of inspiration for art, music, literature, traditions, education and technology throughout Europe and Central Asia (IPBES, 2016). This information on pollinators was compiled for a specific IPBES assessment on the topic, and such evidence is not available for many other contributions from nature to people.

Third, there is *limited empirical evidence on how individual contribution from nature s to people can contribute to the different dimensions of quality of life.* For example, there is only empirical evidence in Western Europe about how nature-based tourism can contribute to physical and mental health, but comprehensive information about its contributions to food security, cultural heritage and identity is missing for the whole of Europe and Central Asia.

Finally, there is a need for *more integrated approaches to the development of knowledge regarding nature's contributions to people that involve multiple social actors, including indigenous and local knowledge holders.* For example, in the case of medicinal resources, there is a need for a much more rigorous multidisciplinary science-driven approach to local and traditional medicines, which also empowers the local keepers of this knowledge and their users (Leonti & Casu, 2013). More integrated research approaches would be beneficial to better explore the knowledge and health potential of medicinal plants. It is essential to ensure that bioprospecting preserves traditional knowledge systems, and works with local communities in a manner that protects those values and protects habitats and species. Involving communities in the sustainable use of biodiversity may also provide important opportunities for local enterprise, and support the continuance of local cultural traditions. This requires direct engagement and collaboration between community organizations, biotech and pharmaceutical industries, national institutes of health and medicine, conservationists, and research funding agencies.

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CHAPTER **3**

STATUS, TRENDS AND FUTURE DYNAMICS OF BIODIVERSITY AND ECOSYSTEMS UNDERPINNING NATURE'S CONTRIBUTIONS TO PEOPLE

Coordinating Lead Authors:

Piero Visconti (Italy/United Kingdom of Great Britain and Northern Ireland), Victoria Elias (Russian Federation), Isabel Sousa Pinto (Portugal), Markus Fischer (Germany/ Switzerland)

Lead Authors:

Valida Ali-Zade (Azerbaijan), András Báldi (Hungary), Sandra Brucet (Spain), Elena Bukvareva (Russian Federation), Kenneth Byrne (Ireland), Paul Caplat (Sweden), Alan Feest (United Kingdom of Great Britain and Northern Ireland), Rodolphe Gozlan (France), Dusan Jelić (Croatia), Zaal Kikvidze (Georgia), Alexandra Lavrillier (France), Xavier Le Roux (France), Oksana Lipka (Russian Federation), Petr Petrík (Czech Republic), Bertrand Schatz (France), Ilya Smelansky (Russian Federation), Frédérique Viard (France)

Fellow:

Carlos Guerra (Portugal/Germany)

Contributing Authors:

Yaakov Anker (Israel), Céline Bellard (France), Steffen Boch (Germany/Switzerland), Monika Böhm (Germany/United Kingdom of Great Britain and Northern Ireland), Anders Dahlberg (Sweden), Ksenia Dobrolyubova (Russian Federation), Johan Ekroos (Finland/Sweden), Daniel P. Faith (Australia), Anat Feldman (Israel), Bella Galil (Israel), Mariana García Criado (Spain), Dmitry Geltman (Russian Federation), Antoine Guisan (Switzerland), Hans Joosten (The Netherlands/Germany), Bakhtiyor Karimov (Uzbekistan), Vladimir Korotenko (Kyrgyzstan), Jonne Kotta (Estonia), Elena Kreuzberg (Canada/ Uzbekistan), Marina Krylenko (Russian Federation), Aleksei Kurokhtin (Kyrgyzstan), Daria Kuznetsova (Russian Federation), Boris Leroy (France), Lada Lukić Bilela (Bosnia and Herzegovina), Shai Meiri (Israel), Tatiana Minayeva (Poland/Russian Federation), Ulf Molau (Sweden), Telmo Morato (Portugal), George Nakhutsrishvili (Georgia), Ana Nieto (Spain), Oxana Nikitina (Russian Federation), Ruslan Novitsky (Belarus), Kristiina Nurkse (Estonia), Angel Pérez Ruzafa (Spain), Kristina Raab (Germany), Uri Roll (Israel), Axel G. Rossberg (United Kingdom of Great Britain and Northern Ireland), Resad Selimov (Azerbaijan), Emil Shukurov (Kyrgyzstan), Andrey Sirin (Russian Federation), Henrik G. Smith (Sweden), Mark Snethlage (The Netherlands/Switzerland), Boris Solovyev (Russian Federation), Tatyana Svetasheva (Russian Federation), Franziska Tanneberger (Germany), Wilfried Thullier (France), Boris Tuniyev (Russian Federation), Fons van der Plas (The Netherlands/Germany), Vigdis Vandvik (Norway), Stephen Venn (United Kingdom of Great Britain and Northern Ireland/Finland), Vladimir Vershinin (Russian Federation), Marten Winter (Germany), Egor Zadereev (Russian Federation), Nugzar Zazanashvili (Georgia)

Review Editors:

Guntis Brūmelis (Latvia), Andreas Troumbis (Greece)

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EXECUTIVE SUMMARY

Biodiversity loss impairs ecosystem functioning and, hence, nature's contributions to people (*well established*) (3.2.1, 3.2.2, 3.2.3). Sustainable delivery of these contributions requires the maintenance of genetic diversity, species diversity, and the diversity of ecosystems and land- and seascapes (*well established*) (3.2.4). The delivery of individual functions over time and at different places, and the delivery of multiple contributions, requires higher biodiversity than provisioning single services at one place and time alone (*well established*) (3.2.5). Higher biodiversity increases the capacity of terrestrial, freshwater or marine systems to capture resources, produce biomass, decompose and recycle nutrients, and to provide pollination (*well established*) (3.2.1, 3.2.2).

Higher biodiversity facilitates stable ecosystem functioning and improved capacity for evolutionary adaptation (*well established*) (3.2.3, 3.2.4). Higher biodiversity also increases ecosystem resilience and biological control of pathogens and invasive alien species (*established but incomplete*) (3.2.1, 3.2.3). To support ecosystem functioning, ecosystem stability over time, and adaptation to future environmental changes, biodiversity is required at different levels, from genetic and phenotypic diversity within populations, to diversity among populations and ecological or morphological types within species, species diversity and phylogenetic and functional diversity within communities, and diversity of communities, ecosystems and land and seascapes (*well established*) (3.2.3).

The higher the number of nature's contributions to people, the longer the time span, and the larger the area, the more biodiversity is required for their delivery (*well established*) (3.2.5). At the land and seascape and larger spatial scales, biotic homogenization, i.e. increasing similarity of the sets of organisms found at different places, reduces nature's overall contributions to people (*established but incomplete*), because of trade-offs between different facets of biodiversity and different contributions of nature to people (*well established*) (3.2.5). Thus, at the landscape and larger spatial scale the supply of multiple contributions of nature to people requires the maintenance and promotion of high biodiversity (*established but incomplete*). This implies high synergy at the land and seascape level between maintaining and promoting biodiversity and maintaining and promoting multiple contributions of nature to people (3.2.5).

Despite including some of the best-studied marine ecosystems, most of Europe and Central Asia's marine ecosystems, especially those deeper than 200 m, and most marine species are data deficient and their status and trends cannot be properly assessed (*well established*) (3.3.4). Of the assessed marine habitats and species, a high percentage are threatened (*established but incomplete*), varying between marine areas (*well established*) (3.3.4.1-7). The abundance, range and habitat size of many marine species is shrinking due to human pressures (*well established*) (3.3.4.1-7, 3.4.6.1). The distribution or phenology of many taxa has changed (*well established*) (3.3.4), including an "Atlantification" and "Pacification" of the Arctic Sea (*established but incomplete*) (3.3.4.5). Positive trends, mainly due to improved fishing practices or to a reduction in eutrophication, include increases in some fish stocks in the North Sea and in plankton diversity in the Black Sea (*well established*) (3.3.4.1, 3.3.4.4). Fifty-three per cent of the benthic shallow habitats in Western and Central Europe are data deficient. This figure is 87% in the Black Sea, 60% in the North East Atlantic, 59% in the Mediterranean Sea and 5% in the Baltic Sea (*well established*) (3.3.4.1-7). Of the assessed benthic habitats, 38% are classified as threatened (critically endangered, endangered or vulnerable), most of them in the Black (67%) and Mediterranean Seas (74%), followed by the North East Atlantic (59%) and Baltic Sea (8%) (*established but incomplete*) (3.3.4.1-7). In the European Union, among assessments of the conservation status of species and habitat types of conservation interest, only 7% of marine species and 9% of marine habitat types show a "favourable conservation status". Moreover 27% of species and 66% of assessments of habitat types show an "unfavourable conservation status" and the reminder are categorized as "unknown" (*established but incomplete*) (3.3.4).

In Europe and Central Asia, 26% of the marine fish species have known trend data. Of those, 72% are stable, 26% have declining populations and 2% have been increasing over the last decade (*well established*) (3.4.6.1). Seabirds, marine mammals and turtles, and habitat formers, such as seagrasses and kelps, also declined in abundance (*well established*) (3.4.2-4). The distribution or phenology of marine phytoplankton, zooplankton, algae, benthic invertebrates, fishes, seabirds and mammals has changed (*well established*) (3.3.4). Such changes are particularly visible in the Arctic Ocean, where they were classified as "Atlantification" and "Pacification" with multiple ecosystem effects (*established but incomplete*) (3.3.4.5)**.** Many changes in species distribution or phenology lag behind the pace of climate change, however (*established but incomplete*) (3.3.4). Forty-eight per cent of marine animal and plant species with known population trends (436 decreasing, 59 increasing, 410 stable) have been declining in the last decade, increasing the extinction risk of monitored species (*established but incomplete*) (3.4).

Marine habitat and species trends are driven by individual and combined effects of overfishing, habitat degradation, climate change, pollution and invasive alien species (*established but incomplete*) (3.3.4.1-7). Invasion by alien species is observed in all marine areas of the region and is particularly fast in the Mediterranean Sea (*well established*). These invasions combined with species range shifts, are responsible for widespread biotic homogenization between subregions and systems (*well established*) (3.3.4.3). Invasive alien species, climate change and selective fishing reduce taxonomic and functional diversity by increasing generalist species and decreasing specialists (*well established*) (3.4). While fisheries are still the main driver of observed marine biodiversity loss across the region, e.g. in the Mediterranean Sea (*well established*), some fish stocks also improved due to decreased fishing pressure in some areas, e.g. the North Sea (*established but incomplete*) (3.3.4.1)**.** In some areas, eutrophication has decreased in recent years and e.g. plankton diversity of the Black Sea has recovered (*established but incomplete*) (3.3.4.4). Other forms of pollution, such as microplastics and noise, negatively affect marine animals, but a full assessment of their impact is still lacking (*established but incomplete*) (3.3.4).

Freshwater species and inland surface water habitats are threatened in Europe and Central Asia (*well established*). Only 53% of the European Union's rivers and lakes achieved good ecological status in 2015. 73% of the European Union's freshwater habitats have an unfavourable conservation status (*well established*) (3.3.3.1). Across Europe and Central Asia, lakes, ponds and streams are disappearing as a consequence of agricultural intensification, irrigation and urban development combined with climate change (*well established*) (3.3.3.1). The extent of wetlands in Western, Central and Eastern Europe has declined by 50% from 1970, while 71% of fish and 60% of amphibians with known population trends are declining (*well established*) (3.3.3.1, 3.4.5, 3.4.6.2). Over 75% of catchment areas in Europe and Central Asia are heavily modified and subject to multiple pressures, resulting in serious threats to biodiversity. In 2015, good chemical status, as defined by the European Union Water Framework Directive, was not achieved for surface water bodies by 22 European Union member States and only 53% of rivers and lakes had good ecological status, despite some improvements (*well established*) (3.3.3.1). Freshwater and saline lake species and habitats are the most threatened in the region. Most known population trends for freshwater and saline lake species have been declining, including fish, amphibians and invertebrates. In Western and Central Europe and the western parts of Eastern Europe at least 37% of freshwater fish and about 23% of amphibians are threatened with extinction. In the same area, freshwater invertebrates are also threatened, with the most threatened group being gastropods (45-70% of species threatened depending on whether or not data deficient species are considered threatened), bivalves (20 to 26%) and dragonflies (15 to 19%) (*established but incomplete*) (3.4.5, 3.4.6.2, 3.4.8).

The main drivers of trends in the biodiversity of inland surface waters are habitat destruction and modification caused by infrastructure for hydro-power, navigation, flood protection, agriculture, urban development and water abstraction; pollution from agriculture and industry; the introduction of invasive alien species and their pathogens; and climate change (*established but incomplete*) (3.3.3). Many lakes, ponds and streams are disappearing as a consequence of agricultural intensification, irrigation and urbanization combined with climate change (*well established*). Water bodies disappear particularly in the Mediterranean region and Central Asia. Lake Akşehir, for example, was among the largest freshwater lakes in Turkey, but has now completely disappeared due to loss of surface and ground water sources through intensive crop irrigation (3.3.3.1). The desiccation of the Aral Sea due to water abstraction for irrigation, followed by wind-borne pollution from former sediments, is globally considered as a major environmental disaster (*well established*) (3.3.3.2).

Water protection has progressed in Western and Central Europe, especially due to the European Union Water Framework Directive. The rate of wetland loss has slowed considerably in Central and Western Europe due to the implementation of binding nature conservation policies or the designation of conservation areas (e.g. Ramsar sites). Nevertheless, the deterioration of freshwater ecosystems is generally continuing in the region (*well established*) (3.3.3).

Most terrestrial species and natural habitats have long-term declining trends in abundance, range and habitat extent and intactness. This is mainly due to agriculture, forestry, transport infrastructure, urban development and climate change (*well established*) (3.3.2, 3.4). Most natural habitats have been declining in extent, especially subtropical and tropical forests with 20% left in Macaronesia and 10% in the Caucasus (3.3.2.5), with the highest loss occurred during the 20th century (*well established*) (3.3.2). These declines are generally continuing, albeit at a slower rate. Forests, grasslands and tundra have been the most impacted terrestrial habitats since the second half of the 20th century (3.3.2). Systematic assessments of habitat conservation status only exist for the European Union. There, 16% of terrestrial habitat assessments in the period 2007-2012 had favourable conservation status; 3% had unfavourable, but improving trends; 37% had unfavourable, but stable trends; 29% had unfavourable and declining trends; 11% had unfavourable status with unknown trend relative to the period 2001-2006 and 4% had unknown status (*well established*) (3.3.2.12).

Forty-two per cent of terrestrial European and Central Asian animal and plant species with known population trends declined in the last 10 years, 6% increased and 52% were stable (3.4.13) (*established but incomplete*).

The main causes of the decline of terrestrial species include habitat conversion and pollution due to agriculture and forestry practices, natural resource extraction, climate change and invasive alien species (*well established*) (3.4, 3.3.2). Loss of forest biodiversity continues due to loss of intact natural forest (*well established*), forest fires, loss of natural structures, such as dead trees (*well established*), fragmentation of populations (*well established*), loss of traditional forestry practices that created open forest (*well established*), increased number and strength of extreme weather events due to climate change (*well established*) and conversion of land use (*well established*). Since the 1950s, biodiversity has decreased in response to both abandonment of, and intensified use of, agricultural land (*well established* for Western Europe and Central Europe; *established but incomplete* for Eastern Europe and Central Asia) (3.3.2.9). The conversion of grasslands to crops and urban areas and conversion of semi-natural grassland to more intensively used pastures are among the main drivers of declining conservation status of non-forested habitats and species (*well established*) (3.3.2.6). Climate change, including increased number and strength of extreme weather events, also accelerates turnover in species composition and species loss in all habitat types, shifts species distributions northwards and upwards on mountain slopes (*well established*), decreases the extent of glaciers (*well established*), decreases the extent of polar deserts with transformation to tundra (*well established*), expands deserts and shifts forest cover and types (3.3.2). Populations of invasive and alien species continuously increase in numbers, exacerbated in northern parts of Europe and Central Asia by climate change (*well established*) (3.3.2).

Drainage-based exploitation of boreal peatlands is gradually giving way to sustainable use, protection and restoration, while southern and mountain peatlands are still threatened by development (*well established*). Unique functions of peatlands such as carbon storage, water regulation and biodiversity maintenance are increasingly lost by drainage and over-utilization (*well established*) (3.3.2.8).

Europe and Central Asia has over half of all known breeds of domesticated mammals and birds, but 75% of local bird breeds and 58% of local mammal breeds are threatened with extinction (3.4.13). The species diversity of arable plants has decreased by 20% since 1950 in Western and Central Europe, and the abundance of rare arable plants has also decreased (*well established*) (3.3.2.9). The genetic diversity of plants cultivated *in situ* declined until the 1960s, due to the replacement of landraces by modern cultivars, and no further reduction or increase of diversity was observed after the 1980s (*well established*). The numbers of at-risk animal breeds have slightly declined since 1999, but exact quantification is hampered by the changing number of documented local breeds (*established but incomplete*) (3.4.13). From 1980 to 2013, the abundance of farmland common bird species decreased by 57% in Western and Central Europe, the abundance of grassland butterflies has declined since 1990 (*well established* for Western Europe) and there have been severe seasonal losses of honey bee colonies over the period 1961-2012 across Europe and Central Asia (*well established*) (3.3.2.9).

Between 44 and 68 recorded species endemic to Europe and Central Asia have become globally extinct since the 15th century (40-62 animals, four to six plants). In addition, between 20 and 88 recorded species have become regionally extinct in Europe and Central Asia (16-80 animals, one fungus and four to seven plants). 37 global extinctions involved marine and freshwater species and seven involved terrestrial species, while most recorded regional extinctions were of terrestrial species (*established but incomplete*). In addition to these extinctions recorded

at large scale, numerous extinction events were recorded at the country level (*well established*) (3.4.1). Around 13% of animal and plant groups living in Europe and Central Asia and comprehensively assessed by IUCN are endemic to the region (*well established*). Thirteen percent of species occurring in Europe and Central Asia with known conservation status are at high risk of extinction. Particularly threatened are mosses and liverworts (50%), freshwater fishes (37%), freshwater snails (45%), vascular plants (33%) and amphibians (23%). Of species endemic to Europe and Central Asia, 30% are threatened. The Central and Western European subregions have the highest percentages of threatened (13%) and endemic species (11%) and the highest percentage of threatened endemics (35%), with these percentages primarily driven by the many threatened endemic species in the Mediterranean hotspot and the Macaronesian Islands. Eastern Europe and Central Asia have lower percentages of species (<10%) and endemic species (<5%), and lower percentages of threatened endemics (<10%) (*established but incomplete*) (3.4.1).

The net change in extinction risk for mammals, birds and amphibians is 17 species moving one category closer to extinction every 10 years. Seven of these are in Western and Central Europe, six in Eastern Europe and four in Central Asia (*established but incomplete*) (3.4.13). From 2007 to 2012 the conservation status of 35 monitored plant and animal populations in EU-27 improved relative to the previous 6 years, versus 41 deteriorations (*well established*) (3.4.13). Overall, 118 monitored species of plants and animals in the European Union have unfavourable conservation status but improving trends, 572 have unfavourable conservation status and deteriorating trends and 905 have unfavourable status and stable or unknown trends (*well established*) (3.4.13).

In Western and Central Europe, the main drivers of recent past population declines across all realms are agriculture (use of biocides and chemicals affected 73% of assessed populations, intensification 42%, modification of cultivation practices 36%); reduction of habitat connectivity (55%); pollution of surface waters (56%); invasive alien species (46%); human induced changes in hydraulic conditions (43%); and forestry (removal of dead trees (39%), clearance (38%), logging of natural and plantation forests (38%)) (*well established*) (3.4.13). A separate assessment of threats to freshwater species found that at least 62% (n=13) of globally extinct species of European freshwater fishes were victims of water pollution and lake eutrophication. Destruction or modification of freshwater habitats, including water abstraction, affects 89% of amphibian threatened species and 26% of threatened freshwater invertebrates (*well established*) (3.4.5, 3.4.8). A quantitative assessment of drivers of biodiversity change in Central Asia and Eastern Europe was not possible due to a scarcity of data, but the same drivers with the addition of overexploitation (hunting, trapping, fishing, harvesting) are reported as the main causes of known trends (*established but incomplete*).

Loss of taxonomic and functional diversity driven by increasing trends and expansion of generalist species and decline of specialists is documented across Europe and Central Asia and all taxa. On land, simplification of ecosystems through land-use intensification (agriculture, forestry, and urbanization) drives this phenomenon. In inland surface waters it is due to changes in water regime, eutrophication, salinity and introduction of invasive and alien species. In the seas, the main drivers are climate change, invasive alien species and fishing of selected species (*well established*) (3.3, 3.4). Loss of taxonomic, and even more so, of functional diversity driven by increasing trends and expansion of generalist species and decline of specialists is documented across Europe and Central Asia for all taxa (*well established*) (3.4). Biotic homogenization in agricultural areas has occurred for a range of biological groups, including birds, butterflies, cultivated plants, weeds, and domestic animals (*well established*). Intensification of forestry and urbanization also has resulted in biotic homogenization (*wel established*) (3.3, 3.4).

Bird communities have experienced extreme levels of biotic homogenization with near-extinction of habitat specialists, especially in grasslands of Western Europe and Central Europe due to landscape simplification. Other groups disproportionally affected are migratory species (hunting and trapping) and seabirds, due to bycatch from fisheries and predation by invasive species (*well established*) (3.4). Amongst forest plants, lichens, birds, mammals and arthropods show declines of specialists of old forests and of deciduous forests, and of cavity-nesters (3.3.2.3, 3.3.2.4, 3.3.2.5, 3.4). All these changes can be related to the intensification of forestry, which does not allow the development of structural elements benefitting specialist communities (*well established*) (3.4). Among freshwater fish communities, functional homogenization exceeds taxonomic homogenization sixfold. Species that are anadromous, slow-growing, large-body sized, diet or habitat specialists have been far more impacted than others. Body-size and specialization have also played a role in biotic homogenization of zooplankton communities (*established but incomplete*) (3.4). Large-bodied and other vulnerable marine fish species are the most threatened in large parts of Europe and Central Asia, and some have gone extinct (*well established*) (3.4.6.1).

Conservation efforts have shown the potential to reverse negative population trends (*well established*) (3.4.13). The long-term population trends of 40% of the breeding bird taxa in Annex I of the European Union Birds Directive are increasing compared with 31% for all breeding bird taxa (3.4.13). Charismatic mammalian mega-fauna, such as the Amur tiger, Far-Eastern leopard, Iberian lynx, and European bison are all recovering from the brink of extinction because of dedicated conservation efforts (*well established*) (3.4.3, 3.4.13). The response of biodiversity to "ecologically-friendly" agricultural practices (stricter pesticide management, reduced tillage and organic farming) is generally positive, but depends on the landscape context, spatial scale of evaluation, and biological groups - with particularly beneficial effects on plants and pollinators (*well established*) (3.4).

Overall, impacts from direct drivers on biodiversity are maintained and the use of biodiversity is not sustainable in the region (3.3, 3.4). Progress has been made in the region in terms of the extent of protected areas (3.3). However, overall trends in biodiversity are still negative (3.3, 3.4). These trends suggest that the corresponding Aichi Biodiversity Targets and Sustainable Development Goals 14 and 15 are not likely to be met (*well established*) (3.3.2.12, 3.3.3.3, 3.3.4.8, 3.4.13). Aichi Biodiversity Target 5 (habitat loss halved or reduced) is unlikely to be achieved given the observed status and trends in extent and biodiversity of terrestrial, inland surface water, and marine habitat (3.3.,3.4). Based on current freshwater biodiversity trends, it is highly unlikely that Europe and Central Asia will achieve the respective Aichi Biodiversity Targets by 2020 (i.e. targets, 6-10) or Target 1 of the European Union Biodiversity Strategy (*well established*), in spite of some progress having been made (3.4, 3.3.3, 3.5.2). Although the rate of natural habitat loss (e.g. of wetlands) has slowed down in some Europe and Central Asia countries due to the implementation of binding nature conservation policies or the designation of sites (e.g. Ramsar), the decline in freshwater habitat continues (*well established*) (3.3.3). Achieving Targets 6 (sustainable management of marine living resources) and 10 (pressures on vulnerable ecosystems reduced) is hampered for the deep-sea by increased habitat degradation and declines in biodiversity (*established but incomplete*) (3.3.4). Achieving Aichi Biodiversity Target 11 for terrestrial ecosystems (at least 17% conserved through protected areas) appears to be on track, which is ensured for Western and Central Europe and likely to be met in Eastern Europe and Central Asia (Chapter 4). Despite some recent progress, Aichi Biodiversity Target 11 and target 14.5 of Sustainable Development Goal 14 have still not been reached for the marine systems of Europe and Central Asia (*well established*), although they have been surpassed in some coastal areas, e.g. of the Mediterranean and North Seas, and by 15 countries protecting more than 10% of their marine waters (3.3.4.8). Some marine systems, especially those further from the coast, are much less protected, however (*well established*). Downward trends in the conservation status of assessed taxa indicate that the Europe and Central Asia region is not on track to meet Target 12, in spite of some decreasing trends in extinction risk (*well established*) (3.4). Despite some progress towards Target 13 (genetic diversity maintained) by developing safeguards for rare domestic breeds and germplasms of cultivated plants, the extinction risk of domestic animal breeds is increasing and genetic diversity of cultivated plants eroding under modern production systems (*established but incomplete*) (3.4.13). Despite advances in protected areas (relevant in the context of Sustainable Development Goals 14 – life below water and 15 – life on land), the negative trends observed for biodiversity currently restrict progress toward Goals 14 and 15 (*well established*) (3.3).

Under business-as-usual scenarios of future global change, the extent of coniferous forests is expected to be maintained or even increase. Meanwhile, tundra, other Alpine ecosystems, Mediterranean ecosystems, and broad-leaved and mixed forests are expected to substantially contract, because of climate and land-use change. Alpine, Scandinavian, and Icelandic glaciers are projected to retreat (3.5.1.3) (*well established*). The expected range of glacier losses depends on climate modelling scenario and varies from 20% to 90% of the 2006 ice volume. Climate change is also expected to further increase the stress on freshwater ecosystems, not only by changing species distribution but also by exacerbating the symptoms of eutrophication due to loss of planktivorous species through warming and salinization (*inconclusive*) (3.5.2). Mean species abundance, local functional and phylogenetic diversity and betwee-sites taxonomic diversity are expected to decrease throughout the 21st century, while local taxonomic diversity is expected to increase in some terrestrial and marine regions as a result of climate-driven range shifts (*established but incomplete*) (3.5.1, 3.5.3). Across species, range contractions are projected to be between 10% and 55% depending on climate scenario and taxonomic group considered (*established but incomplete*) (3.5.1.1). Biomass productivity may increase in some areas due to CO_2 fertilization and temperature increase, especially in the Arctice seas, lakes and boreal forests (*unresolved*) (3.5.1, 3.5.2, 3.5.3).

If key knowledge gaps would be addressed soon, future assessments could provide a more comprehensive account of the relationship between biodiversity and nature's contributions to people and of the status and trends of nature (*well established*) (3.6). Much more information is available on the relationship between biodiversity and ecosystem services from experiments than from the field. Among the experiments those manipulating plant diversity were overrepresented compared with those manipulating other taxa, and most concerned grasslands or aquatic mesocosms. For experiments and field studies addressing the relationship between biodiversity and ecosystem services, comprehensive information across all types of nature's contributions is not yet available (*well established*) (3.2, 3.6).

A broader knowledge basis on trends in habitat extent, intactness and species conservation status was available for Western and most of Central Europe than for Eastern Europe, Central Asia and Balkan countries in Central Europe (3.4, 3.6). For example, exact extent, biodiversity status and trends are hardly known for most terrestrial and freshwater ecosystems in Eastern Europe and Central Asia, and the chemical status of 40% of Western and Central Europe's surface waters remains unknown (*well established*). Biodiversity status and trends are also poorly known for most marine habitats. E.g. 30% of coastal marine habitat assessments in the Mediterranean reported unknown conservation status. Only a minor fraction of the deep-sea floor and of known seamounts have been subject to biological investigation (*well established*) (3.4, 3.6).

Major gaps on status and trends of taxonomic groups concerned invertebrates, most marine and freshwater species, bryophytes, lichens, fungi and microorganisms. Of the estimated 32,000 vascular plant species of Europe and Central Asia, IUCN evaluated 2,483 (approx. 8%) in the Red List of Threatened Species. Of the estimated more than 2,000 bryophyte and more than 7,000 lichen species in the region only 14 and 5 species, respectively, have been evaluated in the IUCN Red List. For invertebrates in general, and freshwater invertebrates in particular, even the current status is available only for a minority of species. Almost a quarter of all European freshwater molluscs are data deficient, many of them likely to be threatened. 76% of freshwater fishes and 83% of freshwater molluscs assessed have unknown population trends (*well established*) (3.4). One to two thirds of marine species are still to be described. Status and trends for marine biodiversity are mostly unknown, even for coastal habitats. Accordingly, 50% of the assessments under the European Union Habitats Directive reported unknown conservation status for cetaceans and turtles and coastal marine habitats in the Macaronesian biogeographic region. And 30% of coastal marine habitat assessments in the Mediterranean reported unknown conservation status. Only a minor fraction of the deep-sea floor and of known seamounts have been subject to biological investigation (*well established*) (3.3., 3.4, 3.6). Indigenous and local knowledge on biodiversity trends was only partially available (*well established*) (3.6).

Due to lack of quantitative knowledge the relative role of drivers of change in determining trends in extent and intactness of habitats and in species diversity and abundance could only be attributed in terms of a coarse classification. Moreover, information is lacking on the interacting effects of several drivers on biodiversity (*well established*) (3.3, 3.4, 3.6)

These knowledge gaps greatly reduce the ability to monitor progress towards international biodiversity targets and to inform policy to avert further biodiversity loss. For example, current instruments such as the European Union Habitats Directive and Natura 2000 programme do not consider algae, fungi or lichens, and only a small fraction of invertebrates (*well established*) (3.6).

3.1 INTRODUCTION

This chapter assesses, for Europe and Central Asia, evidence for the general role of biodiversity for nature's contributions to people (3.2). Then it assesses the past and current status and trends of terrestrial, inland surface water and marine biodiversity by ecosystems (units of analysis) (3.3) and by taxa (3.4). This is followed by an assessment of future trends of terrestrial, inland surface water and marine biodiversity (3.5). Finally this chapter assesses knowledge gaps (3.6) in these respects.

Whereas Chapter 2 of the IPBES Regional Assessment for Europe and Central Asia identifies strong evidence that nature's contributions to people are declining, this chapter provides an assessment of the general underpinning of nature's contributions to people by biodiversity. Moreover, while Chapter 4 establishes that natural resource extraction, land-use change, pollution, climate change, and invasive alien species are the main direct drivers driving biodiversity change in general, this chapter assesses the status and trends of marine, inland surface water and terrestrial biodiversity for different units of analysis and for different taxa, and it attributes these trends to the direct drivers.

3.2 THE RELATIONSHIP BETWEEN BIODIVERSITY AND ECOSYSTEM FUNCTIONS AND SERVICES

3.2.1 General importance of biodiversity for ecosystem functions and services

Theoretical, experimental and field studies have proven that biodiversity is one of the key factors in determining the mean level and stability of ecosystem properties and functioning, such as biomass production, decomposition and carbon sequestration (Cardinale *et al.*, 2012; Tilman *et al.*, 2014). Clear evidence of biodiversity effects on ecosystem functioning has been obtained from experiments, which overall showed that the impacts of diversity loss on ecological processes are of comparable magnitude to the effects of other global drivers of environmental changes such as climate change, ultraviolet radiation, increase in the concentration of CO_2, nitrogen addition, droughts and fires (Cardinale *et al.* 2012; Hooper *et al.*, 2012; Tilman *et al.*, 2012). Experiments can even underestimate biodiversity effects because they do not assess important properties of natural systems that enhance the positive diversity effects, such as complex trophic structures, complementary and mutualistic interspecific relations, non-random biodiversity loss and spatial heterogeneity (Cardinale *et al.* 2012; Duffy *et al.*, 2009; supporting material Appendix 3.1[1]). In addition, biodiversity effects increase with time and at larger spatial scales (Cardinale *et al.* 2012; supporting material Appendix 3.1[1]), which means they may be stronger in real-world systems than in experiments. On the other hand, the range of species richness loss studied in typical biodiversity experiments is far greater than real world biodiversity loss (Vellend *et al.*, 2013).

Comparative field studies have the great potential to show the relevance of biodiversity in real world ecosystems, but they are often not suitable for demonstrating the causality of observed relationships and have difficulties in distinguishing the effects of biodiversity, versus environmental drivers, on ecosystem functioning. Thus, the analysis of field observations needs to separate effects of diversity from other confounding factors (supporting material Appendix 3.1[1]).

In addition to the general consensus about the key role of biodiversity in ecosystem functioning, there is increasing information on the relationships between biodiversity and ecosystem services and, hence, nature's contributions to people (Balvanera *et al.*, 2014). A comprehensive systematic literature review (Harrison *et al.*, 2014) showed that the majority of relationships between biodiversity attributes and the selected 11 ecosystem services were positive. The key role of biodiversity was demonstrated for certain provisioning services (such as wood production in plantations, production of fodder in grasslands, and stability of fisheries yields); and regulating services (such as pollination, resistance to exotic plant invasions and plant pathogens, aboveground carbon sequestration, soil nutrient mineralization, and bioremediation of contaminated water and sediments) (Cardinale *et al.*, 2012; Harrison *et al.*, 2014; Science for Environment Policy, 2015; Thompson *et al.*, 2012). For many other ecosystem services (e.g. long-term carbon storage, suppression of pests and animal disease), the evidence for biodiversity effects is mixed or there are still insufficient data (Balvanera *et al.*, 2014; Cardinale *et al.*, 2012). Overall, however, the evidence to date suggests that sustaining the long-term flow of many ecosystem services will require high levels of biodiversity (Science for Environment Policy, 2015).

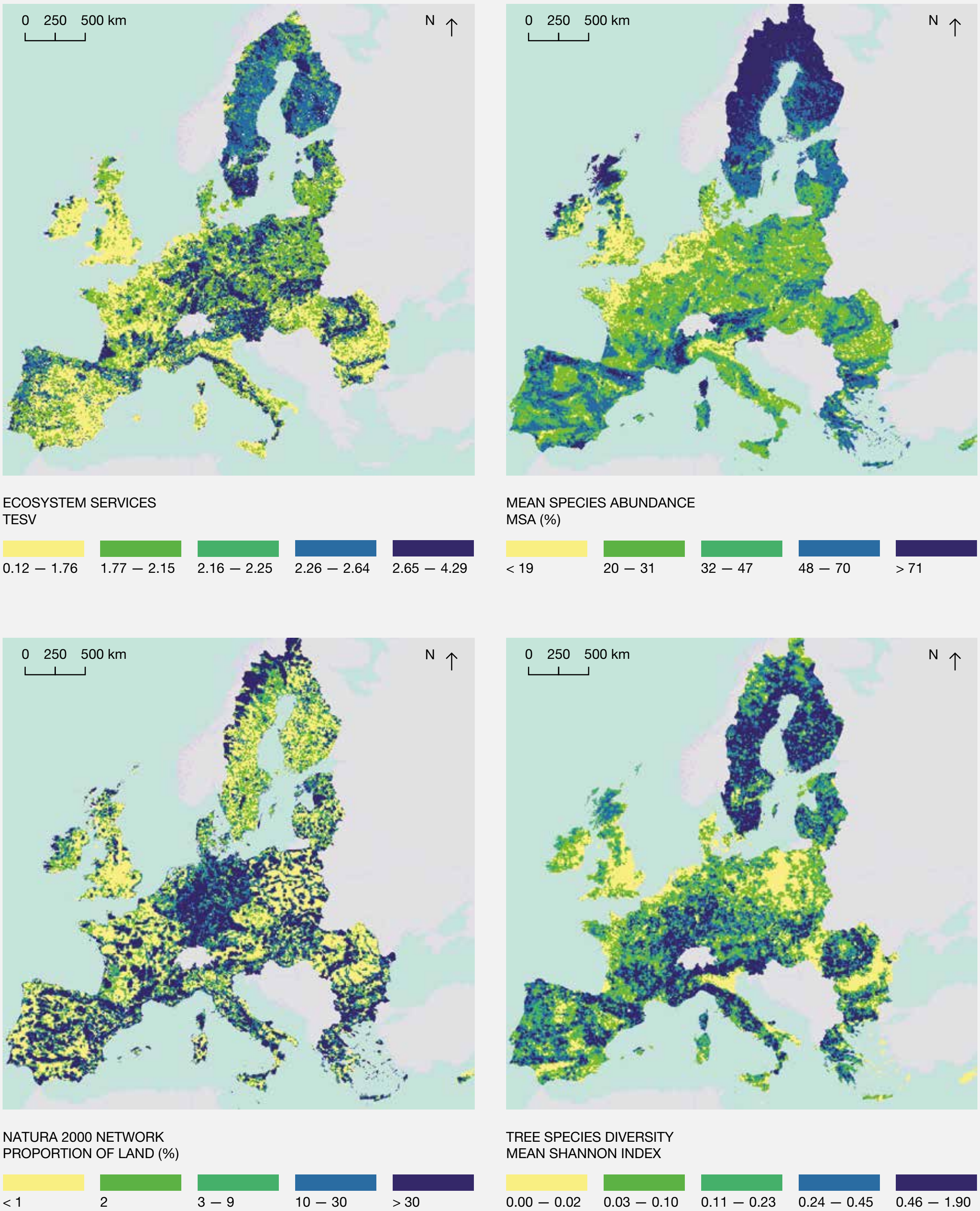
In Europe and Central Asia, field studies revealed generally positive effects of biodiversity on ecosystem services. A European Union-wide assessment (Maes *et al.*, 2012) showed that biodiversity indicators (mean species abundance, tree species diversity and the relative area of Natura 2000 sites) and ecosystem service supply (aggregated index of four provisioning services, five regulating services and one cultural service) were positively correlated with each

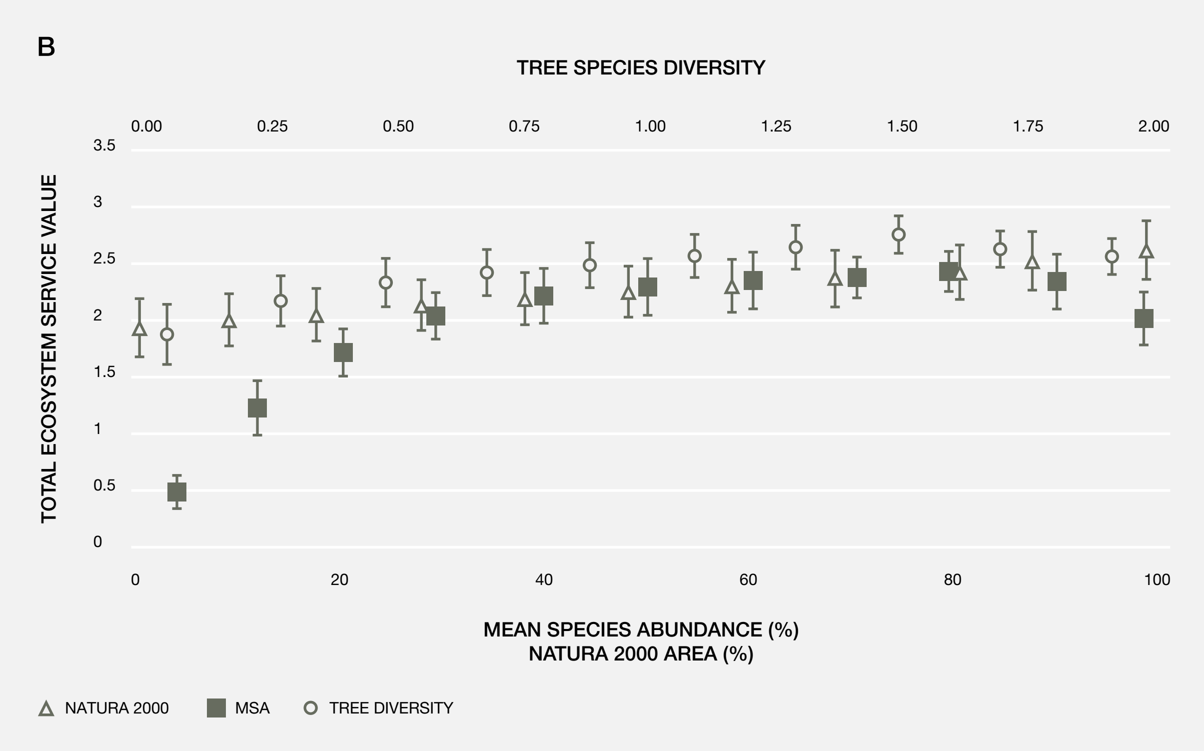
1. Available at https://www.ipbes.net/sites/default/files/eca_ch_3_appendix_3.1_additional_references.pdf

Figure 3 1 **Large-scale relationship between biodiversity and ecosystem service supply in the European Union.**

A Biodiversity and ecosystem services maps. Top left: Total ecosystem service supply calculated as the sum of standardized values for 10 ecosystem service indicators. Top right: Mean Species Abundance. Bottom left: The proportion of protected areas which are part of the Natura 2000 network. Bottom right: The forest tree species diversity measured using the average Shannon Wiener Diversity Index. B Relationship between biodiversity and total ecosystem service supply. Biodiversity is represented using three spatial indicators: Mean Species Abundance (MSA), forest tree species diversity and relative surface area of the Natura 2000 network. Ecosystem service supply is represented by total ecosystem service value. Dots represent the average value of total ecosystem service value for equally distributed classes of the biodiversity proxies. Error bars represent standard deviations. Source: Maes *et al.* (2012).

A





other **(Figure 3.1)**. Overall, habitats in a positive conservation status provided higher levels of biodiversity indicators and had a higher potential to supply ecosystem services, particularly regulating and cultural services, than unprotected areas.

An analysis of data of the UK National Ecosystem Assessment showed that biodiversity plays a key role in providing various types of ecosystem services: as a regulator of ecosystem processes, in providing final ecosystem services, and as a good with intrinsic value (Mace *et al.*, 2012).

An analysis of Swedish forest inventory data showed that relationships between tree species richness and several ecosystem services (production of tree biomass, soil carbon storage, berry production and game production) were positively linear to positively unimodal (Gamfeldt *et al.* 2013). Importantly, no single tree species was able to promote all services, emphasising the need for planting multiple tree species in forest stands to maintain multiple ecosystem services.

Regional studies in Finland (Hanski, 2014; Hanski *et al.*, 2012) confirmed that biodiversity increased immune regulation (von Hertzen *et al.*, 2011) and thus extended the view on ecosystem services to the field of maintaining human health. The findings suggest that loss of biodiversity reduces human exposure to beneficial environmental microbes, with essential immunoregulatory functions and, thus, leads to increasing prevalence of allergies and other chronic inflammatory diseases among urban populations worldwide.

3.2.2 Positive effect of biodiversity on the magnitude of ecosystem functioning

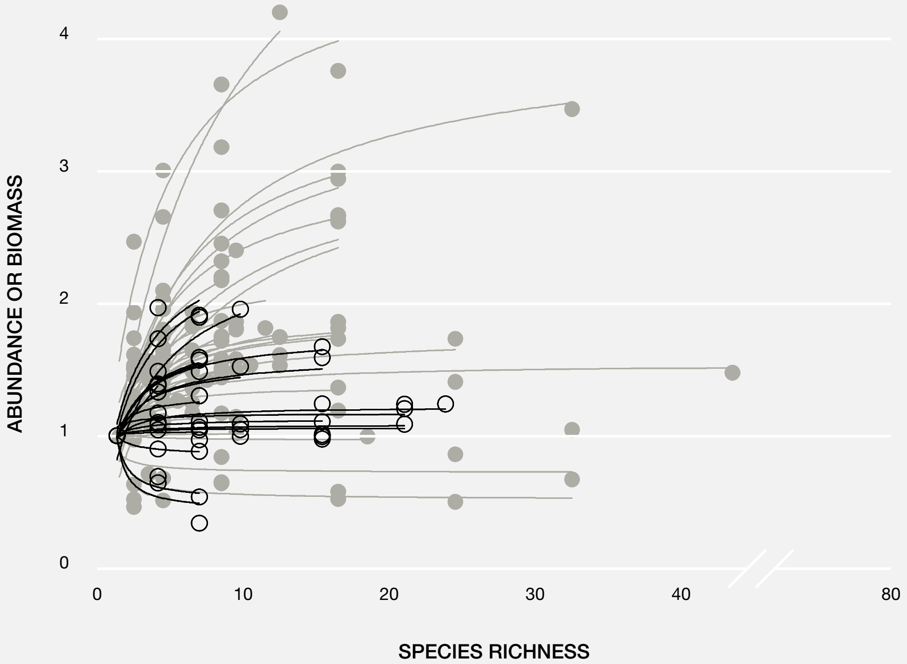
A scientific consensus has been reached that “there is now unequivocal evidence that biodiversity loss reduces the efficiency by which ecological communities capture biologically essential resources, produce biomass, decompose and recycle biologically essential nutrients” (Cardinale *et al.*, 2012). Both diversity within species (intraspecific diversity) and species diversity within communities are important for ecosystem functioning.

Numerous theoretical models describe how competition between individuals of both the same and different species predicts positive effects of species and functional diversity on biomass production and effectiveness of resource use (Tilman *et al.*, 2014). Several hypotheses predict that effects of diversity are more complex and variable in multi-trophic systems, i.e. of systems involving species of different trophic levels of the same food web (see supporting material Appendix 3.1[2]). Population genetics provides a theoretical foundation for the key importance of diversity within a population for population fitness (Lavergne *et al.*, 2010; Wennersten & Forsman, 2012) and thus, their capacity to provide ecosystem functions and services. Theory distinguishes two main classes of mechanisms by which diversity can positively affect ecosystem processes:

2. Available at https://www.ipbes.net/sites/default/files/eca_ch_3_appendix_3.1_additional_references.pdf

Figure 3 2 **The general form of the diversity-biomass production relationship. Effects of species richness on the standing stock abundance or biomass of the same trophic group.**

Each curve corresponds to data from a single study (grey circles and lines – terrestrial studies, black circles and lines – aquatic studies). Source: Cardinale *et al.* (2006). Reprinted by permission from Macmillan Publishers Ltd.



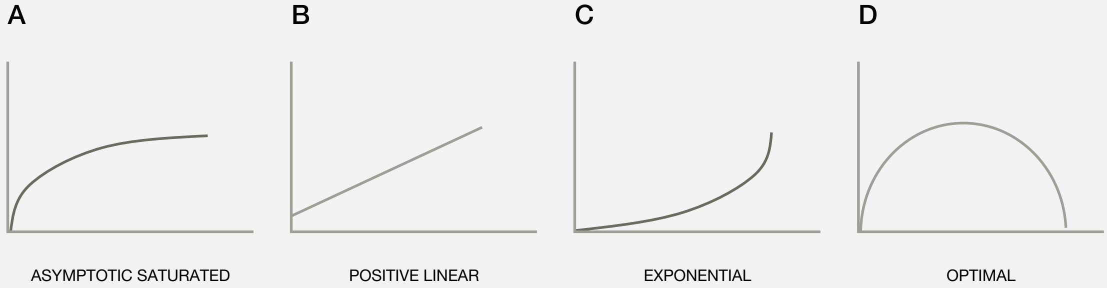
a) complementarity effects, i.e. functional complementarity in, for example, resource use of species or genotypes or phenotypes or due to positive (facilitative) species interactions; and b) selection effects, i.e. selection of particular functional traits of species or genotypes or phenotypes, with beneficial effects for ecosystem processes (for example the tendency of fast-growing plant species to become dominant in diverse communities) (Bolnick *et al.*, 2011; Forsman & Wennersten, 2016; Hughes *et al.*, 2008; Loreau, 2010).

Meta-analyses and reviews of hundreds of experiments revealed predominantly positive effects of species richness on community-level functioning (productivity, biomass, abundance, rate of nutrient cycling, invasion resistance, etc.). Negative effects were also found, but to a lesser extent **(Figure 3.2)** (Bardgett & van der Putten, 2014; Cardinale *et al.*, 2012; Gamfeldt *et al.*, 2015; Handa *et al.* 2014; supporting material Appendix 3.1[2]). Dozens of experiments with bacteria, plants, and invertebrate and vertebrate animals, showed positive effects of genetic diversity on ecosystem functioning (Forsman, 2014; Forsman & Wennersten, 2016; Hughes *et al.*, 2008; supporting material Appendix 3.1[2]). At the population level, high genetic diversity increases productivity, biomass, fitness, resistance and stability. At the community level, high genetic diversity (per species) decreases the probability of alien species invasions, disease levels, and increases the abundance and species diversity of consumers. At the ecosystem level, high genetic diversity in dominant plant species increases decomposition rates and nutrient cycling (Forsman, 2014; Forsman, Wennersten, 2016; Hughes *et al.*, 2008).

Comparative field studies also demonstrated positive impacts of species and functional diversity on ecosystem functioning (productivity, biomass, aboveground carbon stocks, soil carbon content, nutrient cycling, resource use efficiency) in real-world terrestrial, freshwater and marine ecosystems across the world (Grace *et al*, 2016; Lewandowska *et al.*, 2016; Maestre *et al.*, 2016; Mora *et al.*, 2011; supporting material Appendix 3.1[2]). Field observations of plants, invertebrates, amphibians, reptiles, birds and mammals confirmed the importance of intraspecific diversity for population fitness and functioning (Forsman & Wennersten, 2016; Hughes *et al.*, 2008) that was also expressed in a decline of fitness and adaptability due to a loss of genetic diversity in small or anthropogenically disturbed populations (see supporting material Appendix 3.1[2]).

More specifically, comparative field observations also showed that positive biodiversity effects are widespread in Europe and Central Asia. Analysis of forests across Western and Central Europe revealed positive effect of tree species richness on biomass production (Jucker *et al.*,

Figure 3 3 **Shapes of relationships between biodiversity and ecosystem processes. From left to right: asymptotic saturated; positive linear; exponential; optimal.**



2014, 2016; Vilà *et al.*, 2013). Eight Western and Central European field studies of five animal groups (bees, carabid beetles, earthworms, soil nematodes and dung beetles), which deliver several key ecosystem functions (pollination, biocontrol of pests and weeds, bioturbation, nutrient cycling) revealed a positive relationship between functional diversity and ecosystem functioning provided by animals (Gagic *et al.*, 2015).

The shape of the relationship between biodiversity and ecosystem functioning is crucially important for ecological management. Most experiments that manipulated species richness revealed an asymptotic saturating relationship (see A in **Figure 3.3**) between diversity and ecosystem processes (Cardinale *et al.*, 2006, 2012). Most experiments that manipulated genetic diversity revealed a positive linear relationship (B in **Figure 3.3**) (Forsman & Wennersten, 2016). However, two recent large-scale field observational studies on sea communities detected exponential relationships (C in **Figure 3.3**) (Danovaro *et al.*, 2008; Mora *et al.*, 2011).

The asymptotically saturating pattern found in many experiments implies that the loss in ecosystem functioning accelerates as biodiversity loss increases. This suggests that the loss of a few species from a very species-rich community may have less deleterious consequences for ecosystem functioning than the loss of species from a species-poor community. In the case of a linear relationship, the loss of any species will equally decrease functioning. In the case of an exponential pattern, the loss of species will even cause an exponential decline in ecosystem functioning (Danovaro *et al.*, 2008; Loreau, 2008; Mora *et al.*, 2014). The unimodal shape suggests that there are optimal diversity values that correspond to maximum levels of ecosystem functioning, thus both a decrease and increase of diversity away from the optimal values leads to reduced ecosystem functioning. The optimal diversity values can often be regarded as typical for undisturbed populations and communities, which would suggest that the preservation of typical diversity may at the same time maintain ecosystem functioning (see 3.1.4).

Theoretically, the shape of the relationship between species richness and ecosystem processes depends on the degree of species niche overlapping and dominance - if species niches largely overlap (species are functionally redundant) the relationship is asymptotically saturating. If niches practically do not overlap (species carry out different functions) the relationship is close to linear (Loreau, 2000; Petchey, 2000; Tilman *et al.*, 2014). Mutualistic species interrelations can cause an exponential relationship (Loreau, 2008). The order of species extinctions also changes the shape of the relationship, particularly, saturating relationships are observed when species go extinct from the least efficient to the most efficient and exponential relationships when species are lost in the reverse order (see supporting material Appendix 3.1[3]). Unimodal relationships occur when ecosystem functioning peaks at intermediate biodiversity (D in **Figure 3.3**) and are predicted by some theoretical models (Bond & Chase, 2002; Bukvareva & Aleshchenko, 2013; Bukvareva, 2014). These were detected in some experiments manipulating genetic diversity (Caesar *et al.*, 2010; Burls *et al.*, 2014) and in wild populations of spruce and salmon (Altukhov, 2003). Experiments with communities of littoral psammophilous (i.e. sand-living) ciliates of the White Sea showed that the width of the group's trophic niche (i.e. the suite of used resources) was highest at intermediate species richness (Azovsky, 1989). Passy and Legendre (2006) found the highest biovolume (a surrogate for biomass) of algae at intermediate species richness in freshwater communities.

3.2.3 Effects of biodiversity on stability and resilience of ecosystem functioning

There is now a consensus that biodiversity increases the stability of ecosystem functions through time (Cardinale *et al.* 2012). Theoretical models predict that community stability is

3. Available at https://www.ipbes.net/sites/default/files/eca_ch_3_appendix_3.1_additional_references.pdf

an increasing function of species richness, while population stability often decreases with species richness (Tilman *et al.*, 2014). Two main hypotheses known as the "portfolio effect" and the "insurance hypothesis" predict a stabilizing effect of species diversity. The "portfolio effect" posits higher likelihood of stabilization due to asynchrony in species responses to environmental fluctuations and stochastic ecological mechanisms, where the decline of one species is compensated by an increase in another species (Loreau, 2010; supporting material Appendix 3.1[3]). The "insurance hypothesis", positing that more diverse communities have a higher likelihood that at least some species function well under various conditions, was supported by simulation models using data of Central European forests (Morin *et al.*,

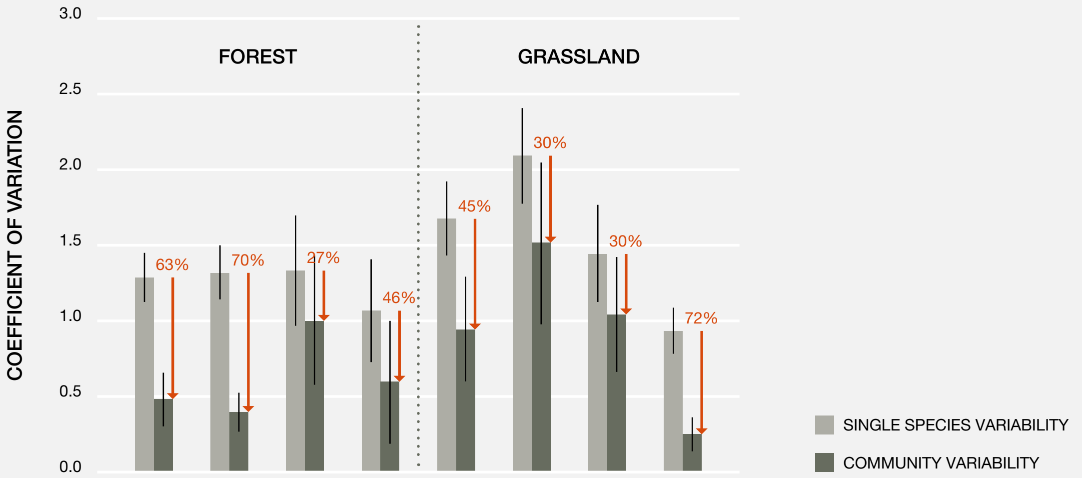
Figure 3 4 **A Biomass stability in diverse grassland and forest communities is higher than within single species.**

Communities had a lower inter-annual variability in total abundance than single species. The figure shows strong decreases in total abundance variability - and thus increased stability (arrows) - compared with the mean species variability, resulting from portfolio effects and species asynchrony. Four taxa with multiple species (arthropods, birds, bats and plants) in forests and grasslands were compared. Differences in stability between forests and grasslands in interaction with taxon were highly significant, whereas the relative stability gain between the two habitats was not. Source: Blüthgen *et al.* (2016).

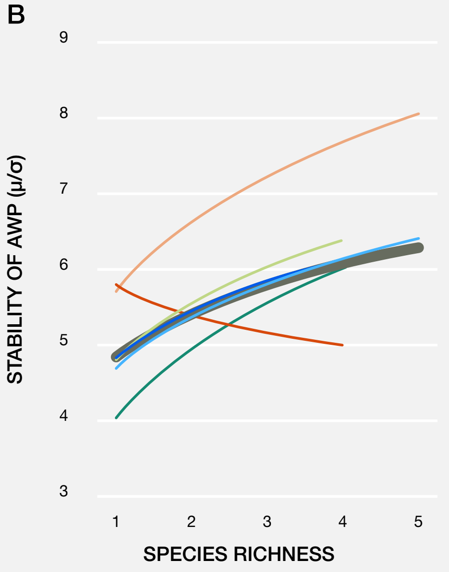
B Community stability as a function of forest tree diversity.

The graph shows the fitted relationship between stability of aboveground wood production (AWP) and species richness across the entire plot network (black line) and for each site separately (coloured lines: Spain = red; Italy = orange; Germany = dark green; Romania = light green; Poland = light blue; Finland = dark blue). Source: Jucker *et al.* (2014).

A



B



2014). Population models predict that similar mechanisms can provide stabilizing effects of intra-population diversity on populations and species (Bolnick *et al.*, 2011; Forsman & Wennersten, 2016; Hughes *et al.*, 2008; supporting material Appendix 3.1[4]). There is also evidence that resilience of ecosystem functioning (i.e. maintenance of ecosystem functioning under a range of environmental perturbations that could occur in the near future) is ensured by all levels of biodiversity - intraspecific genetic diversity, adaptive phenotypic plasticity, species diversity and spatial heterogeneity of habitats (Oliver *et al.*, 2015).

Grassland experiments fully confirmed theoretical assumptions showing that community stability increases with species richness due to averaging effects, while population stability decreases with species richness due to smaller population sizes (Griffin *et al.*, 2009; Gross *et al.*, 2014; Hector *et al.*, 2010; Tilman *et al.*, 2014; supporting material Appendix 3.1[4]). Furthermore, field observations in grasslands across five continents also showed positive relationships between species richness and stability in biomass production, but only in un-manipulated communities of non-fertilized grasslands (Hautier *et al.*, 2014). The importance of intraspecific diversity for population stability has been demonstrated for wild fish populations (see supporting material Appendix 3.1[4]).

In Western and Central Europe, forest surveys showed that aboveground wood production is more stable in forests with higher tree species richness due to asynchronous responses of species to climate and due to greater temporal stability in the growth rates of individual tree species. Thus, the central role of diversity in stabilizing productivity was revealed for European forests (Jucker *et al.* 2014). Furthermore, studies of inter-annual fluctuations of 2,671 plant, arthropod, bird and bat species in German forests and grasslands demonstrated that species diversity provides community stability due to asynchronous changes in the abundance of different species (**Figure 3.4**, Blüthgen *et al.*, 2016).

3.2.4 Importance of all hierarchical levels of biodiversity

Measures of diversity other than species diversity have received less attention in literature on biodiversity and ecosystem functioning. However, intra-population diversity (i.e. genetic and phenotypic variation within populations) and intraspecific diversity (i.e. local populations, ecological and morphological forms composing species) are crucially important for fitness, adaptability and long-term viability of populations and species (Lavergne *et al.*, 2010). Maintaining the evolutionary perspective of species and ecosystems is necessary to ensure ecosystem functioning and services into the future, while the loss of intra-population or intraspecific diversity undermines species' ability to adapt and evolve in a changing environment (Lavergne *et al.*, 2010; supporting material Appendix 3.1[4]). The loss of intra-population or intra-specific diversity also weakens and destabilizes ecosystem functioning (3.2.2 and 3.2.3). Diversity assessments that ignore intraspecific diversity may underestimate biodiversity changes and even lead to ineffective conservation practices. This is highly risky, since the loss of intra-specific diversity is already occurring and is projected to continue in the future in Europe and Central Asia (Balint *et al.*, 2011; Habel *et al.*, 2011; Neaves *et al.*, 2015; Pauls *et al.*, 2013; Taubmann *et al.*, 2011).

Experimental and field studies demonstrated that functional diversity (i.e. diversity of species functional traits or diversity of functional groups of species) is no less important than species diversity (Cardinale *et al.*, 2012; Cadotte *et al.*, 2011; Gagic *et al.*, 2015; Gamfeldt *et al.*, 2015; Gravel *et al.*, 2016; Lefcheck *et al.*, 2015; Mouchet *et al.*, 2010; supporting material Appendix 3.1[4]). Functional traits both of key species and rare species are important because the former have a large influence on community productivity (Cardinale *et al.*, 2012) and the latter can provide the most distinct trait combinations (Mouillot *et al.*, 2013). Phylogenetic diversity is the variation in the evolutionary origin of co-occurring species. It can be important for ecosystem functioning along with species and functional diversity (Cardinale *et al.* 2012; Mace *et al.*, 2003) (see supporting material Appendix 3.1[4]). Functional and phylogenetic homogenization across Europe were predicted for plants, birds and mammals, due to changes of climate and land use (Thuiller *et al.*, 2011, 2014b). Phylogenetic diversity over multiple taxonomic groups is considered as indicator of nature's contribution to people number 18, maintenance of options (Faith, 1992, Gascon *et al.*, 2015, Faith, 2017; Chapter 2, Section 2.2.3.4). Thus, accounting for these biodiversity facets appears important for the prediction of future ecosystem functions and services.

The structure of interspecific relations, including food webs, is also a key feature of biodiversity. Particularly, there is now consensus that the "loss of diversity across trophic levels has the potential to influence ecosystem functions even more strongly than diversity loss within trophic levels" (Cardinale *et al.*, 2012). Experiments and simulations demonstrated the importance of the structure of food webs for ecosystem functioning. For example, the loss of consumers at higher trophic levels can cascade through a food web to influence structure and functioning of the whole ecosystem (see supporting material Appendix 3.1[4]).

The diversity of ecosystems, communities and habitats is also of crucial importance for ecosystem functioning. Recent experiments demonstrated the importance of habitat

4. Available at https://www.ipbes.net/sites/default/files/eca_ch_3_appendix_3.1_additional_references.pdf

diversity for ecosystem multifunctionality (Alsterberg *et al.*, 2017). Because biodiversity responds to environmental conditions and is itself driving ecosystem functioning (3.2.1), communities that are adapted to some conditions typically have high species diversity, while communities adapted to other, more stressful (e.g. Arctic), conditions have a low diversity. Global positive correlations between taxonomic diversity and temperature, evapotranspiration and other proxies of energy supply are well known (see supporting material Appendix 3.1[4]). Meta-analyses across similar communities, especially grasslands, at the global, or regional scales revealed positive, unimodal, and negative correlations between species richness and productivity (see supporting material Appendix 3.1[4]). However, this does not contradict the positive biodiversity effect on productivity within each local community (Loreau *et al.*, 2001; Schmid, 2002).

To maintain stable and effective ecosystem functioning in a landscape, maintaining undisturbed communities adapted to specific conditions (e.g. in peatlands, or rocky or sandy habitats) is required. Even though they typically may have lower species diversity than communities in other types of habitats, the diversity of undisturbed communities is still higher than the one of disturbed communities of the same habitat type. For example, Anderson *et al.* (2009) found that the distribution of carbon stocks in Britain was negatively correlated with species richness, as high carbon stocks were predominantly found in (inherently) species poor heathlands. In this case, communities typical of northern peat ecosystems, with low biodiversity, were likely most suitable for ecosystem functioning. Plant species from more diverse communities present in other habitat types are not adapted to the nutrient-poor conditions in peat ecosystems, and therefore do not function as well as the few species that are more typically found there. This case illustrates that the relevance of biodiversity for ecosystem functioning is revealed by comparisons between differently biodiverse ecosystems of the same type rather than by comparing between different types of ecosystems. Simply correlating biodiversity with ecosystem functioning across different ecosystem types ignores the fact that potential local biodiversity is not the same for all ecosystems, but depends on local environmental conditions (Schmid, 2002).

3.2.5 Long-term maintenance of multiple ecosystem functions and services

Maintaining multiple ecosystem processes at multiple places and times requires higher levels of biodiversity than does a single process at a single place and time, as shown by many studies (Byrnes *et al.* 2014; Cardinale *et al.* 2012; Hector & Bagchi, 2007; Isbell *et al.* 2011; Maestre *et al.* 2012; Zavaleta *et al.*, 2010). For example, Isbell *et al.* (2011) demonstrated that 84% of the 147 grassland plant species in their study, including many rare species, promoted ecosystem functioning in at least one situation. Different species promoted different types of ecosystem functions, during different years, at different places, and under different environmental contexts. These results indicate that even more species will be needed to maintain ecosystem functioning than previously suggested by studies that have considered only the number of species needed to promote one function under one set of environmental conditions.

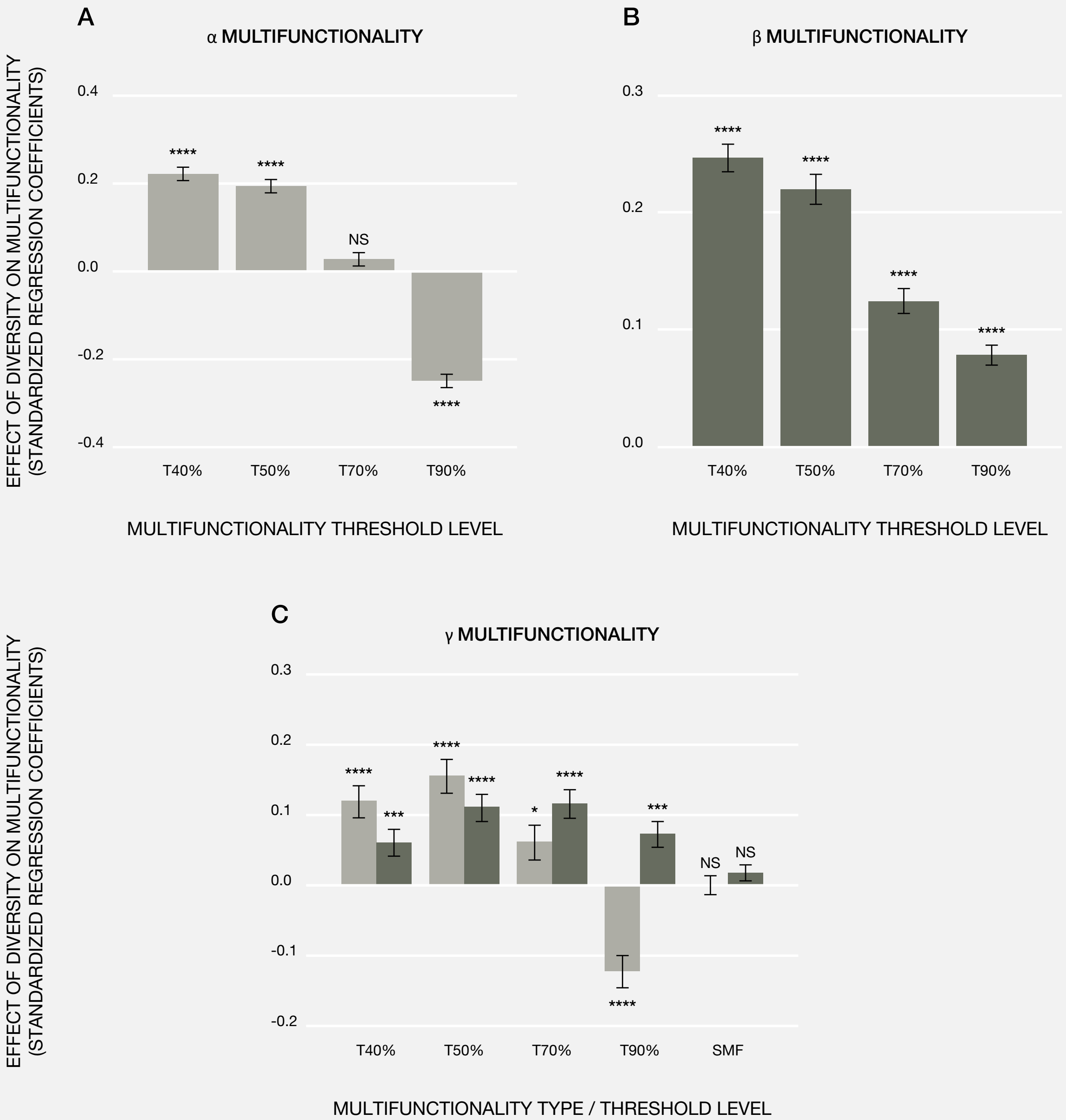
Inclusion of ecosystem multifunctionality (i.e. the provision of multiple ecosystem functions or services) in community models shows that multifunctional redundancy is generally lower than single-function redundancy. This means that a moderate loss of species can lead to a stronger loss of ecosystem multifunctionality than of individual ecosystem functions (Gamfeldt *et al.*, 2008). At the same time, the loss of multifunctionality due to biodiversity loss also depends on non-additive effects of biodiversity on individual functions (Gamfeldt *et al.*, 2017).

Field studies in Europe and Central Asia confirmed an important role of biodiversity for multiple ecosystem functions (ecosystem multifunctionality) in the real world. In a study across six Western and Central European countries, van der Plas *et al.* (2016a) showed that at local scales, relationships between local (so-called α) tree diversity and ecosystem multifunctionality can be either positive or negative, and strongly depend on how multifunctionality is quantified. However, larger scale (so-called β) tree diversity, quantified as the differences in tree species composition among sites, positively affected spatial turnover in the types of ecosystems that were provided at high levels (β-multifunctionality) and hence landscape-scale (so-called γ-) multifunctionality, across countries, emphasizing the scale-dependency of diversity-functioning relationships and the need for landscape-level forest diversity (van der Plas *et al.* 2016b) **(Figure 3.5)**. Hence, forest management leading to biotic homogenization can have negative consequences for large-scale ecosystem multifunctionality, whereas promoting forest stands varying in tree species composition will have positive influences on large-scale forest ecosystem multifunctionality.

A well replicated multisite study of 150 grasslands in Germany showed that plant biodiversity loss driven by land-use intensification also leads to loss of functions related to nutrient cycling, pest control, pollination and cultural services. While the effects on nutrient cycling, pest control and pollination varied among regions, effects of plant diversity loss consistently led to a loss in cultural services (Allan *et al.*, 2015). In the same grasslands, Soliveres *et al.* (2016a) revealed the importance of the diversity of locally rare species (plants, invertebrates, fungi, protists and bacteria) for ecosystem multifunctionality. Locally rare

Figure 3 5 **Effects of local plot-scale richness of tree species (alpha-diversity) and the turnover of tree species among plots (beta-diversity) on local (α) multifunctionality, functional turnover (β multifunctionality) and landscape-scale (γ-) multifunctionality.**

Bars represent the standardized regression coefficients of α-diversity (light grey) and β-diversity (dark grey) in statistical models explaining α- A, β- B, or γ- C multifunctionality. Multifunctionality was quantified at different scales using a threshold approach, with thresholds of 40%, 50%, 70%, and 90%. In addition, sum-based γ-multifunctionality was calculated as the sum of scaled (between 0 and 1) individual function values. Diversity measures were calculated based on individuals of regionally common tree species.
Source: van der Plas *et al.* (2016b).



above-ground species were associated with high levels of multifunctionality, while common species were only related to average, not high, levels of multifunctionality. Furthermore, Soliveres *et al.* (2016b) showed that not only plants are important for multiple ecosystem functions and services, but that the diversity of other trophic groups, particularly aboveground herbivores and microorganisms, is also extremely important for the maintenance of multiple ecosystem functions and services in grasslands.

Different ecosystem services profit from different types of management. Provisioning services often peak under intensive use of populations and ecosystems and at relatively low levels of biodiversity (Science for Environment Policy, 2015). Optimizing ecosystems for certain provisioning services, especially food, fibre and biofuel production has, however, greatly simplified their structure, composition and functioning across scales. While this simplification has enhanced certain provisioning services, it reduced others, particularly regulating services, and this simplification has led to major losses of biodiversity (Cardinale *et al.*, 2012). Mapping of four provisioning services, five regulating services and one cultural service across Western and Central Europe also revealed spatial trade-offs among ecosystem services, in particular between the provisioning service of crop production and regulating services (Maes *et al.*, 2011, 2012).

In summary, provisioning multiple ecosystem services requires maintaining and promoting high biodiversity within and between ecosystems. This implies high overall synergy between the goals of maintaining and promoting biodiversity and of maintaining and promoting multiple ecosystem services.

3.3 PAST AND CURRENT TRENDS IN BIODIVERSITY AND ECOSYSTEMS BY UNIT OF ANALYSIS

3.3.1 Introduction

Europe and Central Asia embrace a diversity of biogeographical regions from Arctic snow and ice-dominated systems in the north to Mediterranean forest and deserts in the south (Chapter 1, Section 1.3.4). The variety of the ecosystems also includes tundra, alpine and subalpine systems, temperate, boreal, tropical and subtropical dry and humid forests, peatlands, grasslands and deserts. The region also has important anthropogenic land cover types including agricultural and urban areas that are found across biogeographical regions. These categories are collectively referred to as terrestrial units of analysis, and in this section on past and current trends are addressed roughly sequentially from the north to the south of the region (Section 3.3.2), along with two examples of special ecosystems of relevance in the region, heathlands, and caves and other subterranean habitats. This is followed by a section on status and trends of biodiversity and ecosystems for inland surface waters (Section 3.3.3), which includes the categories of freshwater habitats and saline lakes. Finally, Section 3.3.4 addresses status and trends of biodiversity and ecosystems for marine systems, including the North Eastern Atlantic Ocean, Baltic Sea, Mediterranean Sea, Black and Azov Sea, Arctic Ocean, and North Western Pacific Ocean, and the Deep Sea parts of the region and progress toward goals of Multilateral Environmental Agreements. The section is concluded by a box summarizing the trends for all terrestrial, inland surface water and marine systems in the overview **Table 3.5** and **Figure 3.43**.

3.3.2 Terrestrial Ecosystems

3.3.2.1 Snow- and ice-dominated systems

OVERVIEW OF THE SUB-SYSTEM

Glaciers and nival mountain belt

Currently glaciers are present in the high Arctic and in mountains in Europe and Central Asia. Glaciers extend for 55,800 km^2 in the Russian Arctic, 35,100 km^2 in Svalbard and 11,800 km^2 in Iceland. The average ice thickness varies from 280-300 m (Novaya Zemlya) to 200 m (Severnaya Zemlya) and 100 m (Franz-Joseph Land). Glaciers flowing into the sea break off forming icebergs in some coastal areas. In mountains, they extend for 25,400 km^2 in Scandinavia, the Alps, the Apennines and the Pyrenees, Siberia, the Caucasus, Altay, Tien Shan and Pamir (Milkov, 1977; UNEP-WGMS, 2008; Kotlyakov, 2010; AMAP, 2012; IPCC, 2013; Roshydromet, 2014; Zimnitskiy *et al.* 2015). The nival belt in mountains is characterized by extremely harsh conditions: low average annual temperature (<3.5°C) and a brief vegetation growing season (<10 days) (Körner *et al.*, 2011). In the higher mountains of the Europe and Central Asia region, "dry permafrost" in bedrock and moraines prevents the formation of continuous vegetation cover. In the northern Scandes, the lower limit for dry permafrost is currently at 1,300 m a.s.l. (Bockheim & Tarnocai, 1998).

Polar deserts

The Arctic deserts are spread over the far north of the Arctic Circle. The scant vegetation of the Arctic desert covers less than 50-60% of the soil surface, consisting of mosses, lichens, algae and a few species of higher plants (Milkov & Gwozdecky, 1969). These landscapes are common on Svalbard, Iceland, Arctic Ocean archipelagos and the Cheluskin Peninsula in Taimyr (Diakonov *et al.*, 2004; Matveeva, 2015).

The vegetation productivity here is negligible (Aleksandrova, 1983). Total biomass stock is less than 5 t/ha, dominated by above-ground biomass, thus distinguishing polar deserts from other habitats. Low vegetation productivity causes poor faunal diversity. At the extreme north of the zone only colonies of sea birds on rocky shores nest in summer and form so-called rookeries (especially on Novaya Zemlya and the Franz Joseph Land) (Milkov, 1977; Bliss *et al.*, 1981; CAFF, 2013).

PAST AND CURRENT TRENDS

The glaciation of the Russian Arctic has decreased by 725 km^2 in area and 250 km^3 in volume over the last 50 years, especially in western and central areas - 30% of it by icebergs and 70% by melting (Kotlyakov, 2010; Roshydromet, 2014). The mountain glaciers of southern Russia have decreased even more: by 40% in the Caucasus, 20% in the Altay and 30% in the Sayan Mountains relative to the mid-20th century (UNEP-WGMS, 2008). In the Alps, glaciers lost 35% of their total area from 1850 to 1970 and almost 50% by 2000 (Zemp *et al.* 2006). The lower limit for high alpine "dry" permafrost has been escalating rapidly over recent decades (IPCC, 2014a; Arctic Council, 2013).

Arctic deserts are extremely vulnerable to climate change because of greater than global average warming, decrease of ice and increase of permafrost melting in the Polar region. The warming and permafrost melting lead to more favourable conditions for plants, leading to an increase in species richness and productivity; and subsequently to the shift of vegetation type to tundra. While plant species richness increases, some vulnerable species are affected negatively and decline (Callaghan *et al.*, 2004; Callaghan *et al.*, 2005; Wolf *et al.*, 2008; IPCC, 2014a; Roshydromet, 2014). At the same time better climate conditions let people use natural resources more actively (Government of the Russian Federation, 2013).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Glaciers play an important regulating role for reindeer in the Altay Mountains in summer, as animals spend day time on ice to avoid blood-sucking insects. Shrinking of glaciers leads to concentration of reindeer in remaining places and limits their population size (Artemov *et al.*, 2013). The same function applies to snowbeds in the northern Scandes, where reindeer herds escape parasitic insects in warm summer days. This also allows them to see predators (e.g. wolverine) before they get close (Reimers *et al.*, 2006).

Reduction of the period during which the sea is covered in ice, means that polar bears are forced to stay on land for longer periods of time. Studies show that a one week shift in the ice melt in spring leads to 10 kg weight loss of a bear (Morgunov, 2011). Permafrost melting also leads to erosion of landscapes and destruction of the sea shore, as previously frozen surfaces become softer and more boggy. This can sometimes result in a fast decline in the area of islands – up to 10 m per year (Roshydromet, 2014).

Pollution and mining can have dramatic local effects, including complete destruction of vegetation. However, most Arctic deserts and mountain peaks are far from main industrial human activity, and are therefore not severely affected (CAFF, 2013; Shukurov *et al.*, 2015).

Tourism development, especially ski slopes, in high mountain ecosystems can cause their fragmentation, disturbance to animals, and land degradation in local plots (Sokratov *et al.*, 2014).

Poaching of rare charismatic animals for illegal trading leads to a decline of their populations in Arctic deserts, especially polar bears (classified as vulnerable A3c, Wiig *et al.*, 2015; CAFF, 2013). The snow leopard (vulnerable C1, McCarthy *et al.*, 2017) is another similar example of a species affected by illegal poaching and human-wildlife conflict in high mountains (Paltsyn *et al.*, 2012).

3.3.2.2 Tundra and mountain grasslands (only high elevation grasslands)

OVERVIEW OF THE SUB-SYSTEM

Tundra

Tundra refers to areas with permafrost, where the temperature is too low, precipitation too high and winds are too strong to allow for forest growth (Wielgolaski, 1972). Tundra is found on islands and on the mainland coast of the Arctic Ocean from the Kola Peninsula in the west to Chukotka in the east; and a vegetation belt in mountains from Scandinavia in the west to Kamchatka in the east and to Pamir and Tien Shan in the south (Milkov, 1977; Bliss & Matveyeva, 1992; Walker *et al.*, 2005).

Arctic tundra is a narrow strip along the ocean coast in Iceland, on many Islands in the Arctic Ocean and from the Barents Sea to Chukotka (Walker *et al.*, 2005). There are only two layers of vegetation, grasses and mosses, with some bushes and open soil (Diakonov *et al.*, 2004; Vasiliev *et al.*, 1941, Aleksandrova, 1970; Bliss *et al.*, 1981). Lichen and moss tundra is located in Iceland and in continental Eurasia, stretching in a band from the Kola Peninsula in the west to the Lena River in the east. Xerophilous and mesophilous mosses and some low shrubs are also abundant (Vasiliev *et al.*, 1941, Aleksandrova, 1970; Bliss *et al*., 1981; Diakonov *et al.*, 2004). To the south on the continent the moss and lichen tundra is replaced by shrubs, commonly consisting of dwarf birches and bush willows. The lichen-moss layer contains more grasses and forest plants (Vasiliev *et al.*, 1941; Aleksandrova, 1970; Bliss *et al.*, 1981).

PAST AND CURRENT TRENDS

Remote and very slow naturaly recovering tundra areas were undisturbed by human impact for centuries. Currently climate change affects the tundra through global warming, opening access into the Arctic. The overall trend is towards a greater human footprint (CAFF, 2013; Government of the Russian Federation, 2013).

The northward (and upward on mountains) range shift of species is also observed by both scientists and Arctic residents. Range shifts of plants averaging 6.1 km per decade toward the poles and 6.1 m per decade in altitude have been identified in response to a mean advancement of spring (initiation of greening) by two to three days per decade (Callaghan *et al.*, 2005; Morgunov, 2011, CAFF, 2013; IPCC, 2014a).

Lemming life cycles have changed in some Arctic regions probably due to changes in timing and quality of snow accumulation, with consequent impacts for lemming predators and alternative prey (Cornulier *et al.*, 2013, Henden *et al.*, 2010; Terraube *et al.*, 2011; Killengreen *et al.*, 2012; Terraube *et al.*, 2012; Schmidt *et al.*, 2012; Hamel *et al.*, 2013; Millon *et al.*, 2014).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Mechanical disturbance of the soil and vegetation cover leads to ecosystem fragmentation (Kumpula *et al.*, 2012), formation of artificial habitats and their colonization by weeds. Off-road driving with tracked vehicles poses a problem in parts of the Arctic, especially in Eastern Europe, where impacts on tundra vegetation can persist for decades following the disturbance (CAFF, 2013). Mechanical disturbances include thermokarst induced by the thawing of permafrost; freeze–thaw processes; wind, sand, and ice blasts; seasonal ice oscillations; slope processes; snow load; flooding during thaw; changes in river volume; coastal erosion and flooding. Biological disturbances include insect-pest outbreaks, peaks of grazing animals that have cyclic populations, and fire (Callaghan *et al.*, 2005). Overgrazing by domestic reindeer causes destruction of vegetation cover (Morgunov, 2011; Aleynikov *et al.*, 2014), - a widespread direct human-induced pressure on terrestrial Arctic in Europe and Central Asia (CAFF, 2013).

The Arctic stands out in terms of climate change effects on biodiversity (Callaghan *et al.*, 2005), including a prolongation of the growing season and an increase in productivity (for plants), nesting period (for birds), and warm season (for invertebrates). Climate change has led to a northward shift of the tundra-forest boundary; the extension of some species ranges, changing migration patterns; and to the introduction of alien species. An increase in the frequency of climatic anomalies such as winter thaw, summer frosts, increased precipitation, including snow, leads to the mass deaths of animals (e.g. reindeer and waterfowl) (Bhatt *et al.*, 2010; CAFF, 2013; Gauthier *et al.*, 2013; Hudson & Henry, 2009; IPCC, 2014a, 2014b; Morgunov, 2011; Raynolds *et al.*, 2006; Xu *et al.*, 2013).

Poaching and unregulated use of biological resources affect rare and vulnerable species. Polar bear poaching in Eastern Russian coastal tundra estimated at 100-200 animals per year (Kochnev, 2004; Morgunov, 2011; Kochnev & Zdor, 2014). While gathering goose down or hunting for birds and animals for food, local people may be unaware of the species national conservation status (Danilov-Danilyan *et al.*, 2001; Lavrinenko & Lavrinenko, 2006) and protection by law (Aleynikov *et al.*, 2014).

Intentional and unintentional introduction of alien species in Arctic ecosystems is ongoing. Fifteen alien invertebrate species, for example, have settled in Svalbard, many of them introduced via imported soils (Coulson, 2015).

Pollution by oil spills, mining or toxic waste dumps can transform or destroy vegetation cover and animal populations (Kumpula *et al.*, 2011; Virtanen *et al.*, 2002). Persistent organic pollutants and heavy metals accumulate in Arctic ecosystems, despite being produced and released in temperate and tropical regions, due to global atmospheric circulation (CAFF, 2013).

Subalpine and Alpine ecosystems

The alpine mountain belt is situated above subalpine and below snow and ice dominated ecosystems. The alpine vegetation comprises mainly perennial grasses, sedges, forbs, prostrate shrubs, cushions, tussocks, bryophytes and lichens (Körner, 2003; Körner *et al.*, 2011). It demonstrates high rates of local endemism (Grabherr *et al.*, 1995). Mountain tundra (as a variant of the alpine type) is most developed in Eastern Siberia, but can be found in all high mountains in Eurasia from the Urals to Kamchatka and from the Arctic to Tien Shan (Vasiliev *et al.*, 1941; Aleksandrova, 1970). Central Asian mountains contain a very specific variation of the alpine belt in extremely dry climate – alpine deserts in Pamir (Breckle & Wucherer, 2006).

The subalpine mountain belt is an ecotone zone between forest or steppe and alpine vegetation belts. It occurs at elevations from the sea level in the Kurily Islands in the Pacific Ocean up to 1,700-2,300 m in the Alps, Caucasus and Mediterranean mountains. The four main types of ecosystems in the subalpine belt are high-grass subalpine meadows; communities of dwarf bushes and shrubs; heathlands and grasslands consisting of short grasses; and subalpine thinned park type and crooked forests (Malyshev & Nimis, 1997).

Alpine and subalpine ecosystems stand out for their extremely high biodiversity. 20% percent (approx 2,500 species) of Europe's vascular plant flora were estimated to being predominantly alpine, i.e. occurring within only 3% of the continent's territory (Grabherr *et al.*, 1995; Väre *et al.*, 2003). Mountains around the Mediterranean basin, such as Sierra Nevada in Spain, are outstandingly rich in local endemic species (Pauli *et al.*, 2003) and there is a general south-to-north gradient of decreasing endemism in mountains across Europe (Favarger, 1972). The subalpine belt is especially diverse in mountains of Europe and Central Asia and includes a large part of endemic species. For example, in Central Asian mountains more than 600 species of vascular plants were found and 50 of them are endemics (Shukurov *et al.*, 2015, Kovalevskaya *et al.*, 1968-1993), in the Central Caucasus mountains the endemism level is higher: 197 from 595 species (Nakhutsrishvili, 2003).

PAST AND CURRENT TRENDS

The subalpine ecosystems in Europe and the Caucasus are strongly modified through a long history of human use. Humans converted large parts of subalpine woodlands into pastures and hay meadows, which resulted in a widespread increase in secondary grasslands below the tree line. The actual tree lines have shifted downwards especially in densely populated mountains such as the Alps and the Caucasus (Körner, 2003; 2012). Unlike in the Alps, in southern Siberia the altitudinal range of the subalpine belt is mostly conditioned by natural factors (Malyshev & Nimis, 1997).

In the Carpathians the subalpine scrub communities almost completely disappeared, being transformed into so-called polonina with matgrass (*Nardus stricta*) swards or communities dominated by blueberry (*Vaccinium myrtillus*) with very low plant diversity (Kricsfalusy *et al.*, 2008). Overgrazing in Tien-Shan in the second half of the 20th century was five to ten times over the tolerance limit (Shukurov, 2007). Pamir alpine deserts are 20% moderately degraded, 25% strongly degraded and 55% extremely degraded (Breckle & Wucherer, 2006). As a result, wild species were crowded out by livestock and their number has dramatically declined (Korotenko & Domashov, 2014). This subsequently led to a decline in the number of predators and scavengers (Shukurov, 2007).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Mountain meadows in Europe and Caucasus suffer from overgrazing, which leads to simplifying of ecosystem structure and decline of population abundance and species richness (European Commission, 2016).

Alpine grasslands today undergo rapid transition driven by changes in land use and climate. Thermophilous species increased while cold-adapted high-elevation species declined in European mountains (Gottfried *et al.*, 2012; Grabherr *et al.*, 2010; Malanson *et al.*, 2011). Upward altitudinal shifts of alpine plant species ranges have repeatedly been observed in mountains (Klanderud & Birks, 2003; Kokorin *et al.*, 2011; Pauli *et al.*, 2012; Wipf *et al.*, 2013), which has led to increased species numbers on mountain tops in northern parts of Europe, but to declines in Mediterranean mountains (Jiménez-Alfaro *et al.*, 2014; Pauli *et al.*, 2012). The rate of tree line change varies across the region, usually several meters per decade and more than 100 m in Sweden and Norway (IPCC, 2014a).

Species population dynamics may lag behind climatic changes due to the persistence of some alpine plant species (Dullinger *et al.*, 2012). Abandonment of traditional farming and rural depopulation has become an evident trend in European and Caucasus mountains (Keenleyside *et al.*, 2010). The consequence is natural reforestation (Gehrig-Fasel *et al.*, 2008; Sitzia *et al.*, 2010), which reduces landscape heterogeneity, increases fire risks and exacerbates human-wildlife conflicts (Körner, 2003; Navarro & Pereira, 2015; Wilson *et al.*, 2012).

Landscape fragmentation and degradation as a result of the development of ski and tourism centres in high mountains have local negative impacts on biodiversity, species decline (especially rare and endemic species) and homogenization. Disturbance of vegetation on steep slopes may result in mudslides and water erosion (Belonovskaya, 1995; Akatov *et al.*, 2003). In Kyrgyzstan mining in high mountain ecosystems has led to degradation, fragmentation and pollution of vulnerable subalpine and alpine grasslands (Korotenko & Domashov, 2014; Shukurov, 2007).

Often changes are due to combinations of drivers. For example, species richness in Scottish alpine areas over a 20–40 year period increased in most habitats, while β-diversity declined, resulting in increased homogeneity of vegetation. Key northern and alpine species declined, while lowland generalist species increased. This change was consistent with impacts of climate change, but other elements of spatial pattern (decline in lichen richness in high deposition areas) were consistent with effects of nitrogen pollution (Britton *et al.*, 2009), which transforms species composition significantly (Bassin *et al.*, 2007).

3.3.2.3 Temperate and boreal forests and woodlands

OVERVIEW OF THE SUB-SYSTEM

Broad-leaved, mixed and coniferous forests constitute most of the potential natural vegetation in about 80% of

Europe (Bohn *et al.*, 2000) and Central Asia. Other patchily distributed forest types include water-influenced forests like black alder carrs and ravine forests on steep slopes. The vast area of boreal forest includes much of Fennoscandia, the middle and northern part of European Russia, Southern Siberia and far eastern part of Russia, covering ca. 809 million ha (Federal Forestry Agency, 2013).

PAST AND CURRENT TRENDS

The main past and current trends in biodiversity have been deforestation and fragmentation. In Western and Central Europe, conversion of deciduous forest to agriculture caused large breaks in connectivity and loss of the typical plant communities. Recovery of ecosystems lags far behind the efforts made in afforestation in these predominantly agricultural landscapes (Hermy *et al.*, 1999).

High biodiversity of various taxa of forest ecosystems is associated with natural disturbances like fires, wind and insect outbreaks, creating patches of dead trees and heterogeneity at different spatial scales. Up to 4,000 species are dependent on coarse woody debris as habitat (Stokland *et al.*, 2012). Protected areas focus on limiting human intervention in forests, with the aim of conserving species dependent on forest cover continuity, deadwood and large trees. Many bryophytes, lichens, fungi, vascular plants, saproxylic beetles and birds and cavity-nesters are associated with old forests (Bilz *et al.*, 2011; Moning & Müller, 2009, Paillet *et al.*, 2010; Roberge *et al.*, 2015; Gregory *et al.*, 2007; Scheidegger *et al.*, 2012; Virkkala *et al.*, 2008).

In the 18th century modern forestry began to reduce traditional forest pasturage, litter raking, charcoal making, pollarding and coppicing (Szabó, 2013). This replacement to high forests led to loss of species like threatened butterfly species associated with these open habitats (Konvička *et al.*, 2006). These changes have shifted the composition of understorey towards more shade-tolerant and nutrient-demanding species (de Frenne *et al.* 2013, Kopecký *et al.*, 2013) and forest vegetation has undergone significant loss of plant specialists (see e.g. De Frenne *et al.*, 2013; Keith *et al.*, 2009), loss of lichens (Reinecke *et al.*, 2014) and decreased multi-functionality at landscape-scale (van der Plas *et al.*, 2016a). This process is visible also in some coniferous forests (Hedwall & Brunet, 2016). Traditionally managed open forest habitats included in European Union protected habitats currently have unfavourable status (EEA *et al.*, 2016).

For the 2007–2012 period, the 27 European Union member States reported that only 26% of forest species and 15% of (non-Mediterranean) forest habitats (29 habitats) of European interest, as listed in the European Union's Habitats Directive, are in favourable conservation status (EEA, 2015a). An additional 7 have unfavourable but improving status with respect to the 2001-2006 period, 54 are deteriorating, 102 are stable or have unknown trends. In Central Europe, 248 assessments were performed (combinations of habitats and countries) and of these 56 were favourable, 16 unfavourable but improving, 46 unfavourable and declining, 123 unfavourable but stable, and 7 had unknown or unreported status and trends. In Western Europe, 380 status and trend assessments were performed, of which 66 were favourable, 25 unfavourable but improving, 83 unfavourable and declining, 125 unfavourable stable and 81 unknown or unreported. The most endangered habitats are forests along rivers and on bogs and water-influenced habitats such as ravine and boreal coniferous forests, riparian alluvial forests, lichen Scots pine forests, old acidophilous oak woods on sandy plain, Fennoscandian wooded pastures and swampy forests (Janssen *et al.*, 2016).

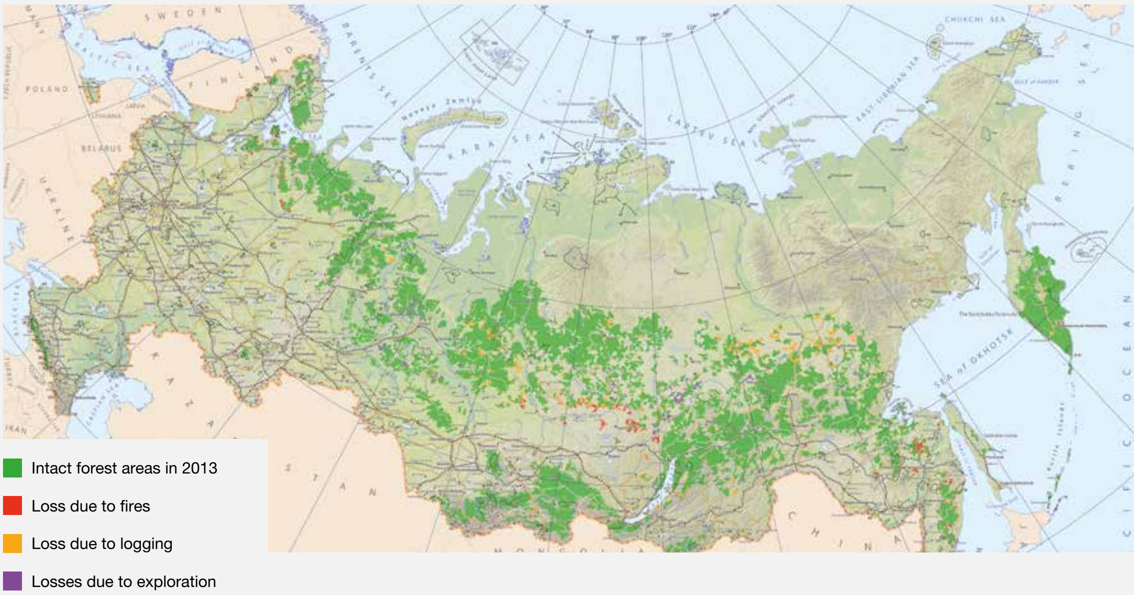
For people in remote forested areas, old-growth mountain or boreal forests are the only source of wood, and a source of food. Planted forests exclusively used for timber cover about 10% of the European Union (EEA, 2016). Throughout the forests of Europe and Central Asia, biodiversity is an important source of non-wood products (berries, mushrooms, game animals and recreation). Mustonen & Helander (2004) reported a decline of certain berry plants such as marsh whortleberries, traditionally collected by the Sami people in Finland.

A significant upward shift in the optimal elevation of forest herb and woody species occurred during the 20th century in various Western, Central and Eastern European forests, including primary forests (Engler *et al.*, 2011; Lenoir *et al.*, 2008; Šebesta *et al.*, 2011). Across several regions, the upper elevational limits of both tree seedlings and saplings were significantly higher than of adults (e.g. Vitasse *et al.*, 2012). However, despite the observed climate change, tree distribution of life-stage has not changed directionally (Máliš *et al.*, 2016). Drought is also known to be increasing fire risk in boreal forest (Drobyshev *et al.*, 2012) which, coupled with inadvertently human-caused ignition, can cause extensive wildfires.

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Direct drivers such as the expansion of infrastructure (urban and transport), unsustainable silviculture (including alteration and embankment of streams and spring drainages, excessive use of chemicals and clear-cutting and afforestation by monocultures of invasive species), conversion to agricultural land use and the lack of natural processes (e.g. floods in floodplain forests or fires in taiga forests) have affected forest ecosystems (Forest Europe, 2015) **(Figure 3.6)**.

Figure 3 6 **State and loss of intact forests in Russia in 2002–2015. Source: WWF (2015).**



It is difficult to disentangle the influence of various drivers on forest indicators; however, repeated surveys (see e.g. initiative www.forestreplot.ugent.be) have revealed significant changes in species composition and distribution ranges.

In Central and Western Europe there have been trends of increasing integrated forest management for conservation of biological diversity by close-to-nature forest management without clear cuts to increase continuity of forest structures, and emulation of natural disturbances (creation of dead wood and natural rejuvenation (Kraus & Krumm, 2013). Large populations of game animals can decimate natural rejuvenation by browsing (Kuijper *et al.*, 2010) or rooting (Brunet *et al.*, 2016).

In addition, the current large tree plantations are prone to invasions by species in the forest understorey (Essl *et al.*, 2010; Pyšek *et al.*, 2009). Among the problematic invasive alien species, 33 (invertebrates, vascular plants and fungi) are regularly found in European Union forest ecosystems or are dependent on trees (EEA, 2016).

Past deposition of SO_2 caused acidification of soil in some areas (Krám *et al.* 2012), resulting in the widespread dieback of Norway spruce plantations and mountainous coniferous forests and associated decline of ectomycorrhizal fungi in the 1980s (Arnolds, 1991). Current atmospheric nitrogen deposition in areas of Central and Western Europe has caused soil eutrophication (Hédl *et al.*, 2011, Lomský *et al.*, 2012, Šebesta *et al.*, 2011), in general and and locally close to urban and industrial areas (Kotlyakov, 2000). This has caused changes in forest plant communities (Ewald *et al.*, 2013; Verheyen *et al.*, 2012).

3.3.2.4 Mediterranean forests, woodland and scrub

OVERVIEW OF THE SUB-SYSTEM

This unit stretches west to east from Portugal to Jordan, includes ecosystems on Madeira, the Azores and Canary Islands in the Atlantic Ocean (Conservation International, 2011; FAO, 2013b) and is characterized by cool wet winters and dry hot summers causing water stress (Allen, 2014; Gauquelin *et al.*, 2016). Similar conditions can be found in the Crimean Peninsula, Turkey, and in lower parts of the Caucasus and Central Asian Mountains, which are sometimes also considered as a part of the Mediterranean area (Takhtazhyan, 1978; Şekercioglu *et al.*, 2011). Further to the east, juniper and pistachio woodlands and scrub become the most common ecosystems (Fayvush & Aleksanyan, 2016; Şekercioĝlu *et al.* 2011; Government of Tajikistan, 2016; Government of Turkmenistan, 2015). In Central Asia, they are composed of pistachio-almond dry woodlands (Venglovsky, 2006).

The Mediterranean area is among the world's richest places in terms of plant diversity, with 25,000 plant species, 50% of them endemic (Blondel *et al.*, 2010). There are 290 tree species (Noce *et al.*, 2016), of which 200 are endemic (Quézel & Médail, 2003; Gauquelin *et al.*, 2016). Two thirds of Mediterranian amphibian species, 48% of reptiles, a quarter of mammals, 14% of dragonflies, and 3% of birds are endemic (Mittermeier *et al.* 2004; Paine & Lieutier, 2016; Lefèvre & Fady, 2016; FAO, 2013b). With 52 plant refuges during ice ages (Médail & Diadema, 2009), the Mediterranean is recognized as a Global Biodiversity Hotspot (Mittermeier *et al.*, 2004).

In scrublands, the dominant maquis has many local names reflecting indigenous and local knowledge, such as matorral in Spain, phryganae in Greece or bartha in Israel. It is characterized by hard-leaved shrubby evergreen species of genera *Cistus, Erica, Genista, Juniperus, Myrtus, Phillyrea,* and *Pistacia*. The term "garrigue" is restricted to the limestone, semi-arid, lowland and coastal regions of the basin and is maintained by grazing and fires.

PAST AND CURRENT TRENDS

The State of Nature in the European Union reports that 139 habitats where assessed for the Mediterranean Ecoregion in the European Union. In the period 2007-2012, 27 of these were of favourable conservation status, 1 is unfavourable but improving with respect to the 2001-2006 period, 49 are deteriorating, 62 are stable or have unknown trends. In Central Europe, 38 assessments were performed (combinations of habitats and countries) and of these 37 were favourable and one unfavourable but stable. In Western Europe, 467 assessments were performed, of which 139 were favourable, 6 were unfavourable but improving, 104 unfavourable and declining, 107 unfavourable stable and 109 unknown or unreported status and trends (EEA, 2015a).

Originally, the Mediterranean region was largely covered by evergreen oak forests, deciduous, semi-deciduous, and conifer (pine, juniper) forests (De Beaulieu *et al.*, 2005). However, as a result of centuries of deforestation, no intact forest is left in the region (Blondel *et al.*, 2010; CEPF, 2010a). Both human intervention and climatic conditions are favouring the development of shrublands and then of sclerophyllous and secondary coniferous forests, replacing the primary semi-deciduous and deciduous forests (Abdurakhmanov *et al.*, 2003; Blondel *et al.*, 2010; CEPF, 2010a; Allen, 2014). UNEP *et al.* (2009) reported that 67% of the sub-system of the Mediterranean forest, woodland and scrub had been converted before 1950, whereas recent changes only represent 3% in terms of area. During the 1990-2005 period the area covered by forest generally increased except in Croatia and Bosnia-Herzegovina (UNEP *et al.*, 2009; FAO, 2013b). Plantations cover about 11% of the area, mostly formed by pines and eucalyptus (Wingfield *et al.*, 2015; de Rigo *et al.*, 2016).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Mediterranean forests are the product of a long history of agro-sylvo-pastoral management by rural populations and of interactions between local societies and the state (mainly through the public forest administration) (Blondel *et al.*, 2010; Gauquelin *et al.*, 2016; Kouba *et al.*, 2015; Lefèvre & Fady, 2016; Paine & Lieutier, 2016; Médail & Diadema, 2009). At low altitudes, the present Mediterranean forests have been managed by coppicing, wood cutting, prescribed fires and grazing, while at higher altitudes they have been conserved (Blondel *et al.*, 2010). Fires and herding are particularly important drivers of vegetation dynamics and selection of plant traits (Arianoutsou, 2001; CEPF, 2010a; de Rigo *et al.*, 2016). After the Second World War, land abandonment resulted in land cover changes from pastures to scrub and later to closed forests, and was accompanied by significant changes in biodiversity (Gauquelin *et al.*, 2016; Lavergne *et al.*, 2005; Mazzoleni *et al.*, 2004; Sirami *et al.*, 2010). The most important threats for Mediterranean woodland species are habitat loss, fragmentation, land degradation and anthropogenic fires causing primary forest cover to decrease and an increase of secondary forest and shrubland (Abdurakhmanov *et al.*, 2003; Peñuelas *et al.*, 2002; FAO, 2013b; Government of Armenia, 2015; EEA, 2002). Nitrogen pollution from agriculture (Sutton *et al.*, 2014; Feest *et al.*, 2014), and unsustainable harvesting and hunting (Peñuelas *et al.* 2002; IUCN, 2008; FAO, 2013a) also contribute to biodiversity loss.

Climate change, withan increase in temperature and frequency of natural disasters, especially droughts, leads to aridification, desertification and a decline of species richness (Allen, 2014; FAO, 2013b; IPCC, 2014a).

With the exception of some pyrophytic species like *Cistus* sp. (EEA, 2004), pine woodlands are more sensitive than scrubland and oak forest to more frequent wildfires (Pausas *et al.*, 2008; Moreira *et al.*, 2011; Dias *et al.*, 2016).

Invasive alien species, including forest pests and diseases (potentially favoured by fires) and plantations of exotic tree species also contribute to biodiversity loss (de Rigo *et al.*, 2016; EEA, 2004; IUCN, 2008). Eucalyptus monocultures can be infected with up to 150 pathogens, spreading more easily in uniform conditions (de Rigo *et al.*, 2016; Wingfield *et al.*, 2015), while pine invasion promotes soil acidification, causing a decrease of taxonomic and phylogenetic diversity (Selvi *et al.*, 2016).

3.3.2.5 Tropical and subtropical dry and humid forests

OVERVIEW OF THE SUB-SYSTEM

There are several types of laurel subtropical forests ("laurifolia" or "laurisilva") on islands in the North Atlantic Ocean, belonging to the Macaronesian biogeographical province. They occupy territories with medium to high precipitation of Azores, Canary Islands and Madeira islands between altitudes of 600 and 1,500 m (Dias *et al.*, 2005; Fernández-Palacios & Arevalo, 1998) and demonstrate a high species diversity: 12,660 species of fungi, plants and animals with extremely high level of endemism – 30% (3,570 species) (Moya *et al.*, 2004).

Two types of mixed and deciduous humid subtropical forests with evergreen elements grow in the Caucasus Mountains: Colchic in the west (Georgia, Russia and Turkey) and Hyrcanic in the east in Azerbaijan (Akhani *et al.*, 2010; Chitanava, 2007; Grossheim, 1926; Gerasimov *et al.*, 1964; Prilipko, 1970; Safarov, 1979; Safarov, 2009; Solomon *et al.* 2014). Other researchers consider Colchic and Hyrcanic forests as specific temperate rainforests, rather than subtropical, because of the mild climate conditions with cooler winters than in many subtropical regions and the presence of the sclerophyllous species only in undergrowth and absent from the tree layer (Borsch *et al.*, 2014; Maharramova *et al.*, 2015; Nakhutsrishvili *et al.*, 2015; Zazanashvili & Mallon, 2009). Colchic forests include about 3,600 vascular plant species, and Hyrcanic forests more than above 1,200 species (Abdurakhmanov *et al.* 2003; Akhani *et al.* 2010; Chitanava, 2007; Filibeck *et al.* 2004; Grossheim, 1926; Gerasimov *et al.*, 1964; Prilipko, 1970; Safarov, 1979, 2009; Solomon *et al.* 2014; Tutayuk, 1975; **Figure 3.7**). Twenty to 30% of Caucasian flowering plants, fish, and terrestrial vertebrates and invertebrates are endemic. Endemism in terrestrial molluscs can reach 75% (CEPF, 2004; Mumladze *et al.*, 2008; Nakhutsrishvili *et al.*, 2015; Zazanashvili & Mallon, 2009). Due to the high diversity of relict Arcto-Tertiary species (Gegechkori, 2011) and the high level of endemism these forests are included in the Caucasus Global Biodiversity Hotspot (CEPF, 2010b; Mittermeier *et al.*, 2004), the Western Caucasus UNESCO World Heritage Site (Succow & Uppenbrink, 2009) and Global 200 WWF ecoregions (WWF, 2006).

Tugai is a type of gallery forest and shrubland interspersed with grasslands along the Caucasus and Central Asian rivers, similar to natural riparian forests in the northern part of Europe and Central Asia (Glazovsky, 1990; Sadygov, 2012; Shukurov, 2009). Primary wild walnut-fruit forests and woodlands are a specific feature of Central Asian mountains and relict ecosystems, remaining as refuges during ice ages. They occupy mountain slopes at 800 - 2,100 m a.s.l. (Janick, 2003; Shukurov *et al.*, 2005; Venglovsky, 2006).

PAST AND CURRENT TRENDS

Subtropical forests have been transformed by human activities. Currently, native subtropical forests in Europe and Central Asia occupy only 20% of initial laurel forest area (Fernández-Palacios & Arevalo, 1998) and about 10% of Colchic, Hyrcanian, Amu Darya and Azerbaijan Tugai forest area. Mostly they have been transformed into agricultural lands. Remaining subtropical forests are fragmented and

Figure 3 7 **Location of Colchic and Hyrcanic forest areas. Source: Nakhutsrishvili *et al.* (2015).**

degraded because of logging and overgrazing, or replaced by Mediterranean type vegetation. This has been the case with laurel forests in Macaronesia and Tugais in Armenia (Government of Azerbaijan, 2014; Bikirov, 2012; Burkhanov, 2013; Fayvush & Aleksanyan, 2016; Fernández-Palacios & Arevalo, 1998; Ionov & Lebedeva, 2004; Janick, 2003; Jungius, 2012; Mumladze *et al.*, 2008; Nakhutsrishvili *et al.* 2011; Shukurov *et al.*, 2015; Treshkin, 2001; Turdieva *et al.*, 2007; Yusifov & Hajiyev, 2004; Zazanashvili & Mallon, 2009). 97% of Macaronesian Laurisilva is in Madeira, and is in unfavourable but stable conservation status, the remaining 3% is in the Canary Islands and is considered in favourable conservation status (EEA, 2015a).

The total number of regional extinctions from subtropical forest is unknown. However, noteworthy is the global extinction of the Caspian tiger (*Panthera tigris* ssp. *virgata*). About 50% of natural Azorean species are in danger of extinction (Dias *et al.*, 2005). Twenty-one species of mammals, birds, reptiles and amphibians in Caucasus forests are globally threatened and included in IUCN Red Lists as vulnerable, endangered or critically endangered. Of these, 8 are endemic (West Caucasian tur (*Capra caucasica*), Clarks' lizard (*Darevskia clarkorum*), Charnali lizard (*Darevskia dryada*), large-headed water snake (*Natrix megalocephala*), Caucasian viper (*Vipera kaznakovi*), Black Sea viper (*Vipera pontica*), Caucasian salamander (*Mertensiella caucasica*) and Persian mountain salamander (*Iranodon persicus*) (Nakhutsrishvili *et al.*, 2011). The population of Bukhara deer declined to 100 animals in Tajikistan (Bannikov & Zhirnov, 1971; Jungius, 2012).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Overgrazing affects all types of remaining subtropical forests, but especially damaged wild walnut-fruit forests in Central Asia because of the lack of good pastures. So far, numbers of livestock (mainly goats and sheep) have been growing. Only in Kyrgyzstan in walnut-fruit forests it increased by 5% from 2012 to 2013 (Asykulov & Chodonova, 2015). This leads to structural homogenization, extinction of rare and endemic species, and introduction of weeds and invasive species like Japanese spiraea (*Spiraea japonica*) (Nakhutsrishvili *et al.*, 2011; Treshkin *et al.*, 1998; Shukurov *et al.*, 2005; Fernández-Palacios & Arevalo, 1998; Prada *et al.*, 2009; Asykulov & Chodonova, 2015).

In Macaronesia tourism exerts pressure on ecosystems through recreational activities, disturbance of species, and risk of fires and wastes. From 1960 to 1998 the number of tourists increased from 940,000 to 12.5 million people each year, 6 times as large as the local population. The resulting anthropogenic pressure impairs natural ecosystem functioning (European Comission, 2014; Fernández-Palacios & Arevalo, 1998).

In Azerbaijan water storage facilities have transformed the water regime downstream the Kura River, making it drier and without regular floods. These conditions are unsuitable for Tugai forest (Sadygov, 2012).

Aridification caused by global warming negatively affects Hyrcanian and walnut-fruit forests - dryer forest types (IPCC, 2014a) and they lose mesophytes (Program and Action Plan, 2015). Increasingly, the frequency of catastrophic floods and forest fires caused by climate change, cause the decline of species richness in all subtropical forests within Europe and Central Asia (Prada *et al.,* 2009; Succow & Uppenbrink, 2009; Zazanashvili & Mallon, 2009).

Invasive species affect all types of subtropical forests (Fernández-Palacios & Arevalo, 1998; Shukurov, 2016). The Azorean flora consists of 1,007 plants species, 707 of which have been introduced mostly in the last fifty years (Dias *et al.*, 2005). An invasion of box tree moth (*Cydalima perspectalis*) in 2012 in the Caucasus exemplifies the magnitude of pest damage in the region. It has developed in an active pest outbreak in 2013, and expanded from common box (*Buxus sempervirens*) into an endemic relict box (*Buxus colchica*) in the wild (Gninenko *et al.*, 2014). In 2015 it reached Abkhazia and Crimea, and has destroyed most Buxus colchica in the Caucasus Colchic forests (Abasov *et al.*, 2016). Pest outbreak effects have been exacerbated by destabilisation of ecosystems due to pesticide application (Shukurov, 2016). Pollution from agricultural sources has caused a strong decrease in the area covered by subtropical forest ecosystems (Kuz'mina & Treshkin, 1997; Shukurov *et al.*, 2005; Zazanashvili & Mallon, 2009).

In Central Asia, mining projects have been developed in walnut-fruit forests, polluting air and water and leading to the degradation of the forest vegetation (Janick, 2003).

After the collapse of the Soviet Union many fields and plantations were abandoned and a process of natural reforestation started (Nakhutsrishvili *et al.* 2011). Today these are gradually being returned to agriculture, thereby preventing the expansion of subtropical ecosystems in this way (Shukurov *et al.*, 2015).

Countries have recognized the necessity to conserve the remaining subtropical forests and species and to establish protected areas (Turdieva *et al.*, 2007; Government of Kyrgyzstan, 2014; Government of Tajikistan, 2014; Government of Turkmenistan, 2015; Government of Kazakhstan, 2015; Government of Uzbekistan, 2015). For example, all remaining laurel forests in the Canary Islands are protected (Fernández-Palacios & Arevalo, 1998), and 37% of Hyrcanian forests in Europe and Central Asia are covered by protected areas (Nakhutsrishvili *et al.*, 2015). Programmes on forest restoration have started in some countries (ENPI-FLEG, 2015), to promote the recovery of species diversity and habitat. Due to implemented measures, populations of some threatened species have become stable or even slowly growing, such as Bukhara deer in Kazakhstan (Greifswald, 2010; Government of Kazakhstan, 2015; Government of Turkey, 2014; Government of Uzbekistan, 2015; Government of Tajikistan , 2014; Government of Kyrgyzstan, 2014; Government of Tajikistan, 2016; Government of Turkmenistan, 2015).

3.3.2.6 Temperate grasslands

OVERVIEW OF THE SUB-SYSTEM

The ecosystem comprises dry or seasonally wet (not overwetting) non-coastal land, more than 30% covered by natural vegetation. Vegetation is dominated by herbaceous, shrub plants and trees. Actively managed grasslands and cultivated lands, high-mountainous (alpine) grasslands, and arid dwarf-shrublands (semi-deserts) are covered in 3.3.2.9, 3.3.2.2. and 3.3.2.7, respectively. Three main grassland types are distinguished in Europe and Central Asia (namely: Steppes, azonal/extrazonal natural dry grasslands, and secondary (semi-natural) grasslands (Bohn *et al.*, 2004; Dengler *et al.*, 2013; Dengler *et al.*, 2014; Ellenberg & Leuschner, 2010; Veen *et al.*, 2009; Vrahnakis *et al.*, 2013; Wesche *et al.*, 2016)). The natural grasslands of the two first types are essentially self-sustaining if the wild herbivore assemblage is present or replaced with a domestic one. The man-made grasslands of the last type require continuous management to preserve their current status (or restore them). The area of original extent of steppes in Europe and Central Asia was assessed as 1,700,000 km^2. The actually remaining steppe area was assessed as 670,000 km^2 (Henwood, 2010).

Europe and Central Asia's grasslands are global hotspots of small-scale (at scales below 100 m^2) vascular plant diversity. Some prominent examples are Transylvanian and Carpathian dry meadows (or meadow steppes) where up to 98 vascular plant species can co-exist on 10 m^2 and 133 species on 100 m^2 (Dengler *et al.*, 2014(b; Török *et al.*, 2016; Wilson *et al.,* 2012). This richness may result from the traditional management practices of local people (Babai & Molnár, 2014). More than 18% of Europe's endemic vascular plants are bound to grassland habitats (Habel *et al.*, 2013; Hobohm & Bruchmann, 2009).

Europe and Central Asia's grasslands provide important habitats for many species of global conservation concern, such as the saiga antelope (*Saiga tatarica*), great bustard (*Otis tarda tarda*), sociable sapwing (*Vanellus gregarious*) (IUCN, 2017b). In Europe, the birds associated with grasslands (and low intensity agricultural) habitats have the highest proportion of threatened species (23%) compared with other habitats (BirdLife International, 2015).

The steppe habitats of Russia harbour 11 mammal species of global conservation concern. The Federal Red Data Book of Russia listed 14 mammal and 14 bird species strongly linked to steppe habitats (two are extinct in the wild in Russia) (Antonchikov, 2005; Smelansky & Tishkov, 2012), and 30 insect species inhabiting only grasslands (presumably steppes) comprising 31% of the whole list of insects (94 taxa) (Red Data Book of Russian Federation, 2001). In Ukraine (Parnikoza & Vasiluk, 2011; Vasiluk *et al.*, 2010) steppe animals comprise 29% of the list of the national Red Data Book (159 from 553). Among 826 species of plants listed in the Red Data Book of Ukraine 33.4% (276) can be found in steppe habitats only (Korotchenko & Peregrym, 2012; Parnikoza & Vasiluk, 2011).

European grasslands have been recognized as threatened hotspots of biodiversity which emphasizes their high conservation priority (Dengler *et al.*, 2014; Habel *et al.*, 2013; Török *et al.*, 2016). Fifty three grassland habitats, distinguished in Europe, are assessed as threatened to some degree, including 12 critically endangered or endangered habitats (Janssen *et al.*, 2016). Nearly half of the bird species associated with grasslands have a threatened population status in the European Union (EEA, 2015d).

In the steppes of Russia only 10% of the protected areas are covered by grasslands (Tishkov, 2005); only 11 of 151 Russian federal strict nature reserves and national parks conserve significant steppe tracts and they comprise only ca. 1% of the total area of federal protected areas (Smelansky & Tishkov, 2012).

PAST AND CURRENT TRENDS

Each main type of grasslands has had a distinct trend. Here we treat Steppe and Azonal natural grasslands together due to similar trends.

Historically, dry grasslands in Europe and Central Asia were ploughed up and turned into croplands on a massive scale. This was the fate of the wet grasslands as well, which were directly drained, or were drained due to drainage of the neighboring arable fields in the landscape (Stoate *et al.*, 2009). The process had accelerated in the Central Europe in 17th century and came to an end in the mid-20th century in Siberia and Kazakhstan (Hejcman *et al.*, 2013; Moon, 2013; Smelansky *et al.*, 2006). In England and Wales 97% of semi-natural grassland disappeared by the mid-20th century (Bullock, 2011). Thus, extensive decline in area, increasing fragmentation, and loss of diversity were dominant trends in grasslands for centuries. As a result, only 3-5% of natural steppe grasslands (and azonal grasslands to a significantly lesser extent) remained relatively intact in Europe (Henwood, 2010) and ca. 20% in Russia (Smelansky & Tishkov, 2012). In the only country where grassland are in relatively good status, Kazakhstan, at least 70-80% of the original extent of grassland remains (from 10% to 90% for different steppe and semi-desert types) (Henwood, 2010; Rachkovskaya & Bragina, 2012). An example of a more detailed assessment can be found in Hungary, where approximately 251 thousand ha (6.8%) of the original total of 3.7 million ha of forest-steppe vegetation survived, of which only 5.5% of the stands may be considered natural, 38% semi-natural, 46% moderately degraded, and 10% strongly degraded (Molnár *et al.*, 2012).

The second most important trend in the last millennium was loss or significant decline of two keystone herbivore guilds naturally grazing over grasslands in Europe and Central Asia: wild nomadic ungulates (Pärtel *et al.*, 2005); and colonial burrowing rodents and lagomorphs (Davidson *et al.*, 2012). Both guilds are the main ecosystem engineers in their grassland ecosystems through grazing, trampling, defecating, and digging activities.

A general trend common for steppes and semi-natural grasslands is a strong dependence on traditional agricultural systems, evolved over centuries of land use by local people (Schneider-Binder, 2007). Many grassland variants in Europe and Central Asia developed under or were supported by traditional low-intensity agricultural land use including livestock grazing, hay making, manuring, tillage and burning regimes (Smelansky, 2003). Many grassland species, for example some birds and insects, are dependent on specific agricultural practices in both Europe (Benton *et al.*, 2002; Cardador *et al.*, 2014; Donald *et al.*; Stoate *et al.*, 2009) and Central Asia (Kamp *et al.*, 2011; Wright *et al.*, 2012). For example, critically endangered sociable lapwing (*Vanellus gregarius*), endemic black lark (*Melanocorypha yeltoniensis*), and some other typical steppe birds strongly prefer heavily-grazed habitats for nesting, but moderately-grazed habitat is optimal for nesting success (Fijen *et al.*, 2015; Sheldon *et al.*, 2013; Watson *et al.*, 2006). Historically, grazing patterns in the steppes of Central Asia were created and maintained by the traditional mobile pastoralists acting for centuries (Krader, 1955; Leeuwen *et al.*, 1994).

In contrast to traditional farming systems, the more recent intensification of farming has resulted in a dramatic decline of grassland biodiversity. Data from Western Europe show a strong decline of grasslands birds and a 45% decline in the butterfly population in recent decades (Donald *et al.*, 2006; EEA *et al.*, 2013).

In general, habitat and species trends for grasslands in Europe and Central Asia are negative **(Table 3.5)**. Habitat degradation is still increasing and habitat area decreasing principally as a result of massive land-use changes and pollution, but significant subregional variation is observed. The conservation status of many endangered species remains unchanged or even becomes worse due to land-use change, overexploitation and pollution. Only species richness is relatively stable, except for semi-natural grasslands,for which it has a negative trend. Climate change accelerates these trends.

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

The most important direct drivers that strongly affect temperate grassland area are ploughing, afforestation, mining and excavation, settlements and industrial area encroachment, land abandonment and climate change (Cerqueira *et al.*, 2015; Kamp *et al*., 2016; Korotchenko & Peregrym, 2012; Prishchepov *et al.*, 2013; Rachkovskaya & Bragina, 2012; Smelansky *et al.,* 2006; Smaliychuk *et al.*, 2016; Smelansky & Simonov, 2008; Smelansky & Tishkov, 2012) **(Table 3.5)**.

Biodiversity and functioning of ecosystems are shaped by differences in subbiome (grassland) type, and latitudinal and evolutionary gradients, site factors (slope, aspect, nutrient status, levels of alkalinity/acidity and moisture), livestock breeding (grazing and mowing), fire, fertilization (manuring, nitrogen deposition), species invasion, and successional dynamics (specifically as a result of abandonment) (Smelansky *et al.*, 2006; Faber-Langendoen & Josse, 2010; Kamp *et al.*, 2016; Korotchenko & Peregrym, 2012; Merunková *et al.*, 2014; Smelansky & Tishkov, 2012).

Except for latitudinal and subbiome differences, the abovementioned drivers are caused or influenced by society. Grazing is a major direct factor influencing biodiversity and ecosystem functioning (Augustine & Mcnaughton, 1998; Díaz *et al.*, 2007). Fire is another major factor, both through wildfires and prescribed burning. Wildfires (including uncontrolled burning) are practiced in extensive areas in Ukraine, Russia, some Central European countries (Romania, Hungary, Bulgaria) and in Central Asia (Valkó *et al.*, 2016; Smelansky *et al.*, 2015) as well as in the Mediterranean (Keeley *et al.*, 2012; Valkó *et al.*, 2016). Fertilization leading to eutrophication is especially important for semi-natural grasslands in Western and Central Europe (Duprè *et al.*, 2010). Many drivers lead to fragmentation of grasslands producing a loss of grassland-specific species and degradation of ecosystems.

3.3.2.7 Deserts

OVERVIEW OF THE SUB-SYSTEM

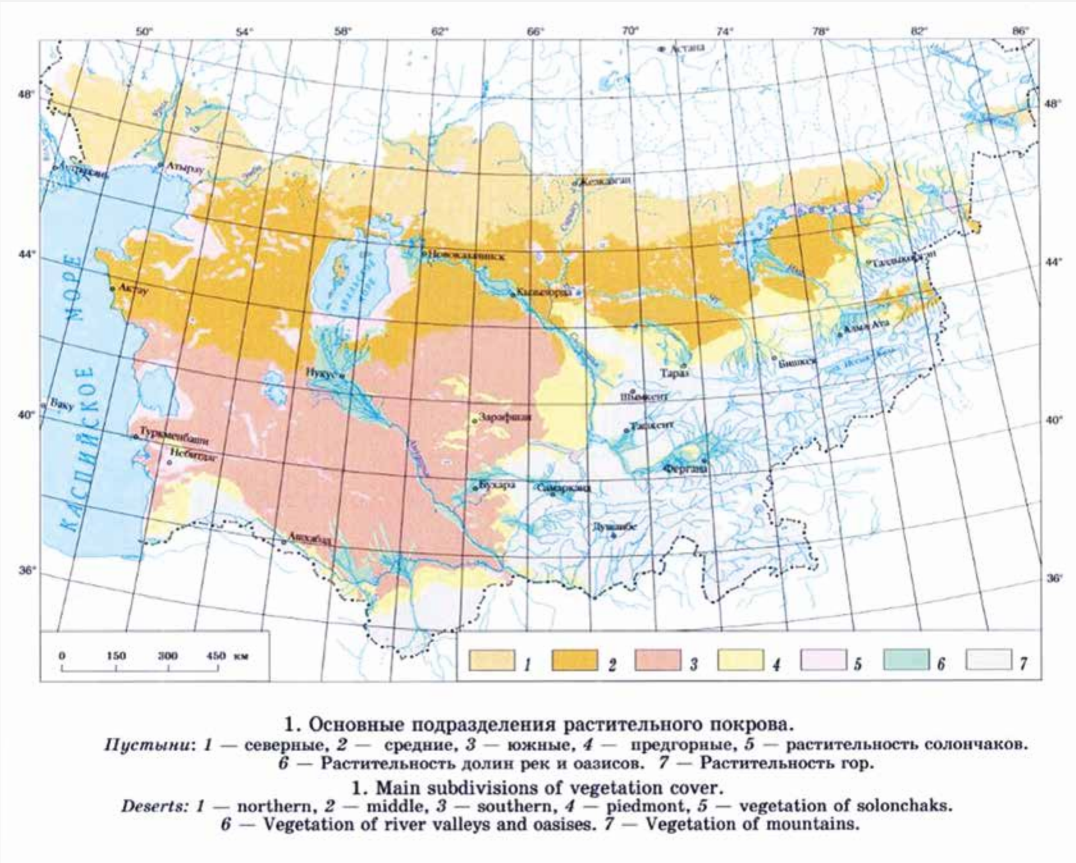
Deserts comprise low and high altitude plains with precipitation of no more than 100 mm/year (FAO, 1989) or no more than 250 mm/year (as per Koeppen-Geiger Classification, Kottek *et al.*, 2006), with rare or absent vegetation on desert soils (Kharin, 2002). While the largest extent of deserts is found across Central Asia, the most arid desert in the region is located in Israel (Western Europe in this assessment). The Central Asian deserts extend from the Kopetdag and Paropamiz mountains in the south, to a latitude of 48° north and from the Caspian Sea in the west to the foothills of Jungar Alatau, Tien Shan and Pamir-Altai mountains in the east. This spans about 1,400 km from north to south and 2,700 km from west to east (Akzhygitova *et al.*, 2003). The Negev Desert in Israel is expanding from the south-eastern section of the Mediterranean Sea eastwards and south-eastwards and with extension northwards along the Dead Sea Rift Valley (Evenari *et al.*, 1982).

Central Asian deserts include: northern or steppified deserts (or semi-deserts) with wormwood gramineous and salt grass plant associations; middle deserts or the true deserts with perennial saltworts and wormwoods and saxaul (*Haloxylon ammodendron*) on sands; and southern deserts with a different composition of wormwoods and salt grass species. Deserts in foothills and in intermontane areas are specifically different in terms of species composition but occupy comparatively small areas (Akzhygitova *et al.*, 2003, **Figure 3.8**).

While the Central Asian deserts form part of the Irano-Turanian floristic region (Takhtadzhyan, 1978; Shmida, 1985), the Negev Desert also has Irano-Turanian vegetation. It becomes increasingly arid towards the south, with features of Saharo-Arabian vegetation. The region has been continuous with the African continent since the Permian (Trewick, 2017; Ziv *et al.*, 2014). Additional more recent geological processes making it a major biodiversity corridor between Africa and Eurasia include the rifting of the Dead Sea Rift Valley (Anker *et al.* 2009).

Aralkum is a new desert formed as a result of the drying up of the Aral Sea following extensive water consumption for irrigation. The current flora consists of 34 families of plants with 134 genera and 300 species. Aralkum covers an area of over 38,000 km^2 and is a source of windblown dust. Dust storms carry away about 100 million tons of toxic dust and salts annually, including fertilizers and pesticides that have been washed away from irrigated fields (Breckle *et al.*, 2012).

Figure 3 8 **Vegetation of Central Asian Deserts. Source: Akzhygitova *et al.* (2003).**



PAST AND CURRENT TRENDS AND THEIR ATTRIBUTION TO DIRECT DRIVERS

The most evident changes of population abundance, functional diversity, and habitat extent in Central Asian deserts were caused by land transformation, fragmentation and degradation (Zoï, 2011). Desert habitats in Central Asia have been fragmented by agriculture for cotton and food production (Kharin, 2002). The irrigated area of Central Asian deserts more than doubled during the 20th century (from 25,000-35,000 km^2 to 70,000-80,000 km^2 and reached 100,000 km^2 in 2013) (Kurtov, 2013). Land degradation caused a species richness decline due to high salinity of abandoned fields. Overall, 40 to 60% of irrigated soils in Central Asia are salt-affected or waterlogged (Gupta *et al.*, 2009; Zoï, 2011). In the Negev wind and water erosion plays an additional significant role (Verheye, 2009). Removal of sand by winds stimulates sand desert expansion by 3-4 m per year on average and up to 9-12 m in Turkmenistan (Veisov *et al.*, 2008).

Central Asian deserts traditionally have been used by local people as pastures – up to 1,700,000 km^2 during the Soviet Union period (until 1991) (Vinogradov, 1977). Poor pasture management and overgrazing deteriorate the natural vegetation (Gupta *et al.*, 2009; Turdiboeva, 2015). They were partly abandoned at the end of the last century, but most of the area still suffers from overgrazing, which causes land degradation and species richness decline (Kharin, 2002; Shukurov, 2016). Different natural conditions in the Negev Desert supported different land-use patterns: crop husbandry at the north and grazing in the south, which were based on water-harvesting practices. The history of ecosystem transformation in the Negev is as long as in the Mediterranean (Verheye, 2009). Until recently, the process of desertification did not affect the Negev profoundly. This was mainly due to large-scale afforestation programmes, restrictions imposed on grazing, and large water subsidies from the less arid parts of Israel to its more arid areas (Portnov & Safriel, 2004). Presently, overgrazing and aridification contribute to biodiversity decline (Verheye, 2009; IPCC, 2014a).

Aridification due to climate change is leading to the increase in desert area and consequent a decline in biodiversity in the centre of deserts (Berseneva, 2006; IPCC, 2014a). It also leads to the spread of deserts to the north and high into the mountains in response to warming. This results in loss of biodiversity in former semi-deserts and dry steppes (Glazovsky & Orlovsky, 1996; IPCC, 2014a).

Fragmentation of habitats by linear infrastructure interrupts migration routes, for example for globally threatened ungulates leading to decline of their populations: saiga antelope (*Saiga tatarica*), khulan (*Equus hemionus*), Goitered gazelle (*Gazella subgutturosa*) (Olson, 2013; Rosen Michel & Röttger, 2014).

Pollution by fertilizers, pesticides, defoliants used in agriculture (Zoï, 2011), and from mining extraction has a large impact, locally up to the total loss of the vegetation cover (Luryeva, 2014). A particular feature of Central Asian deserts is the impact of the Aralkum that is causing overall species richness decline due to the windborne transfer of hazardous substances from remaining sediments of the former Aral Sea bottom to the surrounding areas (Alikhonov, 2011; Zoï, 2011; Breckle *et al.*, 2012).

In spite of large number of invasive species (57 in Turkmenistan alone) and their competition with native ones, they mainly occur in agricultural and urban territories, so their impact is generally not considered a significant driver of the decline of the number or abundance of populations of native species (Kamakhina, 2008).

3.3.2.8 Peatlands

OVERVIEW OF THE SUB-SYSTEM

Peatlands are areas where water-saturated soil causes the accumulation of incompletely decomposed plant material ("peat"). A peatland which is actively accumulating peat is called mire. Several English terms (e.g., marsh, swamp, fen, bog) are used for naming different mire types (Joosten *et al.*, 2017). Henceforth, this assessment report will use the term peatland. Most national definitions require "peatland" to have a minimum peat depth of 30 cm with peat of >30% by dry mass (Joosten & Clarke 2002, Parish *et al.*, 2008, Rydin & Jeglum, 2013). Peatlands have organic soils (histosols), which include soils with shallower organic layers and less organic matter (FAO, 2015b). Areas with shallow peat (< 30 cm) may cover large areas, as in tundra and boreal zones (e.g. Vompersky *et al.*, 1996, 2011), and in the field are difficult to distinguish from real peatlands, but are usually overlooked and not considered as they usually count as tundra or boreal area (Minayeva & Sirin 2012). Most peatlands of Europe and Central Asia were formed after the last Ice Age (~10,000 years ago), and only very few are much older (Joosten *et al.*, 2017).

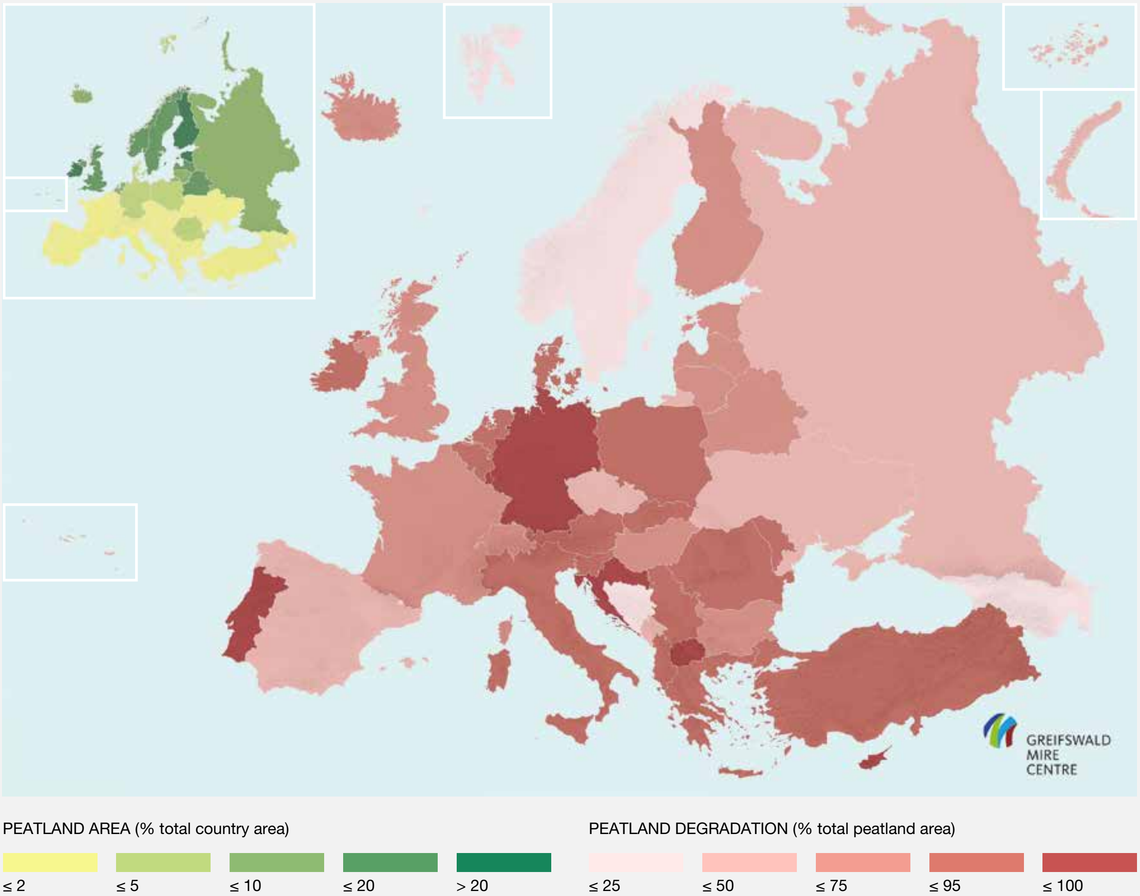
Peatlands often demonstrate a unique structural and functional integrity which has developed over centuries. Saturated peatland conditions select the plant species that may grow and form peat. The accumulated peat (which may consist to more than 90% of water) regulates the moisture balance and further determines the habitat for plant growth. Changes in water regime or vegetation may lead to peat and peatland degradation, causing enormous emissions of greenhouse gases (Parish *et al.*, 2008, Hiraishi *et al.*, 2014). Under favourable conditions, however, peatlands may recover (Bonn *et al.*, 2016, Minayeva *et al.*, 2017a).

PAST AND CURRENT TRENDS

Peatlands are found in every country in Europe and Central Asia. In Western Europe peatlands cover 276,323 km^2, of which 48% are degraded by drainage for agriculture, forestry and peat extraction, or destroyed by infrastructure development, construction, or flooding by dams **(Figure 3.9)**. In Central Europe peatlands cover 47,829 km^2, of which 74% are drained and degraded. In both subregions some 10% of the former peatland area does no longer have enough peat to be considered as peatlands. In the European Union part of Western and Central Europe 51% of mires and bogs assessments were classified as "unfavourable bad" and another 34% as "unfavourable inadequate" (EEA, 2015a). In Eastern Europe (including only the European part of the Russian Federation) peatlands cover 267,130 km^2 of which 38% are drained and degraded (Joosten *et al.*, 2017 and **Figure 3.9**). In the entire Russian Federation peatlands occupy 1,390,000 km^2 or 8.1% of the country and together with shallow peat lands (<30 cm) as much as 3,690,000 km^2 or 21.6%. Most peatlands (85%) and shallow-peat lands (84%) are found in the Asian part of the Russian Federation. Almost 20% of the peatlands are underlain by permafrost, of which 5.3% are polygon mires and 14.5% palsa mires (Vompersky *et al.*, 1996; 2005; 2011). Trees are present on 38% of the peatland area, while about 62% is open. Also, 53% of the shallow-peatlands are open (Vompersky *et al.*, 2011). Most peatlands in Russia are still in a natural state. Degraded peatlands are concentrated in the western and central part of European Russia (Minayeva & Sirin, 2005; Minayeva *et al.*, 2009). In Central Asian countries, peatlands cover only a few thousand square kilometres and are mainly situated in the highlands of Pamir, Tyanshan and Altay (Aljes *et al.*, 2016; Kats, 1971). Highland peatlands play a crucial role for maintaining ecosystem productivity, conserving biodiversity, preserving permafrost, and regulating

Figure 3 9 **Proportion of current peatland area (% total country area) and proportion of degraded peatland area (% total peatland area) in Western and Central Europe and the Western part of Eastern Europe.**

Source: Based on data from Joosten *et al.* (2017) and Global Peatland Database/Greifswald Mire Centre. Map prepared by C. Tegetmeyer. Note: in many countries, the original peatland area was substantially larger than the current peatland area.



water supply (Müller *et al.*, 2016). However, they are often overlooked, not considered as peatlands, treated as dry meadows, and therefore rapidly disappearing.

Peatlands in Europe and Central Asia in the past demonstrably suffered from long-term climate warming (Klimanov & Sirin, 1997), but their diversity and the variety of geographical conditions prohibit drawing unequivocal general conclusions on their reaction to climate change, especially on the scale of decades (Parish *et al.*, 2008).

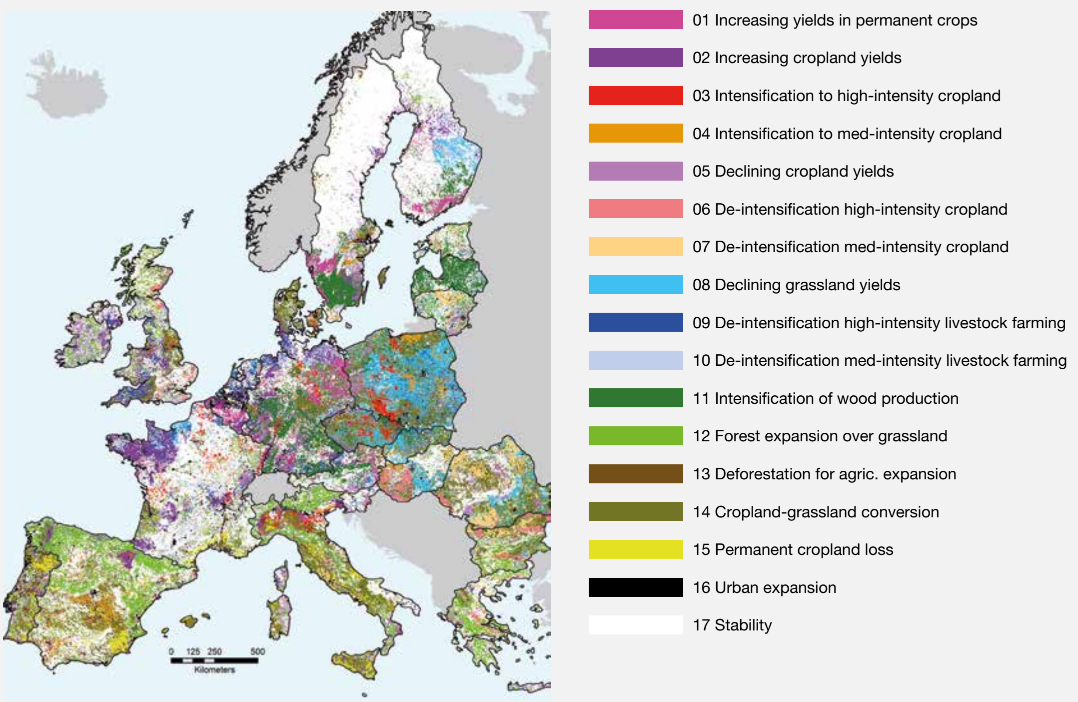
ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Peatlands as ecosystems are rather well adapted to climate change (Minayeva & Sirin, 2012). However, especially in the 19th and 20th centuries, anthropogenic transformation (drainage for agriculture, forestry, peat extraction, infrastructure) has substantially reduced this resilience. Northern permafrost peatlands, which are most sensitive to climate change, are progressively affected by industrial development and intensification of traditional land use (Minayeva & Sirin, 2009; 2010). In the temperate and boreal zones peatlands have been widely drained and used for forestry, agriculture and peat extraction. Many of the earlier drained areas are currently abandoned and subject to – sometimes catastrophic – fires (Minayeva *et al.*, 2013; Sirin *et al.*, 2011).

Boreal peatlands currently show a gradual reverse from drainage-based exploitation towards protection and restoration. In the temperate zone a growing appreciation for ecosystem services has initiated peatland rewetting projects to reverse the impacts of drainage. At the same time, however, the demand for biomass has caused massive expansion of biomass cultivation on peatlands with deeper drainage and more fertilization, which dramatically changes peat soil properties. In semi-arid and desert regions peatlands are being destroyed by overgrazing and drainage, while highland peatlands are often affected by mining. Overgrazing on peatlands leads to peat degradation, massive CO_2 emissions, and a loss of storage and retention capacity for carbon and water (Sirin *et al.*, 2016). All these hazards are aggravated by climate change, especially by decreasing precipitation, rising temperatures, and increased probability of catastrophic events such as droughts, rain storms or fires.

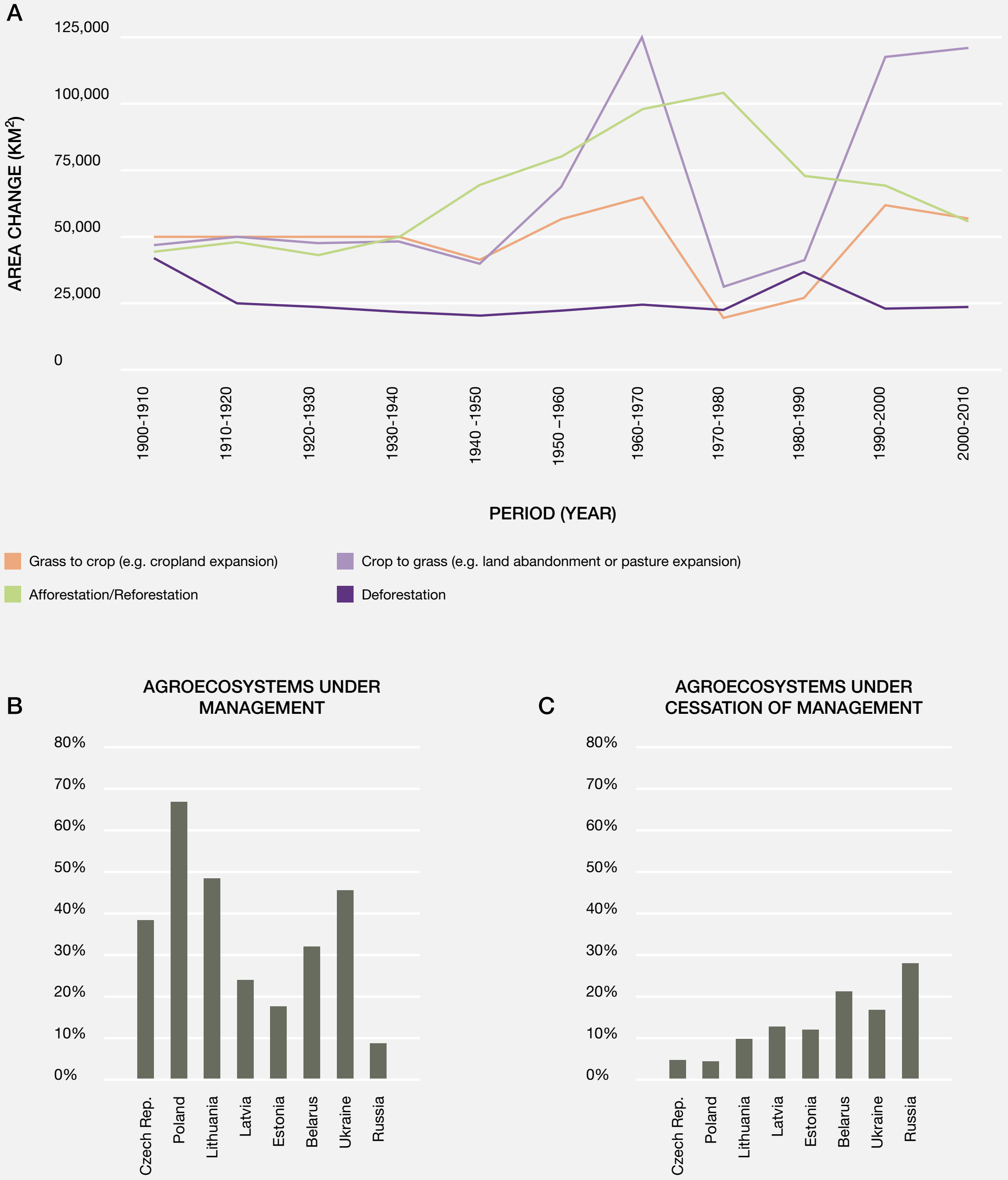
The resilience of natural peatlands to climate change is based on their self-regulation, but this capacity is not unlimited (Minayeva & Sirin, 2012). Substantial changes in peatland hydrology (by drainage), soil hydraulic properties (by long-term drainage), and peatland relief (by oxidation, subsidence and peat extraction) make spontaneous and supported recovery more and more complicated (Parish *et al.*, 2008). In damaged peatlands, climate change is

Figure 3 10 **Spatial distribution of the main changes in the extent of agroecosystem types (classes 01 to 10, 13 and 14) between 1990 and 2006 in the EU-27. Source: Levers *et al.* (2015). With permission of Springer.**



expected to increase the probability of catastrophic events, such as peat fires (Minayeva *et al.*, 2013; Sirin *et al.*, 2011), erosion, and inundation, and will impair the further provision of important ecosystem services, such as carbon storage and water regulation (Parish *et al.*, 2008, Bonn *et al.*, 2016). As peatland degradation enhances climate change (because of the enormous emissions involved) (Hiraishi *et al.*, 2014), the impact on biodiversity reaches far beyond the boundaries of the peatland itself.

Figure 3 11 **A Major gross area changes between the different types of agroecosystems observed for EU-27 and Switzerland per decade since 1910. Source: Fuchs *et al.* (2015). B Extent of agroecosystems under management; and C experiencing cessation of management assessed in 2005 for areas in eight countries of Baltic, Central Europe and Eastern Europe. Source: Alcantara *et al.* (2012).**



3.3.2.9 Agricultural areas

OVERVIEW OF THE SUB-SYSTEM

Agroecosystems include croplands, orchards, horticultural systems and managed grasslands (note that alpine grasslands and natural or semi-natural grasslands are addressed in other sections). Agricultural areas cover around half of the land area and thus represent the largest terrestrial unit of analysis over Europe and Central Asia (EEA, 2015a; FAO, 2013a; Levers *et al.*, 2015).

PAST AND CURRENT CHANGES IN THE EXTENT AND DIVERSITY IN AGROECOSYSTEMS

The legacy of traditional, low-intensity and diverse agricultural systems in Europe and Central Asia is a rich diversity of habitats and landscapes, generally supporting high levels of biodiversity (STOA, 2013 and references therein). However, agroecosystems and their diversity have changed dramatically since the early 1950s, and there has been an increase of highly modified and simplified agroecosystems and agricultural landscapes, in particular in Europe (Poláková *et al.*, 2011). From 1990 to 2006, land-use conversion, de-intensification and intensification took place on 26%, 18% and 15% of land areas, respectively, which corresponds with huge changes in the extent of different agroecosystem types **(Figure 3.10)**.

De-intensified agroecosystems dominated in Eastern Europe and Central Europe (3.5; see also Kuemmerle *et al.*, 2016) and in Central Asia (Kraemer *et al.*, 2015), along with abandoned farmland after the collapse of the Soviet Union (e.g. 26 million ha in Russia, Belarus, Ukraine and Kazakhstan (Lambin and Meyfroidt, 2011). A vast area experienced spontaneous recovery of forest and steppe ecosystems (Kamp *et al.*, 2015). Remote, economically unproductive agroecosystems are increasingly abandoned, reforested, or included in rewilding schemes (MacDonald *et al.*, 2000; Navarro and Pereira, 2012). For the EU-27 plus Switzerland, gross changes in the extent of the different types of agroecosystems resulted in changes to 56% of the area (ca. 0.5% /yr) between 1900 and 2010. This covers twice the area of net changes, with main changes being cropland or grassland dynamics and afforestation **(Figure 3.11)**. Within agricultural landscapes, decreased crop diversity, decreased coverage of natural and semi-natural areas (hedgerows, isolated trees, ponds, permanent grasslands) and lower connectivity between the remaining natural and semi-natural habitats are generally observed in response to intensification of agricultural systems (Robinson and Sutherland, 2002; Stoate *et al.*, 2001, 2009). For instance, hedgerow length and connectivity have strongly decreased in Western Europe (Deckers *et al.*, 2005; Robinson and Sutherland, 2002).

Ample information is available on the status and temporal trends of biodiversity for some broad taxonomic or functional groups in Europe and Central Asia, or at least for Western Europe and Central Europe. A vast number of scientific papers report temporal trends of biodiversity components in agricultural areas in locations or (sub)regions of Europe and Central Asia. Well established information exists for farmland birds (e.g. work of the European Bird Census Council covering at least 28 countries), arable flora (meta-analyses covering croplands from many countries), grassland butterflies (covering 19 countries), and the diversity of avian and mammalian breeds (syntheses performed by FAO over Europe and Central Asia). For the diversity of cultivated crop plants, comprehensive information exists for the number of varieties conserved ex situ, but not for the trends in the (genetic and functional) diversity of major cultivated varieties actually cultivated, i.e. grown *in situ*. In contrast to the Western Europe and Central Europe subregions, agricultural lands in Eastern Europe and Central Asia are often not recognized as having high conservation value, and research on trends of biodiversity in agricultural areas is rare. We summarize the major trends for different components of biodiversity in agricultural areas of Europe and Central Asia in **Table 3.1**.

Farmland birds - From 1980 to 2013, the abundance of common farmland bird species has continuously been decreasing (by 57% in total) in Europe, although the slope of decrease is lower since the 1990s **(Figure 3.12)**. Since 1990, the decline is more pronounced for northern Europe, intermediate for western Europe and new European Union member States, and less important for southern Europe **(Figure 3.12)**. In addition, the functional diversity of farmland bird communities is changing. The abundance of 17 granivorous species and 14 insectivorous species decreased strongly (56% and 46%, respectively), while the abundance of other species (one herbivore, two omnivores, one carnivore and one aerial insectivore) remained constant over 28 European countries (Inger *et al.*, 2015)[5]. Overall, farmland bird communities become more homogeneized (Doxa *et al.*, 2012).

Over the past 25 years in the Eastern Europe and Central Asia subregions the dynamics of farmland bird populations have been mainly driven by the crucial land-use changes related to transition from the Soviet-era planned economy to a market economy. The 1991-2001 period was characterized by massive land abandonment, decreasing crop yields and livestock numbers, and decline of fertilizer and pesticide use, which led to increases of the abundance and species richness of farmland birds in the steppe and forest-steppe geographical zones (Bolnykh & Vengerov 2011; Kamp *et al.*, 2011, 2015; Korovin, 2015), whereas

5. Inger *et al.* kindly reanalysed their published data and computed trends for farmland birds for the present assessment

Table 3 1 **Summary of the major trends reported for several components of biodiversity in agricultural areas in Europe and Central Asia, based on the analysis of over 150 temporal trends reported in the literature.**

For trends in pollinators, see IPBES (2016a). ↑/↓ denote strong and consistent increase/decrease in the indicator; ↗/↘ denote moderate and consistent increase/decrease in the indicator; ↔ stable indicator; ↕ variable trend in the indicator. The numbers reflect the impact of the driver on the trend: 0 no or marginal impact; 1 moderate impat; 2 high impact. P=Past, C=Current. ECA=Europe and Central Asia, WE=Western Europe, CE=Central Europe, EE=Eastern Europe, CA=Central Asia.

Biodiversity Indicators		General trends										Importance of direct drivers									
		Past					Current					Climate		Land use*		Pollution*		Exploitation		Invasives	
		ECA	WE	CE	EE	CA	ECA	WE	CE	EE	CA	P	C	P	C	P	C	P	C	P	C
Farmland birds	Species richness	↘	↘	↘	↘	↘	↘	↘	↘	↔	↘	1	1	2	2	1	1	0	0	0	0
	Species abundance	↓	↓	↘	↘	↘	↘	↘	↘	↗	↔	1	1	2	2	1	1	0	0	0	0
	Functional diversity	↘					↘					1	1	2	2	1	1	0	0	0	0
Avian breeds	Breed richness	↘	↓	↘	↘	↘	↘	↘	↘	↘	↘	0	0	2	2	0	0				
	Local breed abundance	↘	↓	↘	↘	↘	↘	↘	↘	↘	↘	0	0	2	2	0	0				
	Genetic diversity	↘	↓	↘	↘	↘	↘	↘	↘	↘	↘	0	0	2	2	0	0				
Mammal breeds	Breed richness	↘	↓	↘	↘	↘	↘	↘	↘	↘	↘	0	0	2	2	0	0				
	Local breed abundance	↘	↓	↘	↘	↘	↘	↘	↘	↘	↘	0	0	2	2	0	0				
	Genetic diversity	↘	↓	↘	↘	↘	↘	↘	↘	↘	↘	0	0	2	2	0	0				
Butterflies	Species richness	↘					↘							2	2	2	2	0	0		
	Species abundance	↘					↘							2	2	2	2	0	0		
	Functional diversity	↘					↘					1	1	2	2	2	2	0	0		
Arable plants / weeds	Species richness	↘					↘					0	0	2	2	2	2	0	0	1	1
	Species abundance	↘					↘					0	0	2	2	2	2	0	0	1	1
	Functional diversity	Shift					Shift					0	0	2	2	2	2	0	0	1	1
Cultivated plants	Ex situ variety richness	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	0	0	2	2	2	2				
	Ex situ genetic diversity	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	0	0	2	2	2	2				
	Ex situ functional diversity	↘					↘					0	0	2	2	2	2				
	In situ genetic diversity	↘					↘					0	0	2	2	2	2				

*Agriculture intensification encompasses both land-use change and pollution (fertilization, pesticide application)

in the forest zone this promoted an opposite trend (i.e. decreasing abundances and diversity) due to spontaneous reforestation, decreased open habitat areas and reduced habitat diversity (Borisov *et al.*, 2014). At least in part of the Central Asia and Eastern Europe subregions, farmland bird populations have decreased again since the early 2000s (Kamp *et al.*, 2015).

The abundance of grassland butterflies has declined by 30% in 22 European countries from 1990 to 2015 **(Figure 3.13)**. Butterfly communities also became more homogeneized (Eskildsen *et al.*, 2015). However, this negative trend has been locally reversed in some cases **(Box 3.1)**.

Agriculture-detrimental and beneficial insects – Temporal trends in the abundance or distribution of insects, which can cause major changes for agriculture have been reported. For instance, important changes in the distribution of crop pests, in particular due to climate change in northern areas of Europe and Central Asia, have been reported (Roshydromet, 2014; **Figure 3.14 A**). Evidence also accumulates of significant declines for both managed and wild bees (including bumblebees) over the past 60 years in Europe, which has been recently synthesized by a thematic IPBES assessment (IPBES, 2016a). In particular, there have been severe losses of honey bee colonies reported for the 1961-2012 period in many countries of Europe and Central Asia **(Figure 3.14 B)**. However, in the countries of Central Europe, Eastern Europe, and Central Asia subregions, the hive numbers show marked trends of recovery during the past decade (Kazstat, 2005, 2016; Rosstat, 2015).

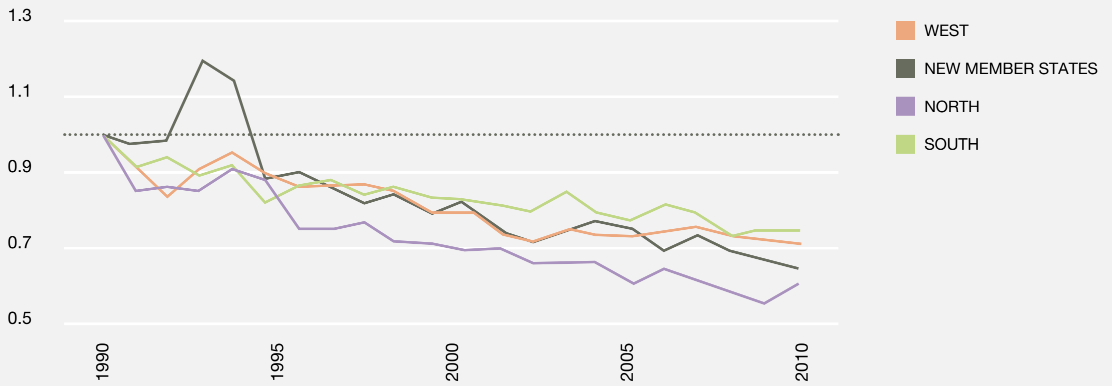
Animal genetic resources for food and agriculture – Geogaphical Europe and the Caucasus have by far

Box 3 1 **Reversing the decline of biodiversity in agricultural areas: a success story for a butterfly species.**

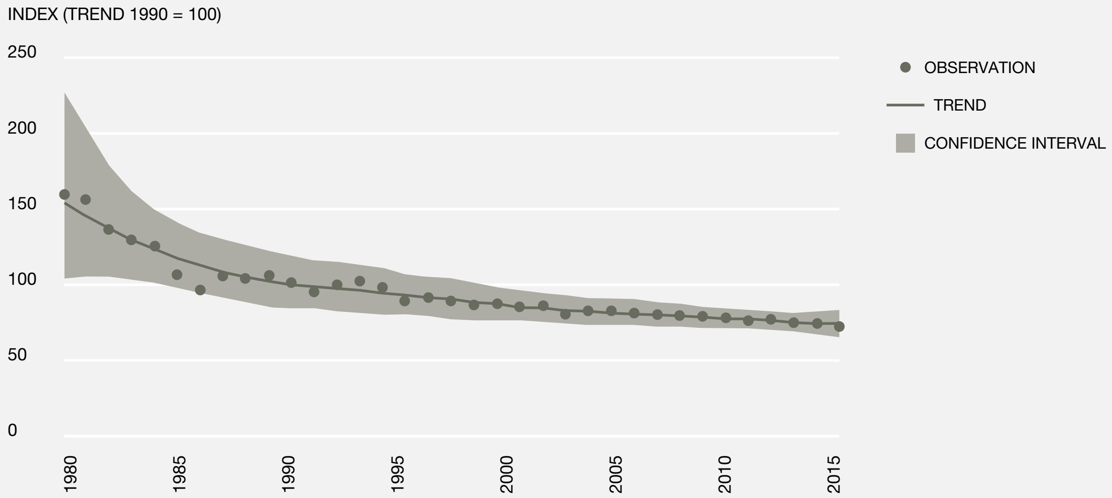
Ecological knowledge was successfully used to guide innovative conservation practices allowing the reversal of the decline of *Maculinea arion*, a charismatic specialist whose larvae parasitize *Myrmica* ant societies (Thomas *et al.*, 2008). *M. arion* larvae were found to be adapted to a single host-ant species inhabiting a narrow niche in grassland. Inconspicuous changes in grazing and vegetation structure caused host ants to be replaced by other ant species unsuitable for the butterfly larvae, explaining the extinction of European *Maculinea* populations. Once this problem was identified, ecosystems were perturbed by appropriate practices, and the predicted subsequent recovery of the butterfly and ants was validated for 78 sites. Such successful identification and reversal of the problem provides a paradigm for other science-based actions to reverse the decline of biodiversity in agricultural areas.

Figure 3 12 **A Temporal variations in the abundance of common farmland birds between four European regions between 1990 and 2011. Source: Pe'er *et al.* (2014).**
B Temporal variation in the abundance of common farmland birds for 28 European countries and for 39 species from 1980 to 2015.
Source: http://www.clo.nl/en/indicators/en1479-farmland-birds.

A



B



the highest proportion of animal breeds at risk in the world (31 and 35 per cent of mammalian and avian breeds, respectively) and the highest absolute number of at-risk breeds (446 mammalian and 75 avian breeds corresponding to 79% and 91% of total breed extinction at global scale, respectively) **(Figure 3.15)**. In several countries, populations of native breeds, although generally well adapted to local circumstances and resources and forming an important part of our cultural heritage and regional identity in Europe and Central Asia, remain at critically low numbers, being replaced by a few and widespread highly productive breeds. Native breeds make up only a small part of the total population, and nearly 40% of native breeds are at risk in Europe and Central Asia, i.e. the highest value for all global regions (FAO, 2015a). Overall, the situation of animal genetic resources is stable but negative in Europe and Central Asia.

Arable plants and weeds - The species diversity of arable plants has decreased since 1950 (by around 20%) (Richner *et al.*, 2015). The abundance of arable plants has also decreased (Meyer *et al.*, 2013; Richner *et al.*, 2015). In particular, the abundance of rare arable plant species characteristic of traditional management has decreased since the 1950s. These trends probably hold true all over Europe and Central Asia. The functional diversity of arable plants has changed from the 1950s to 2011, with an increase of arable weeds linked to high nutrient demand and resistance to extreme pH, and herbicides (Richner *et al.*, 2015). 25% of weed taxa are threatened in Tajikistan, including 18 endemic and four subendemic plants (Nowak & Nowak, 2015; Nowak *et al.*, 2014).

Plant genetic resources and crop wild relatives for food and agriculture - The number of plant varieties conserved *ex situ* has increased in Europe, as a result of selection and efficient storage approaches. However, much of the diversity of crop wild relatives and underused species relevant for food and agriculture still needs to be secured for present and future use (FAO, 2015a). Regarding the genetic diversity of crop plants actually cultivated *in situ*, a reduction in diversity occurred up to the 1960s due to the replacement of landraces by modern cultivars and to the low number of cultivars actually cultivated over large areas, while no further reduction or increase of diversity was observed after 1980 (Bonnin *et al.*, 2014); but the trend is likely species-specific. However, the actual genetic diversity of crop species found in fields is often not documented.

Among 572 species of European wild relatives of economically important crop species, 11% are threatened, and a further 4.5% of the species are near threatened (Bilz *et al.*, 2011; Kell *et al.*, 2012). More species are threatened at national level.

Figure 3 13 **Temporal variation in the abundance of 17 grassland butterfly species averaged across 22 European countries during the 1990–2015 period. Source: van Swaay *et al.* (2017).**

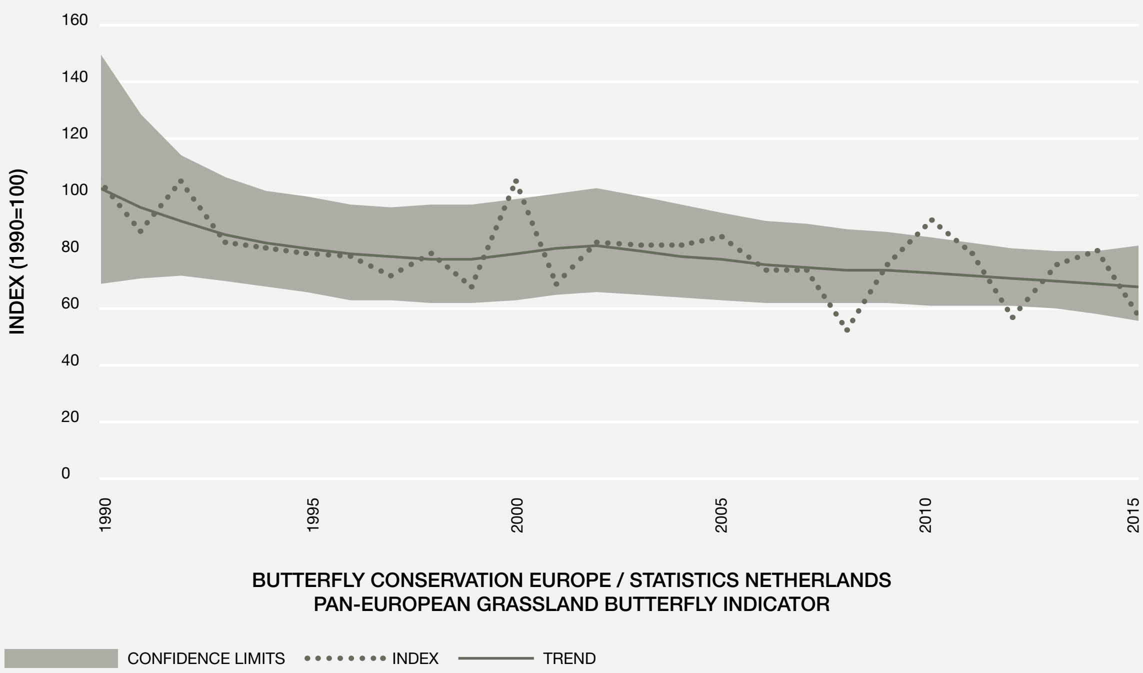


Figure 3 14 A Change in the climatic range of the Colorado beetle from 1991 to 2010 compared with 1951 to 1970. 1: unsuitable areas for the beetle; 2: range increment; 3: suitable in both periods. Source: Popova & Semenov (2013). B Annual growth rate (%/yr) in the number of honey bee colonies for countries reporting those data to FAO between 1961 and 2012. Source: FAO (2013a).

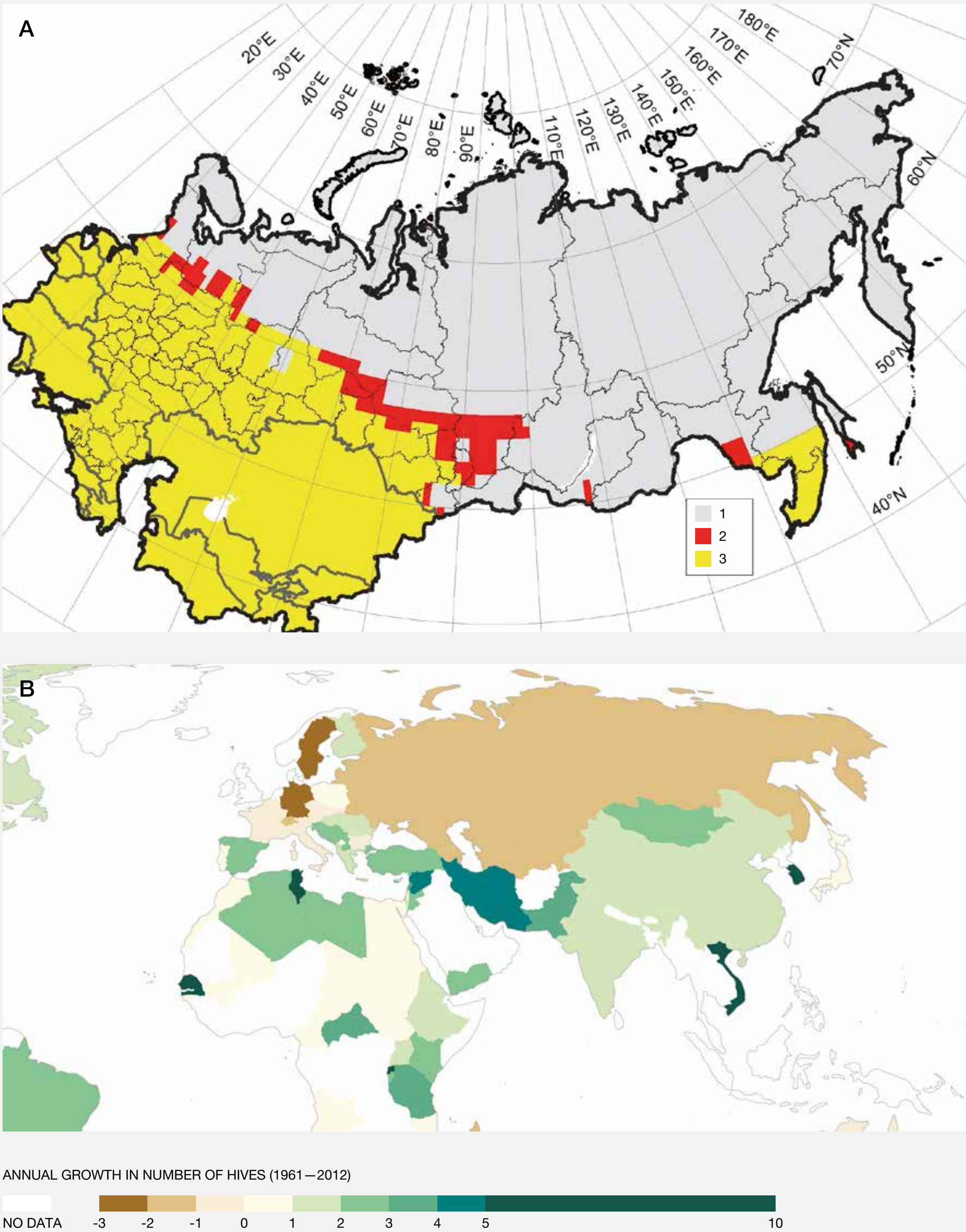
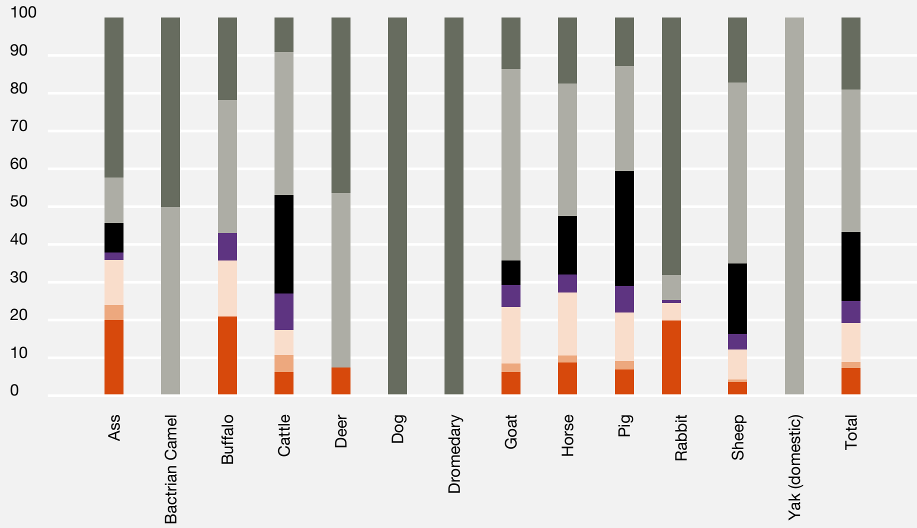


Figure 3 15 **Risk status of mammalian breeds in geographical Europe and the Caucasus up to December 2005. Relative (figures) and absolute (tables) numbers are presented. Source: FAO (2007).**



RISK STATUS	Ass	Bactrian Camel	Buffalo	Cattle	Deer	Dog	Dromedary	Goat	Horse	Pig	Rabbit	Sheep	Yak (domestic)	Total
Critical	10		3	35	1			15	41	23	38	26		192
Critical-maintained	2			24				5	8	7		5		51
Endangered	6		2	37				34	78	42	8	65		272
Endangered-maintained	1		1	51				13	22	21	1	32		142
Not at risk	6	2	5	205	6			117	163	90	13	375	1	983
Extinct	4			142				16	72	102		148		484
Unknown	21	2	3	48	6	13	1	30	79	41	127	133		504
TOTAL	50	4	14	542	13	13	1	230	463	326	187	784	1	2628

While scientific publications on biodiversity trends in agricultural areas in Central Asia and some parts of Europe are not numerous, precious information can be derived from indigenous and local knowlegde. For instance, Hungarian herders have a deep understanding of biodiversity and its trends in managed grasslands, and they also report a biodiversity decline, in particular for bird and plant species richness and abundances (Molnár, 2014; Varga & Molnár, 2014).

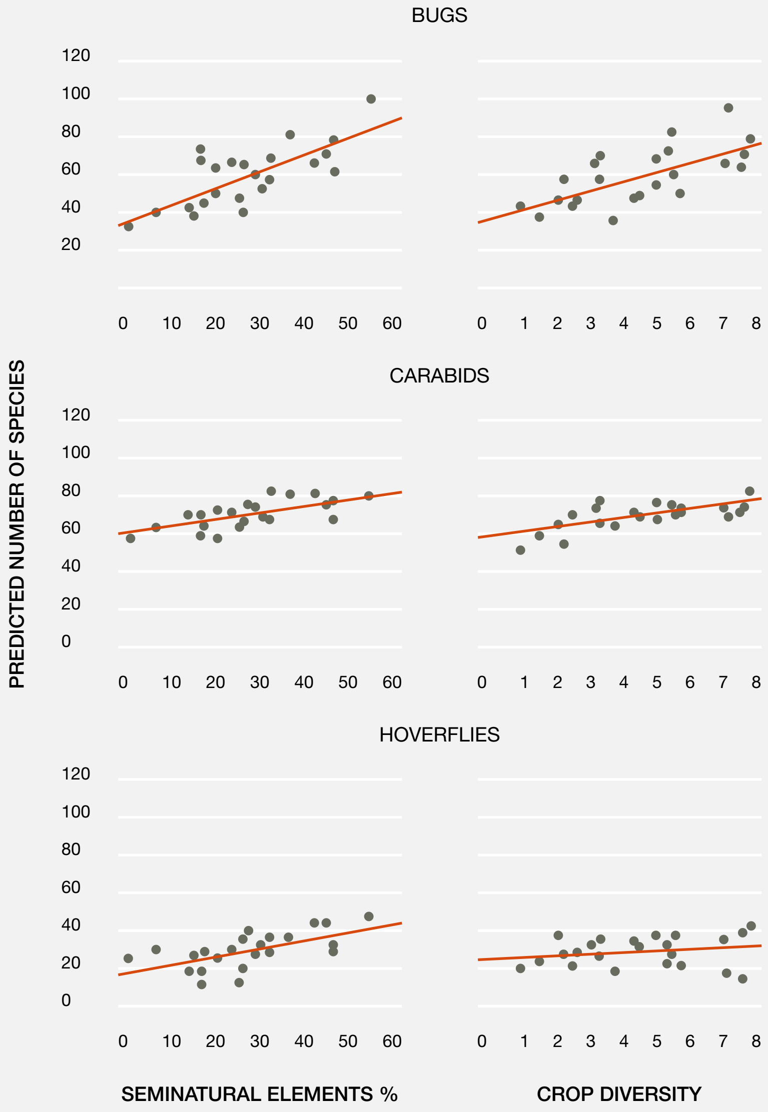
ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Main drivers influencing biodiversity in agricultural areas: The moderate utilization of lands in historical times was associated with high species richness in the rural landscape of Europe (Kull and Zobel, 1991; Pykälä, 2003), leading to the concept of high nature value farmland (Halada *et al.*, 2011). The traditional, non-intensive agriculture and the management of marginal lands generally have a positive role in maintaining high biodiversity levels.

As reported by a large majority of the many studies on this subject, lower biodiversity levels are very generally observed with increasing intensification of agricultural systems (Le Roux *et al.*, 2008). These are mostly related (1) at the landscape scale to decreased percentage of natural and semi-natural elements, decreased habitat diversity or crop diversity, and to a lesser extent reduced coverage of extensively managed crops; (2) at the field scale to increased addition of pesticides and fertilizers, and other practices like drainage; and to a lesser extent (3) to decreased connectivity between habitats (Le Roux *et al.*, 2008; STOA, 2013) **(Figure 3.16)**.

Overall, the effects of the level of agricultural intensification on the diversity of several taxonomic groups are now well documented, but are complex and depend on both the considered group, aspect of intensification and spatial scale (e.g. Jørgensen *et al.* 2016b for farmland birds). Intensive farming also has impacts on biodiversity outside agricultural areas and outside Europe and Central Asia (STOA 2013). In

Figure 3 16 **The species richness of aboveground invertebrate groups (here bugs, carabids and hoverflies) increases with the percentage of semi-natural elements and crop diversity in twenty-five 16-km² agricultural landscapes from seven European countries. Source: Billeter *et al.* (2008).**



parallel, partial or complete abandonment of agricultural management on non-intensively managed systems is a major threat to biodiversity in Europe and Central Asia (Billeter *et al.*, 2008; STOA, 2013), and many studies have reported that biodiversity declines following abandonment for several biological groups (Le Roux *et al.* (2009) and references therein). In parts of Central Asia, the decline in cooperative farms and intensive agriculture based on relatively few economically important crops has led to a return to a more diverse crop production, offering opportunities to biodiversity.

Main drivers influencing particular taxonomic groups: The steep decline in farmland bird populations during the 1980s and 1990s was associated with increasing agricultural specialisation and intensity in some areas, and large-scale marginalisation and land abandonment in others (Pe'er *et al.*, 2014). As these changes have expanded eastwards, a steeper decline has been reported in Central Europe in recent years (EBCC, 2013). Agri-environment schemes implemented after revision of the European Union's agri-environmental programmes in 2007 were not more effective for farmland bird diversity than schemes implemented before revision (Batáry *et al.*, 2015). In post-

Box 3 2 Does biodiversity increase in response to agri-environmental schemes?

A meta-analysis (Batáry *et al*., 2015) showed that agri-environment schemes benefit species richness and abundance, but several reviews reported that current schemes are not sufficient to reverse the decline of farmland biodiversity in Europe (Berendse *et al.*, 2004; Kleijn *et al.*, 2006). This is likely due to the fact that many agri-environment schemes do not sufficiently target biodiversity conservation or are not applied over a sufficient land cover (STOA, 2013; see Chapter 6).

soviet countries in Eastern Europe and Central Asia, the dynamics of farmland bird populations were mainly driven by land-use changes linked to the transition to the market economy (Kamp *et al.*, 2015; Kessler & Smith, 2014).

Intensifying agriculture on the one hand, and abandoned land (mainly in Eastern Europe and Southern parts of Western and Central Europe) on the other, are the two main driving forces affecting the populations of grassland butterflies (van Swaay *et al.*, 2015).

Evidence has accumulated of a significant decline in populations of bees (including bumblebees) over the past 60 years in geographical Europe, resulting mainly from agriculture intensification (IPBES, 2016b). Many of the environmental threats to wild bee diversity in Europe are associated with modern agriculture and, in particular, shifting agricultural practice and increasing intensification of farming (Nieto *et al.*, 2014). In addition, while agriculture has become increasingly pollinator-dependent, the number of honeybees required to provide crop pollination across 41 countries from the region has risen 4.9 times faster than honeybee stocks between 2005 and 2010 (Breeze *et al.*, 2014; Schatz & Dounias, 2016).

Bats, rodents, and herbivorous and carnivorous mammals, are all in decline due to agriculture intensification in geographical Europe since mid-20th century (e.g. Flowerdew, 1997; Pocock and Jennings, 2008). Among different drivers linked to intensive agriculture (Stoate *et al.*, 2009), molluscicides and rodenticides are considered the greatest risk to mammals, both through primary and secondary exposure (Shore *et al.*, 2003), while poisoning by pesticides persists or tends to decrease locally (Barnett *et al.*, 2006). It is noteworthy that several large mammals such as the wolf (*Canis lupus*), brown bear (*Ursus arctos*), lynx (*Lynx lynx*) wild boar (*Sus scrofa*), and moose (*Alces alces*), are probably gaining from land abandonment, expansion of forest cover or subsequent increase in ungulate mammal prey in Europe and Central Asia (Moreira and Russo, 2007; Falcucci *et al.*, 2007; Russo, 2007; Sieber *et al.*, 2015).

The role of ecologically-friendly agricultural practices: During recent decades, agricultural practices and systems alternative to intensive ones have been developed (including new practices or previously widespread ones), such as leaving field margins unsprayed, stricter pesticide management, reduced tillage, and organic farming (EBCC, 2017; see Chapter 4 for details and temporal trends). The effects of these "ecologically-friendly" agricultural practices on biodiversity are generally positive, but can vary, e.g. according to the landscape context and spatial scale of evaluation **(Box 3.2)**.

In particular, organic farming has been shown to increase local species richness of wild organisms, although with large variation between studies (Tuck *et al.*, 2014). The effect differs between taxonomic groups (Dicks *et al.*, 2016; Fuller *et al.*, 2005), with particularly beneficial effects on plants and pollinators (Batáry *et al.*, 2011, Tuck *et al.*, 2014). Other differences between studies can be attributed to the effect of landscape context (Tuck *et al.*, 2014), the local extent of organic farming (Gabriel *et al.*, 2010) and time since conversion to organic farming (Jonason *et al.*, 2011). However, beneficial effects of organic farming may be mainly local (Bengtsson *et al.*, 2005), and it is not clear whether effects on local biodiversity scale up to effects on biodiversity at regional scales (Gabriel *et al.*, 2006; Schneider *et al.*, 2014).

Given the low uptake of organic farming in areas with high agricultural intensification, where the effects on biodiversity would be greatest (Rundlöf & Smith, 2006), the actual effect of organic farming on general biodiversity trends may be smaller than expected. Organic farming may contribute to the maintenance of agriculture in marginal areas of high value for biodiversity (Gabriel *et al.*, 2009), but the extent of this effect remains unknown.

The question of how farmland conservation initiatives actually contribute to the policy objectives of halting the decline of agrobiodiversity largely remains to be addressed in a quantitative manner (see Kleijn *et al.* (2011) and references therein) and using adequate indicators.

3.3.2.10 Urban areas

OVERVIEW OF THE SUB-SYSTEM

Urban green infrastructures comprise systems of indigenous habitats, formal (e.g. parks, cemeteries) and informal (e.g. ruderal, transportation areas) green space, artificial habitats (e.g. green roofs and walls, ponds), semi-natural and rural habitats. Taxa that occupy these habitats vary in their sensitivity to urbanization, with some assemblages comprising generalist species and others retaining specialist species and contributing more to biodiversity (Niemelä & Kotze, 2009). During the expansion phases of cities, both through outward expansion into the peri-urban region and densification, changes occur in the provision of green space and the composition of species assemblages (Kotze *et al.*, 2014). The European Union "Plan of Action on Subnational Governments, Cities and Other Local Authorities for Biodiversity (2011-2020)" emphasizes the essential role of cities in achieving the Aichi Biodiversity Targets. Also the 7th Environment Action Programme supports the development of initiatives for the conservation of biodiversity.

Urbanization has changed habitats, both spatially and through the release of heat, waste, nutrients and contaminants. Cities generate novel habitats and assemblages, as many species adapt to urban conditions, and urban habitats acquire characteristic communities. Disturbance is typical of urban habitats and they tend to remain at early to mid-successional stages, which can have high levels of species diversity. A number of the species that have become most adapted to cities originate in rocky habitats, such as the rock pigeon (*Columba livia*), the common swift (*Apus apus*) and the alpine swift (*Tachymarptis melba*) (Kelcey & Rheinwald, 2005). In Central Asia, the core urban avian fauna comprises 7 to 17 species (Fundukchiev, 1987) with distinctive adaptive traits to urban conditions.

Such novel features as green roofs and green walls have been introduced into many cities as potential means of enhancing the provision of supplementary habitats. Studies show that these can develop diverse assemblages of arthropods and vascular plants (Madre *et al.*, 2013), and they probably have the potential to support the biodiversity of some taxa.

PAST AND CURRENT TRENDS

As a result of intensive urbanization in the 20th and 21st centuries, patches of indigenous habitats have become fragmented, and many species have declined or disappeared. The overall result is generally a loss of species across most taxa, particularly specialized species, and a subsequent assemblage of mostly generalist species that are adapted to urban conditions.

Many species have adapted to urban conditions and are recognized as typical urban species. These include the European red fox (*Vulpes vulpes*) and feral pigeon (*Columba livia domestica*), and in Central Asia the common myna (*Acridotheres tristis*). In addition, many species have been periodically recorded as expanding into urban areas, such as the flying squirrel (*Pteromys volans*) in Helsinki (Mäkeläinen *et al.*, 2016), the Eurasian eagle owl (*Bubo bubo*) in numerous cities (König & Weick, 2008) and the Eurasian lynx in Tallinn and Espoo. These probably result from declines in resources in peri-urban regions and availability of resources within urban regions. Vulnerable taxa, such as ground-nesting birds, do not persist in cities due to many threats.

Fish species have declined in urban areas, with the loss of migratory species, such as salmon (*Salmo salar*), sturgeon (*Acipenser sturio*) and river lamprey (*Lampetra fluviatilis*), through fragmentation due to obstacles to free movement along rivers. Modification of rivers by straightening channels, dredging and canalizing, has resulted in the loss of species that inhabit or breed in gravel beds and river margins. Recently there have been initiatives in many cities to restore natural features of rivers, improve water quality and enhance connectivity. Some fish species that are present outside urban areas, such as three fish species endemic to the River Danube, *Gymnocephalus schraetzer*, *G. baloni* and *Zingel zingel*, which are all occasionally recorded in Budapest (Tóth-Ronkay *et al.*, 2015), have potential to benefit from restoration of urban river systems.

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

There is a high level of impact of land-use change on both the extent of habitat and the biodiversity status. The loss, degradation and isolation of both terrestrial and aquatic habitats, is a major cause of declines in biodiversity. Habitat loss is mainly due to replacement of green space with urban infrastructure, and the conversion of indigenous habitats to managed habitats, such as parks and gardens (Kabisch & Haase, 2013). There is a high level of variation within the region **(Figure 3.17)** (Siedentop & Fina, 2012).

Habitat degradation includes qualitative changes in habitats that are not destroyed, but converted, such as woodlands converted to parks, species-rich grasslands - to lawns, or water bodies that are dredged, drained, canalized or diverted into pipes. Homogenization due to management practices leads to loss of specialized species and domination of communities by a small number of generalist species.

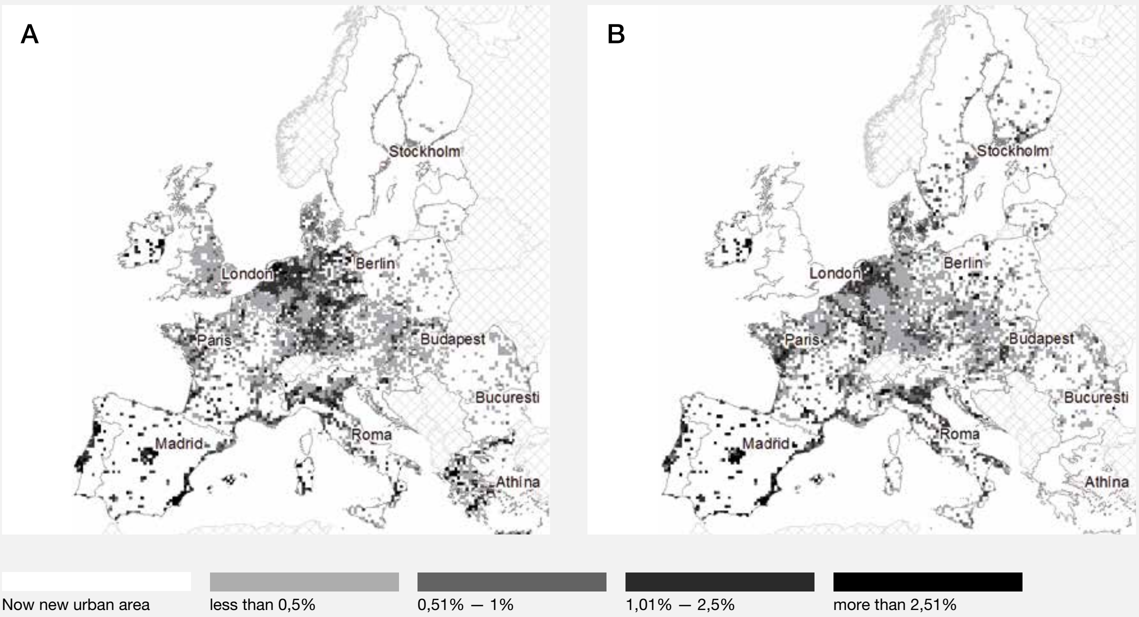
Relict natural habitats such as steppe grasslands and limestone caves in Budapest (Tóth-Ronkay *et al.*, 2015) and calcareous sand dunes in Rotterdam (Van de Poel *et al.*, 2015), support communities of specialized species, though fragmentation often leads to species losses and reduces the potential for re-colonization. Large old mature trees in parks, often more common even than in mature forests, can provide nesting cavities for birds and support communities of saproxylic insects (Venn *et al.*, 2015) and fungi, such as polypores, though they have been reduced in some cities for safety reasons. Such habitats may be lost outside cities and become increasingly valuable for biodiversity (Gilbert, 1989), depending on their size and capacity to retain characteristic species communities.

Fragmentation and loss of connectivity is one major cause of biodiversity decline. Migratory species such as the common frog (*Rana temporaria*), which migrates between running water, still water and terrestrial habitats during its annual life cycle, are particularly vulnerable (Šťastný *et al.*, 2015). Fragmentation and isolation of habitats results from the development of urban infrastructure, particularly communication networks, such as roads, but can also include noise, light and chemical barriers both within and between habitats (Vershinin *et al.*, 2015). Some cities retain large green space elements and extensive corridor networks, often following the courses of rivers, such as riparian forests (Herrera *et al.*, 2015).

Climate change has less negative impacts in urban areas than in many other systems, as urban areas are warmer, lighter and drier, and thus their assemblages tend to contain mainly thermophilic species. However, cities in northern parts of the region, such as Helsinki and Rotterdam, are experiencing an ongoing influx of species of many insect taxa, including Lepidoptera, Carabidae, Odonata and Apidae, as a consequence of range expansions due to climate change (Moerland *et al.*, 2015; Venn *et al.*, 2015).

Pollution affects habitats and communities most intensively and extensively in urban regions. Pollutants include heavy metals, pesticides, nutrients, salt, other chemicals, heat and light. In many cities, legislation has been introduced to control pollution, with consequent decreases in their levels in green infrastructure. Heavy metals are common in most urban soils, and lead levels can be high adjacent to major roads, due to the use of lead in petrol fuels prior to the 1990s. Pesticide residues (DDT, DDD, DDE, phosphorus organic-trichloroform) are present in high concentrations in suburban regions of some eastern European cities (Peskova, 2000). Some rare plants, with tolerance to metals, including a number of orchid species, occur at sites containing calcareous metalliferous spoils in the UK (Johnson *et al.*, 1978). The urban heat island phenomenon can increase temperatures by approximately 2–3°C in the urban core (Vershinin *et al.*, 2015). In northern Europe, many cities contain thermophilic species due to suitable microclimatic conditions. These include fish and amphibians in aquatic habitats and also fig trees (*Ficus carica*), for instance, in some UK cities (Gilbert, 1989). Thermal pollution can also result in phenological changes (Belimov & Sedalishchev, 1980; Fominykh & Lyapkov, 2011; Piano *et al.*, 2017). High levels of light pollution, particularly in Central and Western Europe **(Figure 3.18)** cause a disorientating effect on some nocturnally flying insect

Figure 3 17 **Patterns of annual change of urban land cover across 26 European countries for the periods A 1990–2000 and B 2000–2006. Source: Siedentop & Fina (2012) based on CORINE land-cover data.**



taxa and can compromise pollination (Knop *et al.*, 2017). Bats, amphibians and entomophagous mammals use this niche, i.e. streetlights, illuminated buildings, for foraging. Recently there have been initiatives to reduce the amount of energy used for lighting and the amount of light lost into the atmosphere.

Overexploitation in the urban systems is attributed to excessive utilization of recreational areas, which can lead to erosion. Tourism pressure has also had an impact on vulnerable biotopes in the Mediterranean region (Mansuroglu *et al.*, 2006). Land-use change, recreational activities and the intensification of fish farming have also affected populations of amphibians, as has the spread of the chytrid fungus *Batrachochytrium dendrobatidis*, which has devastated amphibian populations in many parts of Europe and Central Asia (Šťastný *et al.*, 2015; Tóth-Ronkay *et al.*, 2015).

Alien and invasive species seriously affect ecological equilibria, and displace indigenous species or hybridize with them (Rhymer & Simberloff, 1996). Urban sites are among the most invasible biomes (Richardson & Pysek, 2006). Exotic species are a problem in most cities. Both escapes of garden plants and the release of pets maintain alien species populations (Herrera *et al.*, 2015). It has been estimated that 2,000 exotic species of arthropods were introduced to Europe during the 20th century (Kobelt & Nentwig, 2008), mostly via cities. In the case of taxa introduced incidentally via anthropogenic activity, such as spiders and other arthropods, the majority of these arrive via international trade (Kobelt & Nentwig, 2008). Many cities have programmes for the control of alien invasive species, though a major problem is the delay between recognition of invasiveness and initiation of control measures. Some invasive plant species, such as *Elodea canadensis, Solidago canadensis, or Heracleum* species have colonized virtually the whole of Europe. Invasive plant and tree species, such as *Robinia pseudoacacia* and *Acer negundo*, also lead to homogenization of woodlands and loss of microhabitats and associated communities.

In aquatic communities, introductions of alien fish species including carp (*Carassius* spp), rainbow trout (*Oncorynchus mykiss*), silver carp (*Hypophthalmichthys molitrix*) and

Figure 3 18 **NASA satellite image of global city lights (2008). Source: Craig Mayhew and Robert Simmon, NASA GSFC. Based on data from the Defense Meteorological Satellite Program.**

eel (*Anguilla anguilla*), reduce the potential for restoring indigenous communities (Herrera *et al.*, 2015; Šťastný, 2015; Tóth-Ronkay *et al.*, 2015).

CONSERVATION INITIATIVES

There are many cases of habitat and population restoration and species reintroductions in cities of Europe and Central Asia (McNeill, 2010). Many of these have been accomplished through EU LIFE actions. Many cities have biodiversity plans, or biodiversity incorporated into other strategic policy. There is ongoing encroachment of large areas of green space for development, due to the dwindling availability of suitable land for construction. Wetlands, rocky hills and other habitats have been conserved and many, such as the riparian forests of Dresden and Leipzig, have been protected (Haase & Gläser, 2009).

Parks and woodlands can also be valuable, and in many cities they are now managed less intensively, with retention of decaying wood for saproxylic species. Spider assemblages of cities are diverse and include a considerable number of species benefitting from humans and urban spaces (Fedoriak *et al.*, 2012). Many of these are also present in green infrastructure and some species have adapted to inhabiting buildings since the 1930s.

Lepidopteran species of meadows and open habitats, are particularly sensitive to urbanization, with poor levels of diversity in urban areas and higher diversity restricted to more natural areas at the periphery (Šťastný, Červený, Řezáč, *et al.*, 2015). The decline of Lepidoptera has resulted from intensive urban development, widespread use of pesticides during the post-war period and light pollution, which attracts and disorientates males of nocturnal species (Manu *et al.*, 2015). Many cities have had more diverse assemblages of Lepidoptera during the early 20th century (e.g. Manu *et al.*, 2015). Replacement of vegetation with solid surfaces is probably a major reason for this decline. River banks and remnant forest habitats still retain some noteworthy species, such as the ash hawkmoth (*Dolbina elegans*) in Bucharest (Manu *et al.*, 2015).

Cities also provide opportunities through the allocation of municipal resources to conservation for the maintenance of urban biodiversity. This can include mowing and grazing of meadows for the benefit of plants and insects (Venn *et al.*, 2015), management of wetland vegetation for amphibians (Šťastný, Červený, Rom, *et al.*, 2015) and control of invasive species. This is particularly important for species that decline due to the cessation of suitable management regimes of semi-natural habitats. However, many of these are affected by landscape change on such a large regional scale that local initiatives alone do not have the capacity to improve the situation dramatically.

3.3.2.11 Special systems

3.3.2.11.1 Heathlands

OVERVIEW OF THE SUB-SYSTEM

Dwarf-shrub dominated heaths are among the principal cultural landscapes of the Atlantic regions of Western Europe (Janssen *et al.*, 2016). These heathlands developed about 4,000 years ago as a result of forest clearances, and have since been maintained by a land-use regime that may include year-round free-range grazing by domestic ungulates, prescribed burning, cutting of vegetation and turf for fuel, and harvesting of vegetation for fodder (Gimingham, 1972; Kaland, 1986; Odgaard, 1994; Jansen *et al.*, 1997). Heathlands have since been an intrinsic part of the agricultural system, with the pattern and intensity of their use closely linked with the local agricultural economy (Diemont & Jansen, 1998; Kaland, 1986, Diemont *et al.*, 2013).

Heathlands harbour unique landscape and habitat qualities and specialized biodiversity, and are thus of nature conservation interest (Janssen *et al.*, 2016, Halada *et al.*, 2011, Rosa Garcia *et al.*, 2013, Halvorsen *et al.*, 2015, Nybø & Evju, 2017, Webb *et al.*, 2010). They support characteristic plant and animal assemblages (Webb, 1986), which respond to, and in part are dependent on, the interplay between traditional management practices and underlying environmental variability (vascular plants and bryophytes (Vandvik *et al.*, 2005; Velle *et al.*, 2014), carabid beetles (Bargmann *et al.*, 2015), other insects (WallisDeVries *et al.*, 2016), and soil invertebrates (Ponge *et al.*, 2015)). The long-term land-use history of heathlands has also had evolutionary consequences, for example, *Calluna vulgaris* seed germination is stimulated by smoke in heathlands, a trait that is lacking in populations from other habitats not regularly subject to burning, such as alpine areas (Vandvik *et al.*, 2014).

PAST AND CURRENT TRENDS

Traditional management practices maintained open heathlands until the beginning of the 20th century. During their maximum extent **(Figure 3.19)** heathlands occurred over several million hectares, but today less than 350,000 ha remain (Diemont *et al.*, 1996; Webb 1998).

The heathlands of Western Europe are now threatened throughout their range (https://bd.eionet.europa.eu/; Lindgaard and Henriksen 2011). In the Mediterranean parts of Western Europe, major heathland habitat types (European Union habitat number 4010 - Northern Atlantic wet heaths with *Erica tetralix*, 4020 - Temperate Atlantic wet heaths with *Erica ciliaris* & *E. tetralix*, and 4030 - European dry heaths), are reported by European Union member States to be in

Figure 3 19 **Distribution of lowland heathlands in Western and Central Europe during their maximum extent, ca. 1850. Source: Haaland (2002).**

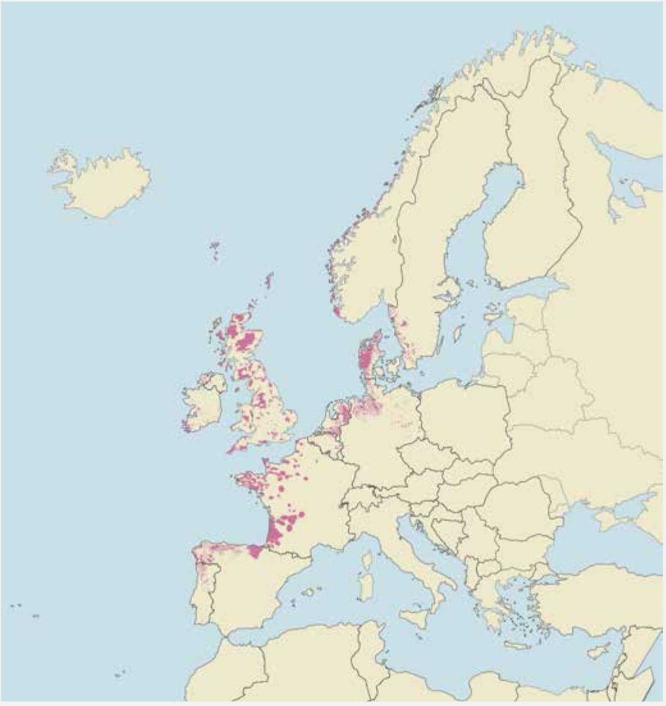


Figure 3 20 **Distribution and conservation status of Habitat 4030 Dry Heaths across Europe.**

Green: Favourable status. Grey: Unknown. Yellow: Unfavourable-Inadequate status. Red: Unfavourable-Bad status. Note that heaths of countries not party to the Habitats Directive are not reported and mapped in Eionet. Source: https://bd.eionet.europa.eu.

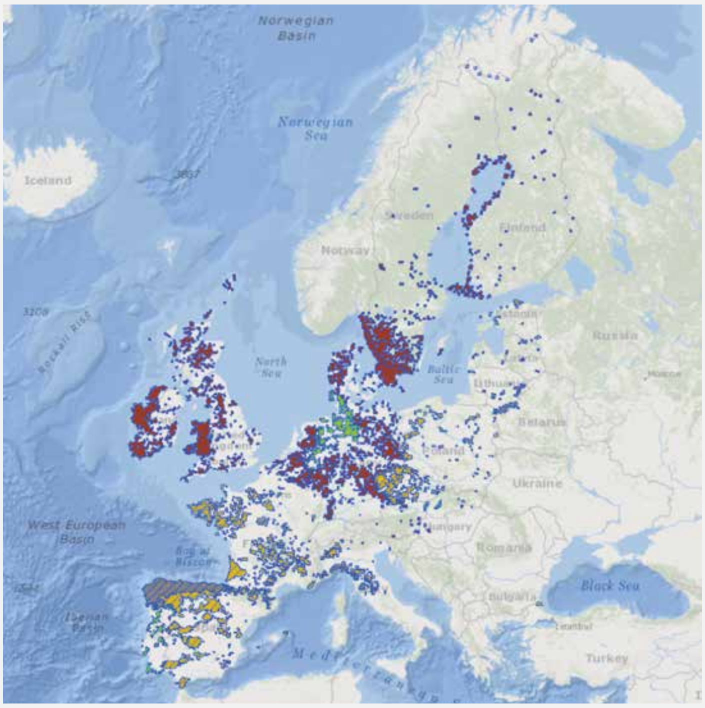
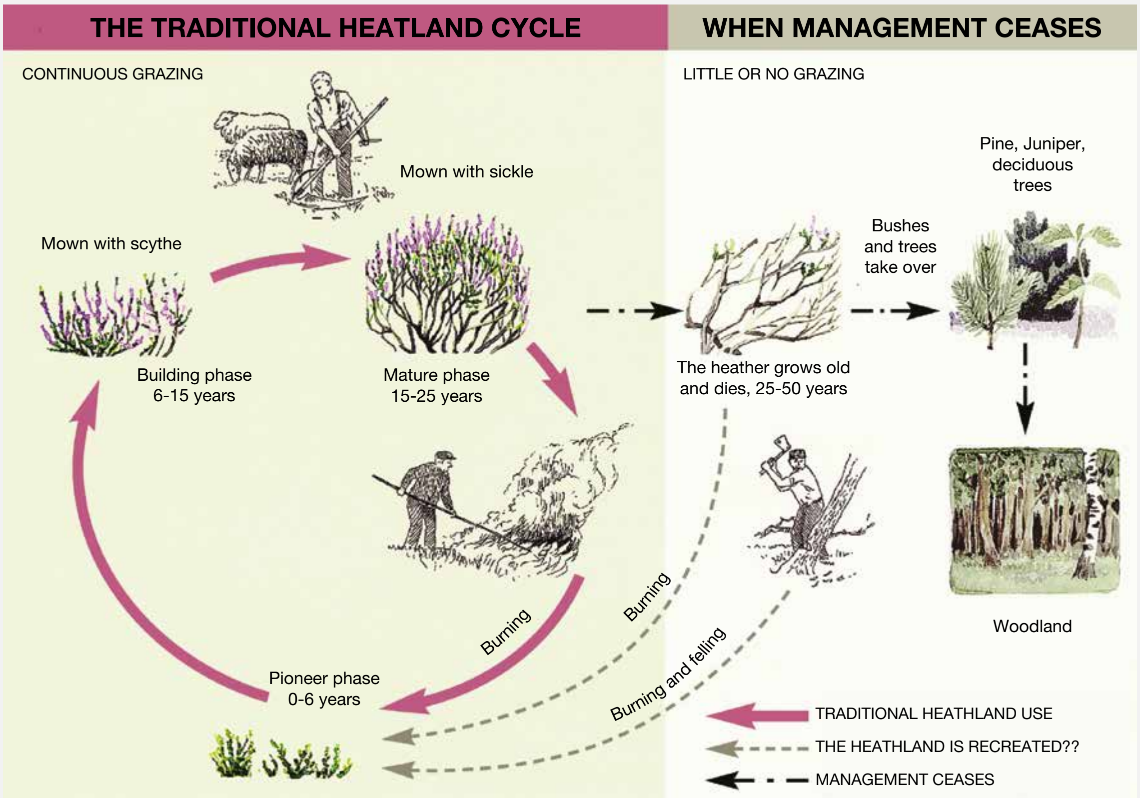


Figure 3 21 **The traditional management cycle with prescribed burning, grazing, and mowing, and the successional dynamics occurring after abandonment of management in heathlands. Source: Developed from Gimingham (1972).**



"inadequate" conservation status. In the Continental, Boreal and Atlantic parts[6] these same habitats are reported to have "bad" conservation status. Dry Atlantic coastal heath with *Erica vagans* (Habitat 4040) is somewhat less threatened, its status being classified as "inadequate". The European Red List of Habitats (Janssen *et al.*, 2016) classifies some heathland types (F4.1 Wet heath and F4.2 Dry heath) as "vulnerable". Approximately one third of the latitudinal distribution of heathlands is found in Norway, which is not party to the Habitats Directive. The corresponding Norwegian Red List for ecosystems and habitat types classifies northern coastal heathlands as "endangered" (Lindgaard & Henriksen 2011, **Figure 3.20**).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Across their range in Western Europe, heathlands thus suffer from poor conservation status and loss of biodiversity and ecosystem functions. The underlying drivers of these negative trends vary. Pollution (especially atmospheric nitrogen deposition and associated acidification), land-use intensification, and habitat loss or fragmentation are the main drivers in the central parts of the heathlands' range (Härdtle *et al.*, 2009; Aerts & Heil, 2013). Land abandonment and habitat conversion, including afforestation, dominate in the southern, westernmost, and northern parts (Britton *et al.*, 2017; Fagúndez, 2013; Halvorsen *et al.*, 2015; Nybø & Evju, 2017). Contrasting processes may drive changes within the same landscape or region. For example, in the UK declines in the quality of lowland heaths have occurred due to increasing stocking in privately owned sites and succession towards woodland in areas managed for forestry or conservation (Diaz *et al.*, 2013). In the uplands of the UK over-exploitation for sheep grazing is a critical concern (Pakeman & Nolan, 2009). In some important parts of heathland range future prospects are undermined by controversies over their ecological importance and the sustainability of management regimes **(Figure 3.21)** (Davies *et al.*, 2016).

6. Continental, Boreal and Atlantic parts of Western Europe as per EU Habitats Directive

3.3.2.11.2 Caves and other subterranean habitats

OVERVIEW OF THE SUB-SYSTEM

Subterranean habitats represent an extreme environment with unique particularities including trophic dependence on surface ecosystems. The relative constancy of abiotic factors makes these habitats and their associated fauna one of the most vulnerable on Earth to any disturbance (Juberthie, 2000). The absence of photosynthetic activity, limited supply of organic material, as well as stable temperature, high relative humidity and low rates of evaporation create an environment that determines the distribution and population density of cave fauna (Holsinger, 1988). Subterranean ecosystems encompass terrestrial and aquatic systems - the latter constituting freshwater, anchialine (with an underground connection to the ocean) and marine systems.

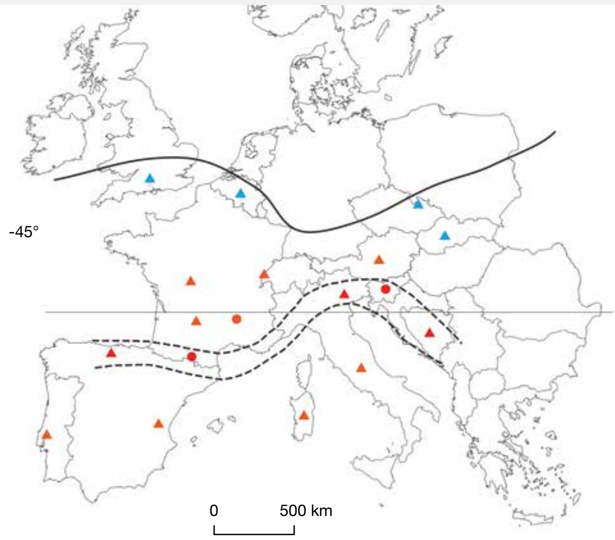
We distinguish to two types of subterranean systems, subterranean terrestrial systems (dry caves, epikarst, MSS (*milieu souterrain superficiel*)) and subterranean aquatic systems (flooded caves, groundwater, interstitial).

Typically, two main zones are recognized in the karst: epikarst (cutaneus zone, the surface; and soil and subcutaneus zone, the regolith and enlarged fissures) and endokarst (vadose zone, water unsaturated, and phreatic zone, water saturated) (Ford & Williams, 2007; Palmer, 1991). Karst systems provide heterogeneous habitats of interconnected cracks, fissures and draines, filled with air or water. The karst process is polyphasic through geological time and related to the change of level of sea and landmass, so inactive (fossil) caves may be present at different elevations. Moreover, shallow subterranean habitats, as areas of habitable space that are less than 10 metres in depth beneath the surface (ranging from large areas such as lava tubes, to tiny areas such as cracks in cave ceilings or pore spaces in soil) have little in common with caves except for the absence of light and a specialized fauna with typical "cave" morphology (Culver & Pipan, 2014).

Subterranean habitats and there fauna are extremely vulnerable and endangered mostly by anthropogenic influences (pollution, overexploitation of caves, changing of water regime, building of hydropower plants and dams) as well as climate changes. Ecological categories are defined as stygoxene and trogloxene (stygo- relates to aquatic and troglo-to terrestrial) species, which spend their complete life cycle in surface environments and are only accidentally found in subterranean habitats; stygobite and troglobite species, which spend their complete life cycle in subterranean environments; stygophiles and troglophiles may have several kinds of life cycles— some populations live in surficial habitats and others in

Figure 3 22 **Map of species richness patterns of Western and Central European obligately subterranean terrestrial species (troglobionts).**

The blue triangles are areas with few if any troglobionts, the orange triangles are areas with fewer than 50 species, usually much fewer than 50, and the orange circle is Ardeche, with fewer than 50 species in 5000 km^2 of area or less. The red circles are the diversity hotspots in Slovenia and Ariege. Red triangles are other possible diversity hotspots. The boundary of the Pleistocene ice sheet is shown as a scored solid line. A pair of dashed lines indicates the hypothesized position of the high-diversity ridge. Source: Adapted from Culver *et al.* (2006); Culver & Pipan (2013).



subterranean habitats, or individual life cycles necessitate use of both surface and subterranean environments (Gibert & Deharveng, 2002).

By 2000, approximately 5,000 obligate subterranean aquatic (stygobionts) and terrestrial (troglobionts) species from Central Europe had been described. 1,200 had been described from Asia, 500 from Africa, and 1,000 from North America (Gibert & Culver, 2005). Central Europe is both a hotspot of subterranean biodiversity and a hotspot of research into subterranean biology, both historically and at present (Deharveng *et al.*, 2009). The Dinaric karst in the western Balkan Peninsula is a global hotspot of subterranean biodiversity, with more than 900 aquatic and terrestrial obligate subterranean species recorded (Sket, 2012a). Troglobiotic beetles are considered the most important contributors to terrestrial subterranean biodiversity in most temperate karst regions, including the Dinaric karst, where they present about 42% of the terrestrial troglobionts (Sket *et al.*, 2004). Subterranean biodiversity in Europe is actually higher than on other continents as indicated by (Culver & Sket, 2000).

Figure 3 23 **Distribution of the species richness of obligately subterranean terrestrial (troglobiotic) beetles in Dinaric karst at different grid cell sizes: A 80 x 80, B 40 x 40, (C) 20 x 20, D 10 x 10, E 5 x 5 km.**

Included are all records with localities of positional accuracy of 3 km or less, including 254 species (Lambert Conformal Conical Projection). Source: Zagmajster *et al.* (2008).

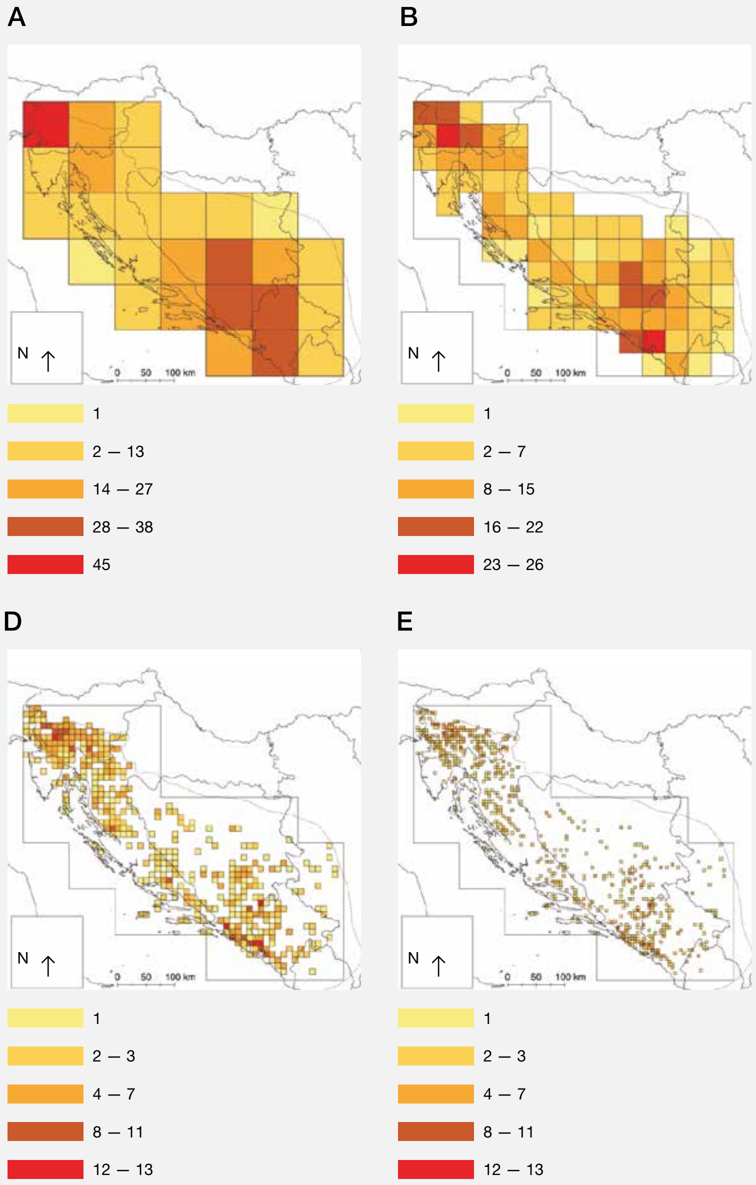


Figure 3 24 **Map of obligately subterranean aquatic (stygobiotic) species numbers in 0.2 x 0.2 ° grid cells distributed across six Western and Central European countries. Source: Deharveng *et al.* (2009).**

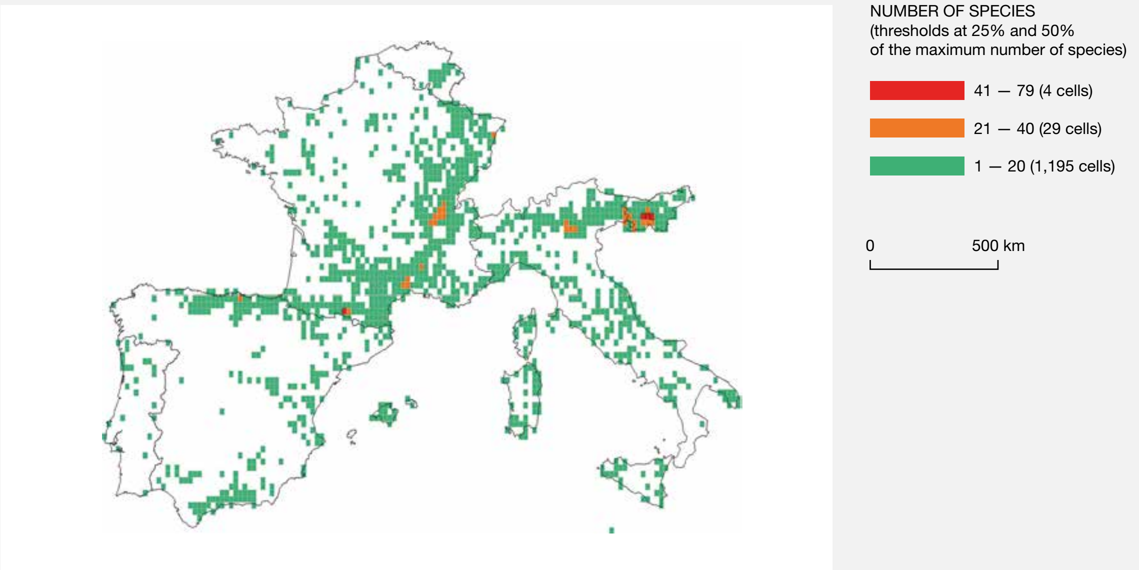


Figure 3 25 **Olm *Proteus anguinus*, an endemic species of Dinaric karst (Rupećica Cave in Ogulinsko Zagorje, Ogulin, Croatia, 2014). Photo: Dušan Jelić.**

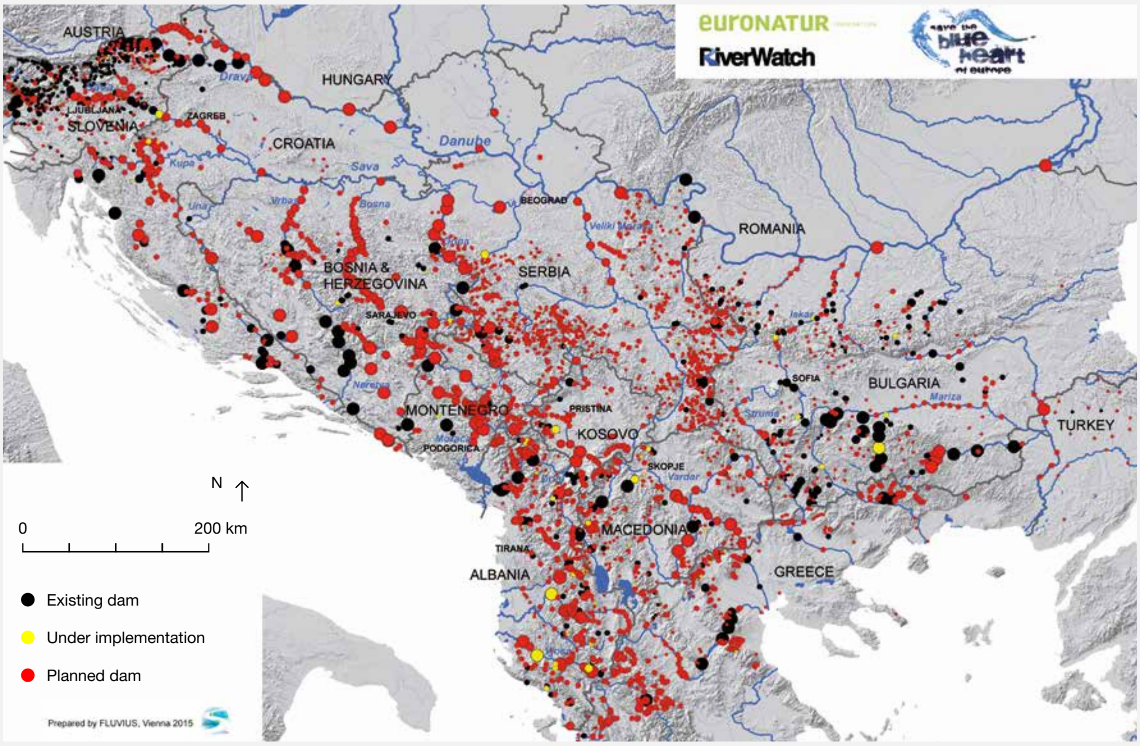
There are also visible geographic patterns within Western and Central Europe. The first one is a gradient in species richness with diversity decreasing from south to north and highest biodiversity within the mid-European high subterranean diversity ridge **(Figure 3.22)**. For details see Culver & Pipan (2013).

Some of the biodiversity hotspots are in the western Balkans (northeast Italy, Slovenia, Croatia, Bosnia and Herzegovina, and Serbia) and the Pyrenees (France and Spain). Increased diversity of stygobionts in the western Balkans could be explained by the complex biological and geological history of the Dinaric mountains (Sket, 1999) and complex history of the Mediterranean Sea (including its almost complete drying about 6 million years ago during the Messinian crisis) **(Figure 3.23, Figure 3.24)**.

Population data are deficient compared with Western Europe, but information has recently improved for a few species, including olm *Proteus anguinus* (Trontelj & Zakšek, 2016; Trontelj *et al.*, 2009), chiropteran species (data collected by EUROBATS) and the bivalves *Congeria kusceri* and *C. jalzici* (Bilandžija *et al.*, 2014; Jovanović Glavaš *et al.*, 2017).

The Dinaric Arc is a habitat to one of the best-known representatives of stygofauna, the cave dwelling, blind salamander (olm; **Figure 3.25**). It is only found in the

Figure 3 26 **Planned hydropower plants in the Balkan Peninsula. Source: Schwarz (2012).**



Installed megawatts (MW)

0.1 < 1* 1 – < 10 MW 10 – 50 MW > 50 MW

* Class incomplete for existing SHHPs

Dinaric karst region of the Balkan Peninsula (Italy, Slovenia, Croatia and Bosnia and Herzegovina; endemics of Dinaric karst) and is a globally vulnerable species (VU) (Arntzen *et al.*, 2009). Its distribution is severely fragmented, and there is a continuing decline in the extent and quality of its habitat (underground aquifers) (Jelić *et al.*, 2012; Sket, 2012b). The olm is the largest strictly cave adapted (stygobiont) species in the World (23-25 cm) and, until recently, it was the only exclusively cave-dwelling vertebrate species found in Europe. Then, in 2012 the first cave loach (*Cobitis damlae*), was discovered in the Dalaman river drainage which flows into the karstic plain of western Turkey (Erkakan & Ozdemir, 2012).

IMPACT OF DIRECT DRIVERS ON SUBTERRANEAN HABITATS AND FAUNA

In the nineteenth and early twentieth centuries, some animals were caught in large numbers for illegal trading purposes (Sket, 2012b). The trend of collecting and trading in rare and endangered fauna or even paleontological samples (for example *Ursus speleous*) still persists (Lukić-Bilela *et al.*, 2013).

The main threats are habitat loss, water regulation and flooding, dam projects, overextraction, quarries, and pollution. Moreover, due to a lack of research species are likely being lost before they are even scientifically described.

Shifts in water level regimes and seasonal cave flooding due mainly to hydropower development pose extreme threats to underground ecosystems. More than 2,700 new hydropower plants are being implemented or planned in the south of Central Europe (area of the Balkan Peninsula) **(Figure 3.26)**.

Above-ground pollution was reported to seeps directly into the subterranean habitats and destroys unique biodiversity (Danielopol *et al.*, 2003; Slingenberg *et al.*, 2009).

Climate change impacts these fragile ecosystems through reduction of water in aquifers and lack of seasonal flooding (Hunkeler, 2007). Cave temperature are generally strictly connected with the external climate (Badino, 2004) and thus increase.

Subterranean ecosystems are generally extremely oligotrophic habitats, receiving very little degradable organic matter from the surface. Conversely, anthropogenic impacts on underground ecosystems (for example from intensive tourism and recreational caving) cause important alterations to the whole subterranean environment. In particular, artificial lighting systems in show caves support the growth of autotrophic organisms (the so-called *lampenflora*), mainly composed of cyanobacteria, diatoms, chlorophytes and mosses (Mulec & Kosi, 2009; Falasco *et al.*, 2014).

3.3.2.12 Progress towards Multilateral Environmental Agreements for terrestrial ecosystems

EUROPEAN UNION BIODIVERSITY STRATEGY

The European Union Biodiversity Strategy Target 1 "Fully implement the Birds and Habitats Directives" and Target 2 "Maintain and restore ecosystems and their services" define actions to ensure habitats and ecosystems protection. According to the 2015 mid-term review of the implementation of the Strategy by the European Environment Agency progress toward these targets is insufficient: 15.6% of terrestrial habitat assessments in the period 2007-2012 had favourable conservation status; 3.3% had unfavourable, but improving trends; 36.7% had unfavourable, but stable trends; 28,8% had unfavourable and declining trends; 11.2% had unfavourable status with unknown trend relative to the period 2001-2006 and 4.3% have unknown status (EEA, 2015d).

At the same time the network of Natura 2000 sites has progressed and is largely completed for terrestrial habitats, since 2010 it has grown by 1.4% and in 2015 covered 18.1% of land in the European Union. Overall, the European Union biodiversity targets 1 and 2 will not to be fully met by 2020 should the rate of progress not improve.

AICHI BIODIVERSITY TARGETS

Aichi Biodiversity Target 5 requires at least to halve the rate of loss of all natural habitats, including forests, and where feasible to bring it close to zero, and significantly reduce degradation and fragmentation. This is to be achieved through improvements in production efficiency and land-use planning, and enhanced mechanisms for natural resource governance combined with recognition of the economic and social value of ecosystem services provided by natural habitats (Nelson *et al.*, 2009, see Chapter 4). The emphasis for this target is specially made on preventing the loss of high-biodiversity value habitats, such as primary forests and wetlands. Recent evidence suggests that the rate of deforestation in Europe and Central Asia is decreasing (see 3.3), with some variations by country in Central Europe and Central Asia. Concerning terrestrial habitats, achievement of Target 5 is unlikely without increased implementation of integrated forest management targeted at conservation of biodiversity and without halting negative trends of biodiversity in agricultural and other areas in Europe and Central Asia.

The network of Natura 2000 sites has progressed and is largely completed for terrestrial habitats, covering about 18% of the land in Western Europe and Central Europe. Countries in Central Asia and Eastern Europe traditionally report on the coverage of strictly protected areas and do not account for other effective area-based conservation measures. In their national biodiversity strategies and action plans (NBSAPs) reports to the Convention on Biological Diversity Eastern European and Central Asian countries committed to achieve protected areas coverage by 2020 at the level of 12% in Eastern Europe and 15% in Central Asia, and at the level of 22% and 19% for all types of sustainably managed and protected terrestrial areas. Thus, Western and Central Europe has largely progressed toward achieving Aichi Biodiversity Target 11. Further, the implementation of the NBSAPs commitments of 2017 would allow for meeting Aichi Biodiversity Target 11 for terrestrial ecosystems in Eastern and Central Europe.

3.3.3 Inland surface waters

3.3.3.1 Freshwater systems

OVERVIEW OF THE SYSTEM

Freshwater habitat includes streams, rivers, lakes, ponds (temporary or not) and also their sources (glaciers, aquifers or rainfall). Freshwater biodiversity includes organisms that either live permanently in water, or spend part of their life cycle in water. The freshwater ecosystems of Europe and Central Asia are very diverse. Based on the distribution and composition of freshwater fish species and major ecological and evolutionary patterns, almost 60 different freshwater "ecoregions" were depicted for this area (Abell *et al.*, 2008). They include large rivers in the Atlantic, Arctic and Pacific Ocean basins and the Mediterranean, Black, Caspian and Aral Sea basins. Lakes of different sizes are numerous in all subregions with Lake Baikal in eastern Russia dominating in size and volume, containing almost 20% of the world's freshwater. Overall, almost 60% of world water volume stored in lakes is located in Europe and Central Asia (Messager *et al.*, 2016). Out of four global biodiversity hotspots identified for the region, the Mediterranean basin is considered a hotspot for freshwater systems.

Freshwater systems are consistently at higher risk than their terrestrial or marine counterparts (Dudgeon *et al.*, 2006) and the quantity and quality of habitats and abundance of many species is declining in Europe and Central Asia. Agriculture is the biggest user of fresh water, constituting 70–90% of the annual water demand for many countries (Rabalais *et al.*, 2010), and this is expected to further increase due to a growing population. In many regions, the lack of regulation of groundwater extraction has led to a decline in water tables. If all of the water in a river is used by agriculture and industry, leaving nothing for the aquatic environment, freshwater biodiversity will inevitably decline and freshwater ecosystems will disappear. Of course, this crisis point is unlikely to happen if technological solutions (e.g., change in farming practices, recycling waste water) are put in place to close the gap between supply and demand. Climate change is expected to intensify the hydrological cycle and alter evapotranspiration, with implications for ecosystem services but also feedback to regional and global climates. As a result, increased stress on freshwater ecosystems is expected in the coming decades.

The overall diversity of freshwater species in Europe and Central Asia has routinely been reported to increase towards lower latitudes, along with the proportion of threatened species. However, according to Dehling *et al.* (2010), in Europe this pattern differs for lentic (standing water) and lotic (running water) animal species. In Europe and Central Asia there is a high proportion of freshwater species with unknown population trends, for example in the case of 76% of European freshwater fishes and 83% of freshwater molluscs (Cuttelod *et al.*, 2011). This highlights the urgent need for monitoring and data collection across the region. However, according to Vörösmarty *et al.* (2010), the highest incidence of freshwater biodiversity threats worldwide is for Europe and Central Asia and correlates with the incidence of human water security threats.

PAST AND CURRENT TRENDS

Unfortunately, historical information and long-term data are rare for freshwater biodiversity and thus the patterns of species richness, for example, are known with much less confidence than for terrestrial systems (Carpenter *et al.*, 2009; Strayer & Dudgeon, 2010; Tockner *et al.*, 2008; Tockner *et al.*, 2011). This lack of quantitative freshwater biodiversity data is severe (e.g. 32% of IUCN evaluated freshwater invertebrate species in Europe are data deficient) especially for Central Asian freshwater ecosystems, as they have not yet benefited from IUCN Red List assessments.

The extent of wetlands in Western, Central and Eastern Europe has declined by 50% from 1970 to 2008 (Dixon *et al.*, 2016). According to the State of the Environment Report review of the state of freshwater systems, only 53% of geographical Europe's rivers and lakes have a good ecological status in 2015 (EEA, 2015a) **(Figure 3.27)**, despite several major European water initiatives in the past 15 years. Ecological status is a criterion for the quality of the structure and functioning of surface water ecosystems.

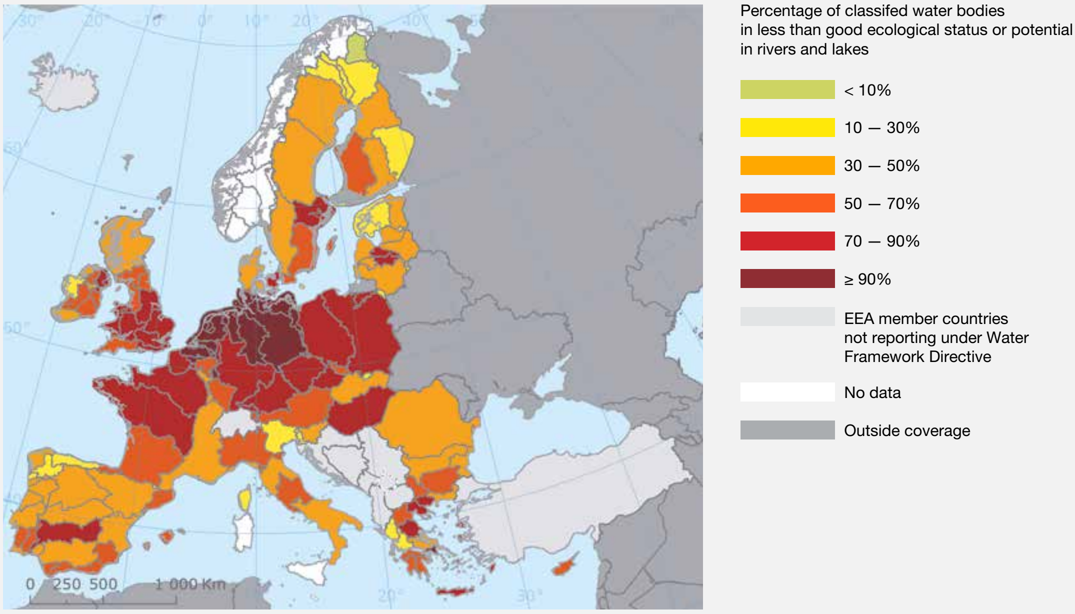
Based on current freshwater biodiversity trends, it is highly unlikely that Europe and Central Asia will achieve the relevant Aichi Biodiversity Targets by 2020 (i.e. Targets 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14) or Target 1 of the European Union Biodiversity Strategy. Furthermore, several water bodies in the region are drastically declining in size, and many ponds and streams are even disappearing from the landscape as a consequence of agricultural intensification, draining, dam construction and urbanization in combination to climate change (UNDP, 2015; Jeppesen *et al.*, 2015; Bagella *et al.*, 2016; Bogatov & Fedorovskiy, 2016; Boix *et al.*, 2016). Examples of water bodies disappearing are particularly found in the Mediterranean region and Central Asia (Jeppesen *et al.*, 2015). An example is Lake Akșehir, which was previously one of the largest freshwater lakes in Turkey, but completely disappeared due to loss of surface and ground water sources through intensive crop irrigation (Doğan, n.d.; Jeppesen *et al.*, 2009).

In the Mediterranean region, there is sometimes no legal requirement for a permanent minimum water outflow from dams and this often has dramatic consequences in summer when rivers dry out downstream (Benejam *et al.*, 2016; Freyhof, 2011).

A further issue of concern is the conservation of ponds in Europe and Central Asia at landscape scale, which harbour a significant proportion of aquatic biodiversity but are under increasing pressure. They have been historically neglected particularly in the Mediterranean region (Boix *et al.*, 2016; Céréghino *et al.*, 2008) and remain excluded from the provisions of the European Union Water Framework Directive. Natural wetlands (marshes and bogs) decreased by 5% between 1990 and 2006, one of the largest proportional land cover change of all habitats (EEA, 2010). In the Mediterranean region, temporary ponds contain rare, endemic or Red Data List species and as such form an irreplaceable type of habitat for a variety of freshwater biota (Céréghino *et al.*, 2008). However, the shallowness and small size of many temporary ponds have made them very vulnerable to human impacts as they can easily be drained for agriculture, urbanization, tourism, or industrial purposes (Boix *et al.*, 2016; Zacharias *et al.*, 2007). Moreover, annual rainfall has been declining substantially since 1900 in several parts of the Mediterranean region owing to climate change, and already dry periods in rivers and wetlands have been markedly prolonged.

European Union member States reporting under the Habitats Directive indicate that 17% of Europe's freshwater habitats have an "unfavourable to bad" conservation status, while 56% were classified as "unfavourable to inadequate" (EEA, 2015a) **(Figure 3.27)**. Yet relatively unaffected parts of the European Union include parts of the Balkans which, although not devoid of pressures, are freshwater biodiversity hotspots of continental and global value (Griffiths

Figure 3 27 **State of Western and Central European rivers and lakes. Good ecological status is defined "slightly" differently than high ecological status (with no or minimal human impact) and represents the target value that all surface water bodies have to achieve in the near future. Source: EEA (2015a).**



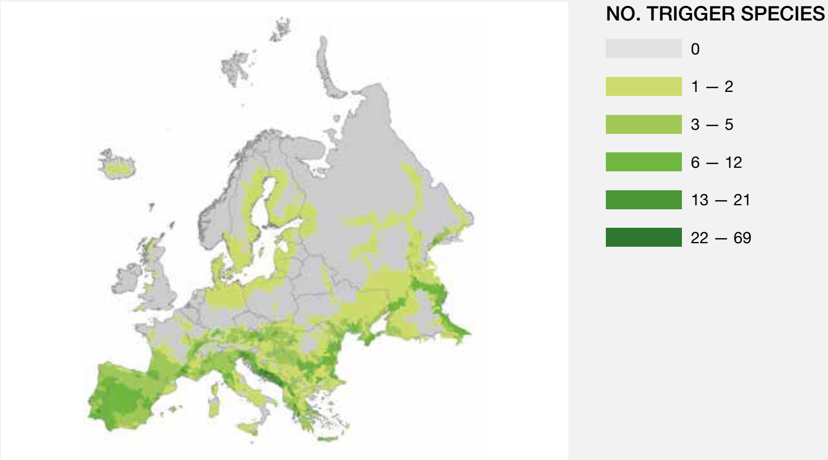
et al., 2004). Concerning species, 30% assessments have an "unfavourable to bad" conservation status and 45% assessments were classified as "unfavourable to inadequate" (EEA, 2015a). For Eastern Europe, fresh water quality remains poor, with variation from contaminated to extremely polluted for the majority of large rivers in Russia (Government of the of Russian Federation, 2016). In Central Asia in mountainous regions water bodies were assessed as clean and even very clean, when in lowlands they were assessed as moderately polluted and sometimes as extremely polluted (UNECE, CAREC, 2011).

Increased air temperatures result in melting of the glaciers which feed rivers and streams of Central Asia (e.g. Amu Darya, Syr Darya), causing changes in their hydrological regime (Zoï, 2009). Many formerly perennial wetlands are now seasonal, while several formerly seasonal wetlands are now rarely flooded. In other parts of Europe and Central Asia, recent climate change has produced contrasting trends. For example, floods in the Artic Ocean basin are becoming more prevalent due to an increase in winter runoff over the past 30 years, underpinned by the melting of Central Asian glaciers (Georgievsky, 2016; Gurevich, 2009). The Central Asian subregion also suffers from a drastic water loss that constitutes over 70% of global net permanent water loss. This water loss is due a combination of drought and human activities including river diversion, damming and unregulated water intake (Pekel *et al.*, 2016).

In addition, in the southern Caucasus and in Central Asia, there is a decline in surface water quality due to poor water treatment facilities. This leads to an increase in organic pollution, with about 20% of untreated sewage directly discharged into rivers (Barenboim *et al.*, 2013; Georgiadi *et al.*, 2014). Freshwater salinization is also a threat across Europe and Central Asia (Cañedo-Argüelles *et al.*, 2016; Jeppesen *et al.*, 2015), however, it is most relevant for the arid parts of Central Asia and the Mediterranean region due to irrigation and land washing salt pollution (Crosa *et al.*, 2006; Jeppesen *et al.*, 2015; Karimov *et al.*, 2014a). The lack of international and inter-sectoral coordination (e.g. between the irrigation and energy sectors) of water resource management in Central Asia and the Caucasus in the construction of irrigation systems, canals and water storage reservoirs in the lower reaches and deltas of the Central Asian Amu Darya, Kura, Syr Darya, Hrazdan and Ural Rivers has resulted in a severe environmental crisis (Petr *et al.*, 2004). Overall, despite contrasting trends in the availability of water resources in part of Europe and Central Asia (i.e. drying of ponds, flooding of rivers), the resulting environmental trend is a rapid decline in freshwater habitat quality and the decline in the most fragile species.

According to a recent study that identified the most important catchments for the conservation of freshwater biodiversity in geographic Europe (see Carrizo *et al.*, 2017), protected areas do not currently provide sufficient

Figure 3 28 **Critical catchments (i.e. catchments that contain sites likely to qualify as freshwater "key biodiversity areas") for fishes, molluscs, odonates and aquatic plants, with 706 catchments shaded by the number of distinct trigger species. Source: Carrizo *et al.* (2017).**



coverage to the most important "critical catchments" (i.e. catchments that contain sites likely to qualify as freshwater "key biodiversity areas") **(Figure 3.28)**. Without improvement to the current configuration and perhaps management, European countries are unlikely to meet international obligations to reverse the loss of freshwater biodiversity.

Alien species trends

The rate at which alien freshwater species have been introduced in Europe and Central Asia has doubled in the space of 40 years, with the principal motives being aquaculture (39%) and improvement of wild stocks (17%) (EC, 2014; Gozlan, 2008, 2015). Most sought-after freshwater species have already been introduced in Europe and Central Asia rivers and lakes and have contributed to biotic homogenization (Gozlan, 2016; Vilà & Hulme, 2017). In Central and Western Europe, 16% of lakes contain alien fish species (Jeppesen, Winfield, *et al.*, 2017). The role of alien species in the emergence of novel diseases in the region has clearly been demonstrated in the last three decades through the increased geographic distribution of pathogens and parasites and also as facilitators of host-switching (Peeler *et al.*, 2011). In the European Union, the historical trends of alien species introduction have been slowed down due to legislation (European Union, 2007) concerning use of alien and locally absent species in aquaculture. This regulation establishes a "framework governing aquaculture practices to assess and minimize the possible impact of non-native species on aquatic habitats and in this manner contributes to the sustainable development of the sector".

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Analyses of data on freshwater biodiversity show that more than 75% of Europe and Central Asia catchment areas are subject to multiple pressures and have been heavily modified, resulting in serious threats to their biodiversity (EEA, 2010; Tockner *et al.*, 2008). General threats to inland water ecosystems such as overexploitation, water pollution, flow modification, habitat degradation, invasive alien species and salinization (Dudgeon *et al.*, 2006), are also the most relevant for Europe and Central Asia. Vörösmarty *et al.* (2010) have classified the importance of these drivers for biodiversity status and have shown that the main drivers threatening biodiversity in areas where incident threat is greater than the 75th percentile (i.e. most of the region), is water resource development (e.g. dams, river fragmentation), followed by pollution (e.g. organic pollution and sediment loading). In comparison, the effects of fishing and aquaculture pressure remain relatively limited, while the impact of alien species is projected to increase in the future (EEA, 2015d). This is further illustrated by another recent study at continental scale based on 4,000 monitoring sites across Europe (Malaj *et al.*, 2014) which showed that the health of almost half of all European freshwater ecosystems are at risk from toxic organic chemical pollution. The chemical risk to freshwater ecosystems is strongly influenced by human land use, with areas of natural vegetation at significantly lower risk. Pollution pressures particularly affect central and north-western parts of Western European areas with intensive agricultural practices and high population density. Notably, the chemical status of 40% of Europe's surface waters remains unknown (EEA, 2015b) and a good chemical status (as defined by the European Union Water Framework Directive in terms of compliance with all quality standards established for chemical substances at European Union level) was not achieved in surface water bodies in 22 member States in 2015. Furthermore, although in most parts of Europe the potential for hydropower is almost fully exploited, the Balkans, which are a freshwater biodiversity hotspot of continental and global value, rank under the top world regions concerning planned dams and impoundments (Griffiths *et al.*, 2004; Zarfl *et al.*, 2015). The boom in hydropower development threatens the remaining free-flowing rivers and near-natural freshwaters including in Siberian rivers (Saltankin, 2012). Similarly, according to current plans, Turkey's rivers and streams will see the construction of almost 4,000 dams, diversions, and hydroelectric power plants for power, irrigation, and drinking water by 2023 (Şekercioĝlu *et al.*, 2011).

According to the State of the Environment Report 2015's (EEA, 2015a) review of the health of freshwater systems in Western and Central Europe, the pressures reported to affect most surface water bodies are pollution from diffuse sources, in particular from agriculture, causing nutrient enrichment. More than 40% of rivers and coastal water bodies and more than 30% of lakes and transitional waters in European Union subregions are affected by diffuse pollution from agriculture (EEA, 2012). Between 20% and 25% are subject to point source pollution, for example, from industrial facilities, sewage systems and wastewater treatment plants. Across Europe and Central Asia, industrial and agricultural developments also influence water quality and threaten biodiversity in some highly diverse ecosystems (e.g. Selenga River and Lake Baikal in eastern Russia) (Sorokovikova *et al.*, 2013). Nevertheless, pollution and nutrient enrichment are the only pressures that are reported to be decreasing in part of Western and Central Europe (EEA, 2015a; Jeppesen *et al.*, 2005). Agriculture is the main reason for groundwater over-abstraction, an activity that is frequent in areas with low rainfall and high population density, and in areas with intensive agricultural or industrial activity, such as Italy, Spain, Greece and Turkey, among others. The result is sinking water tables, empty wells, draining of wetlands, higher pumping costs and, in coastal areas, the intrusion of saltwater from the sea which degrades the groundwater (Rabalais *et al.*, 2010). Climate change and other components of global change, such as a growing population demanding higher food production, are expected to intensify these problems. Global warming can also exacerbate the symptoms of eutrophication in lakes and thus lower nutrient loading will be needed in a future warmer world to achieve the same ecological status as today (Jeppesen *et al.*, 2017).

Invasive alien species

Although increasing with the number of introductions, the risk of ecological impact after the introduction of an alien freshwater fish species is less than 10% for the great majority of alien freshwater species introduced (Gozlan, 2008). However, alien species are very numerous in many freshwater bodies (Altermatt *et al.*, 2014) there are specific threats associated with the introduction of freshwater species which clearly need to be mitigated, such as the risk of alien pathogen introductions (Peeler *et al.*, 2011) and alien species that have been clearly identified as ecosystem engineers. The heightened risk associated with these species is that they are especially difficult to eradicate (Cacho *et al.*, 2006) and capable of significantly altering the functioning of ecosystems.

3.3.3.2 Enclosed seas and saline lakes

The Aral Sea

OVERVIEW OF THE SYSTEM

In the mid-twentieth century, the Aral Sea was the fourth largest lake in the world with an area of 67,499 km^2 (Aladin & Plotnikov, 2008) and water volume 1,064 km^3 (Glazovsky 1990). The biodiversity of this moderately saline (around 10 g/l salt) lake (Dobrovolskii and Zalogin, 1982) included about 200 species of invertebrates (Plotnikov, 2016), 34 fish species (Aladin and Plotnikov, 2008; Ermakhanov *et al.*, 2012; Zonn *et al.*, 2009), and 30 species of macrophytes (Zhakova, 2013).

The Aral Sea is, however, now a much smaller and more saline body of water **Figure 3.29**. Salt-dust and sandstorms originating from the desiccated seafloor are affecting agricultural systems and the livelihood and health of the people in the region (Breckle *et al.*, 2012). Full restoration of the Aral Sea in the foreseeable future appears impossible (Micklin, 2007).

PAST AND CURRENT TRENDS

From the 1960s, the Aral began to shrink because of large-scale water extraction from the two main in-flowing rivers, the Amu Darya and the Syr Darya (Boomer *et al.*, 2000). The sea split into two isolated lakes, the Small and Large Aral Lakes. By 1989 the Large Aral Sea divided further into Western and Eastern parts (Aladin & Plotnikov, 2008). By 2014, the eastern part of the Large Aral Sea had dried completely, but later some water appeared again **(Figure 3.29)** (Lindsey, 2016; NASA, 2014). Climate changes have also contributed to transformation of the Aral Sea (IPCC, 2014b).

The desiccation of the Aral is considered the world's worst aquatic ecology crisis in recent history (Pekel *et al.*, 2016). Negative effects of the Aral's retreat on the ecology, economy, and quality of human life in the region are manifold and dramatic (Micklin, 2007; Zavialov, 2005).

Figure 3 29 **NASA's image: shrinking of the Aral Sea. 1 – Small Aral; 2 – Large Aral; 3 – Western Aral; 4 – Eastern Aral. The fine line shows the approximate shore line in 1960. Source: Lindsey (2016).**

Figure 3 30 **The Caspian Sea. Source: NASA (2004).**

A dam separating the Small Aral basin from the Large Aral basin has resulted in an increase in the water level and decrease in salinity of the Small Aral. As a result the biodiversity of invertebrates has increased (Plotnikov, 2016). The Small Aral was stocked with fish and now even provides some commercial fish yields. The Large Aral Sea has split to several hypersaline lakes with biodiversity limited to species which are tolerant to high salinity, with a few species of invertebrates (Plotnikov, 2016) and macrophytes (Zhakova, 2013), but no vertebrates (Aladin *et al.*, 2017).

The Caspian Sea

OVERVIEW OF THE SYSTEM

The Caspian Sea is the largest saline inland sea or lake in the world, it contains about 40% of all inland lake waters (Messager *et al.*, 2016) **(Figure 3.30)**. This brackish water body, with salinity up to 14 g/l (Mamaev, 2002), is a home to 1,814 species and subspecies (Dumont *et al.*, 1999; Kasymov, 1987; Kazantcheev, 1981). Endemism at the species level is very high, especially among molluscs and fish. There are five sturgeon species that are endemic or shared only with the Black Sea and constitute 85% of the standing stock of the world's sturgeon population (Dumont *et al.*, 1999; Mamaev, 2002). The only aquatic mammal is the endemic Caspian seal (*Pusa caspica*) (Mamaev, 2002), assessed as endangered by the IUCN (Goodman & Dmitrieva, 2016). The Caspian Sea lies on migration routes of many birds and offers refuge for a number of rare and endangered bird species (Mamaev, 2002).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Changes in the level of the Caspian Sea play a significant role for ecosystems, but their causes are uncertain. They may be caused partly by climate change and decrease of inflow after the construction of dams on the Volga River (Barannik *et al.*, 2004; IPCC, 2014a; Dobrovolskii and Zalogin, 1982; Mamaev, 2002). Since 1995 the level of the Caspian Sea has not changed significantly, but it is impossible to predict the scale and direction of future fluctuations (Pekel *et al.*, 2016).

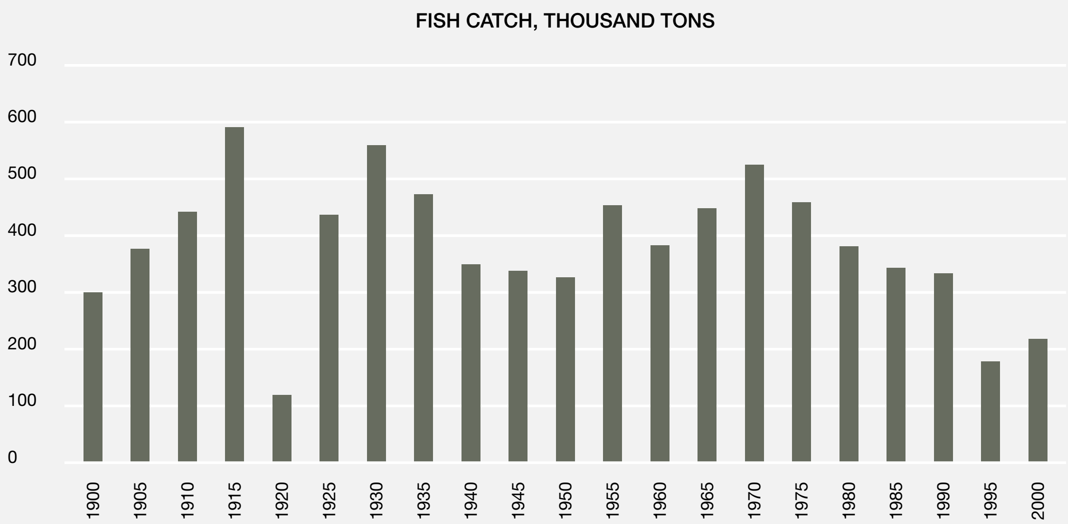
The Caspian Sea is threatened by pollution from untreated wastewater from industry and agriculture along the Volga River (an estimated 80% of the total load) (Glantz & Zonn, 1997) offshore oil and gas production, processing, extraction and transportation, and shipping. Industrial pollution impacts biological processes including the growth of commercially important fish (Dumont *et al.*, 1999; Mamaev, 2002).

The Lenin Canal between the Don and Volga Rivers, which opened the Caspian to maritime navigation in 1954, led to invasions by Mediterranean biota such as small crustaceans, marine molluscs (e.g. *Mytilaster Zineatus*) and comb-jelly (*Mnemiopsis lediyi*), which drove some endemic species (e.g. the bivalve *Dreissena caspia* or one of the main fish resources *Clupeonella*) to almost total extinction (Dumont *et al.*, 1999; Rintelen & Van Damme, 2011; Zoï, 2012).

Fishing has significantly dropped during the 1990s, and slowly grew thereafter (Makoedov *et al.*, 2007; **Figure 3.31**). During the 1990s, illegal fishing vastly increased and negatively impacted mostly sturgeon and salmon. A special moratorium on sturgeon fishing was signed by five Caspian countries in 2013. All Caspian sturgeon species are protected under CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora), but the Convention is not in force in Turkmenistan. A quota system, introduced together with a temporary ban on pelagic fishing, does not appear to have been effective in reviving the dwindling sturgeon population (Mamaev, 2002).

The population of the Caspian seal (*Pusa caspica*, a globally endangered species) has declined by 70% in the last

Figure 3 31 **Total fishing catch in the Caspian Basin. Source: Makoedov *et al.* (2007).**



twenty years. This is primarily due to unsustainable hunting, trapping as by-catch of the illegal sturgeon fishery, and loss of prey-base due to fishing and invasive species (Goodman & Dmitrieva, 2016; Harkonen *et al.*, 2012). A canine distemper epidemic starting in April 2000 also contributed to the seal decline (Mamaev, 2002). Limitations on hunting were introduced in the 1940s but illegal killing of seals is still common (CEP, 2007; Mamaev, 2002).

Saline lakes

OVERVIEW OF THE SYSTEM

In Western and Central Europe saline and brackish lakes can be found predominantly in the Mediterranean region (Čížková *et al.*, 2013). To the east, saline water bodies are found in many terminal basins in a wide territorial belt with semiarid or arid climate including Turkey, the Caucasus, Central Asia and southern Siberia (Comin and Alonso, 1988; EEA, 2002; Kazanci *et al.*, 2004; Kotova *et al.*, 2016; Kulagin *et al.*, 1990; Montes & Martino, 1987; Orlov *et al.*, 2011; Örmeci & Ekercin, 2005; Government of Turkey, 2014; Stenger-Kovács *et al.*, 2014; Williams, 1981; Zektser, 2000).

The biodiversity of saline and brackish lakes is variable and depends strongly, among other factors, on salinity (Balushkina *et al.*, 2008; Boros *et al.*, 2013; Brucet *et al.*, 2012; Ventosa & Arahal, 2009). It can be quite high in large and moderately saline lakes, for example Lake Issyk-Kul (Kulagin *et al.* 1990; Savvaitova & Petr, 1999). Generally, however, increased salinity leads to a decrease in biodiversity (Kipriyanova *et al.*, 2007). In hypersaline lakes like the Dead Sea in Israel or Lake Elton in Russia, only some algae (*Dunaliella salina*), halophilic bacteria and fungi can be found (Nissenbaum, 1975). At the same time, many hypersaline lakes harbour high and unique bacterial diversity that has high scientific, ecological and biotechnological values (Oren, 2006).

Saline and brackish lakes in Europe and Central Asia are crucially important for birds during seasonal migrations and wintering. Many of them are located along transcontinental migration routes, as for example, the Torey lakes in the Daurian steppe in Russia. Some are crucial stops along the Australian-Asian migration route, providing temporary habitats for rare species such as 70% of the world population of the threatened white-headed duck (*Oxyura leucocephala*), which overwinters at Lake Burdur, Turkey, which is a designated Ramsar site (Ramsar, n.d.).

Figure 3 32 **Lake Chany. An example of a large saline lake with fluctuating water level, salinity and biodiversity. Source: Landsat-8 (2016).**

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

There are no comprehensive assessments of changes in biodiversity in saline and brackish lakes in Europe and Central Asia. Many saline lakes in the region experience large fluctuations in water level and salinity, with corresponding biodiversity and ecosystems shifts (Namsaraev *et al.*, 2008) **(Figure 3.32)**.

Fishery volume exceeds sustainable use and fish resources dwindle in the largest saline and brackish lakes in Central Asia (Karimov *et al.*, 2009; Thorpe *et al.*, 2011; Zoï, 2012), however rehabilitation measures for fish resources (stocking of lakes with fish larvae, protection of spawning areas, etc.) usually are not conducted (Karimov, 2011).

Water withdrawal for irrigation from tributaries led to the decline of many saline lakes' area and volume, rise in salinity and destruction of fish spawning areas and species' migration routes (Bai *et al.*, 2004; Karimov *et al.*, 2009; Government of Turkmenistan, 2015). Another factor that contributes to decline of water level in saline lakes is climate change. This process is especially strong in the arid zones of Europe and Central Asia (IPCC, 2014b). It affects salinity level and, as a result, leads to decline in biodiversity and threatens the total extinction of the majority of species (Bai *et al.*, 2004).

It is projected that many lakes in the Mediterranean climate zone will be markedly affected by aridification and water abstraction, with related changes in water level, salinity, biodiversity and the ecology of lakes and reservoirs (Jeppesen *et al.*, 2015). Artificial saline lakes are also created in natural depressions of Central Asia by storing collector-drainage water after irrigation (Stone, 2008; Thorpe *et al.*, 2011; Yakubov, 2011). They are extremely polluted by agricultural chemicals, initially with low biodiversity limited to some algae and bacteria (Glazovsky, 1990; Orlov *et al.*, 2011). However, there are projections that these man-made ecosystems can be important for biodiversity conservation, fisheries, migration birds and recreation (Karimov *et al.*, 2014b; Government of Uzbekistan, 2015; Thorpe *et al.*, 2011).

As large saline and brackish lakes have a long history of isolation from each other, they have been refugees for rare and endemic species. These species are more strongly affected than others by non-native invasive species, which reach saline lakes sometimes accidentally, sometimes through introduction by humans to improve fisheries, like in Issyk-Kul lake (Kulagin *et al.*, 1990; Thorpe *et al.*, 2011).

3.3.3.3 Implementation of the Ramsar Convention by the countries of Europe and Central Asia

All countries in Europe and Central Asia are Contracting Parties to the Ramsar Convention, except San Marino.

According to a national reports review undertaken by the Secretariat of the Convention (Ramsar, 2015a, 2015b), Ramsar wetlands in the region face increasing pressures from rapid urbanization and land-use changes for tourism, infrastructure development (transport and energy) and non-sustainable exploitation of natural resources (e.g. water, gravel, peat, oil, gas). Ongoing climate change increases environmental risk and the frequency of natural hazards such as floods, droughts, storms and landslides, especially in Central Asian countries. The regulating services that wetlands can provide are only rarely taken into account. Wetlands in Eastern Europe and Central Asia are under increasing pressure especially from conversion due to population increase (Central Asia) and development

Table 3 2 **Implementation of the Ramsar Convention in Europe and Central Asia: reporting statistics.**

Subregion	Number of countries reporting to the Convention	Total sites number	New sites last reporting period	Sites under threat or with changed ecological character	Official reporting on Ramsar site ecological character change
Western Europe	18 of 24	805	46	62 (8% of all sites)	17 (27% of sites changed or under threat)
Central Europe	13 of 18	174	11	27 (15%)	15 (55%)
Eastern Europe	5 of 7	110	6	17 (15%)	1 (6%)
Central Asia	1 of 5	21	1	1 (n/a)	1 (n/a)

Table 3 3 **Implementation of the Ramsar Convention in Europe and Central Asia: progress toward goals. Yes = goal achieved; In part = goal partially achieved; No = Goal not achieved.**

Subregion	Goal 1: Wise use of wetlands	Goal 2: Network of Wetlands of International Importance (Ramsar Sites)	Goal 3: International cooperation	Goal 4: Institutional capacity and effectiveness
Western Europe	Yes	No	Yes	No
Central Europe	Yes	In part	Yes	No
Eastern Europe	In part	Yes	Yes	In part
Central Asia	In part	In part	In part	In part

projects (Eastern Europe), overuse of wetland resources, expansion of human habitats and infrastructure, agricultural, recreational and development activities, and pollution. In Central Asia there are difficulties with water availability for wetlands, and there is competition for water within and between countries. There are cases in Central Asia of wetland loss due to the natural disasters – such as droughts and landslides.

An assessment of Ramsar Convention implementation was undertaken **(Table 3.2)** considering progress towards the four main goals of the Convention: 1 - wise use of wetlands, 2 - creating a network of wetlands of international importance (Ramsar Sites), 3 - international cooperation, and 4 - institutional capacity and effectiveness **(Table 3.3)**.

The number of Ramsar sites is highest in Western Europe, while these sites cover smaller areas than in other subregions. Western Europe is also more active in designating new sites. Fewer sites in Western Europe are under threat than elsewhere. Nevertheless, those that are under threat are reported by NGOs or local communities, and seldom via official channels to the Ramsar Secretariat. Eastern and Central Europe has a higher portion of endangered sites, but more often reported via official channels. In Central Europe 55% of sites with changing ecological character were reported via official channels, while in Eastern Europe it was only in 5% of cases. Central Asia cannot be assessed due to a lack of information except for Kazakhstan, which also reports its endangered Ramsar site officially and was visited by a Ramsar mission.

As part of the wise use of wetlands, countries are reporting on successful wetland restoration projects and work related to water policies and river basin management including the European Union Water Framework Directive **(Table 3.3)**. Within goal 2, countries report on the development of management plans for Ramsar Sites and the implementation of their provisions; wetland monitoring and inventory activities; and the preparation and designation of new Ramsar Sites and synergies with the European Union Natura 2000 network of protected areas. Goal 3 is on international cooperation. The steps to meet goal 4 mostly are communication, education and outreach activities, including World Wetlands Day; and the development of national policies for conservation, biodiversity and wetlands including national biodiversity strategies and action plans.

The greatest difficulties reported are limited administrative capacity resulting from limited human and financial resources; slow administrative processes to put effective policies in place; and insufficient coordination between wetland, water, and river basin management authorities. Progressing with wetland ecosystem conservation on the ground is difficult, because it needs to be based on time-consuming inter-sectoral stakeholder consultations. Agricultural, urban and land-owner interests hinder the implementation of Ramsar objectives. The lack of political interest, economic incentives in the absence of wetland valuations, and sufficient wetland inventories are reported by Europe and Central Asian countries.

3.3.4 Marine systems

The marine environment of Europe and Central Asia, which includes open ocean areas and semi-enclosed seas encompassing several marine ecoregions (Spalding *et al.*, 2007) is very diverse at genetic, community, ecosystem and seascape levels. This environment has been significantly impacted by human activities for millennia but marine research in some parts of the region is well established, resulting in some of the best studied marine ecosystems in the world. Still about 53% of the benthic shallow habitats in Western and Central Europe were found to be data deficient in recent habitat assessments (Gubbay *et al.*, 2016). Of the assessed benthic habitats, about 38% were classified as threatened in the categories critically endangered, endangered and vulnerable. In the European Union, among assessments of the conservation status of species and habitat types of conservation interest, only 7% of marine species and 9% of marine habitat types show a "favourable conservation status". Moreover, 27% of species and 66% of assessments of habitat types show an "unfavourable conservation status" and the remainder are categorized as "unknown".

For the purpose of the current assessment the marine environment was divided into the different ocean basins and semi-enclosed seas of the region including the North East Atlantic Ocean, with different sections for the Baltic, Mediterranean and Black Seas, the Eurasian Arctic Ocean and the North West Pacific Ocean, focusing on the exclusive economic zones of countries of Europe and Central Asia, and of the relevant regional agreements.

3.3.4.1 North East Atlantic Ocean

OVERVIEW OF THE SYSTEM

The European part of the Atlantic Ocean (*sensu lato*, i.e. North Sea, Irish Sea, English Channel, Iberian coast, and the Macaronesean Island coasts except for Cape Verde) encompasses large latitudinal gradients, several biogeographic provinces from Artic to warm temperate systems realms (Spalding *et al.*, 2007), and a diversity of ecosystems and habitats, including complex structural habitats like seagrass meadows, kelp forests and biogenic reefs, providing a diverse set of nature's contributions to people (Prather *et al.*, 2013; Smale *et al.*, 2013; Worm *et al.*, 2006). Despite knowledge gaps, several trends are well established thanks to the sustained observation of marine biota particularly in the Celtic Sea, English Channel, North Sea and Bay of Biscay (e.g. Barceló *et al.*, 2016; Beaugrand *et al.*, 2009; Daan *et al.*, 2005; EEA, 2015c; Frederiksen *et al.*, 2013; Mieszkowska *et al.*, 2014; OSPAR, 2010, 2017).

PAST AND PRESENT TRENDS

Changes in distribution and species abundance are the most well documented trends, across diverse taxonomic groups, as illustrated in over 670 observational data points extracted from Poloczanska *et al.* (2013)2 and summarized in **Figure 3.33**.

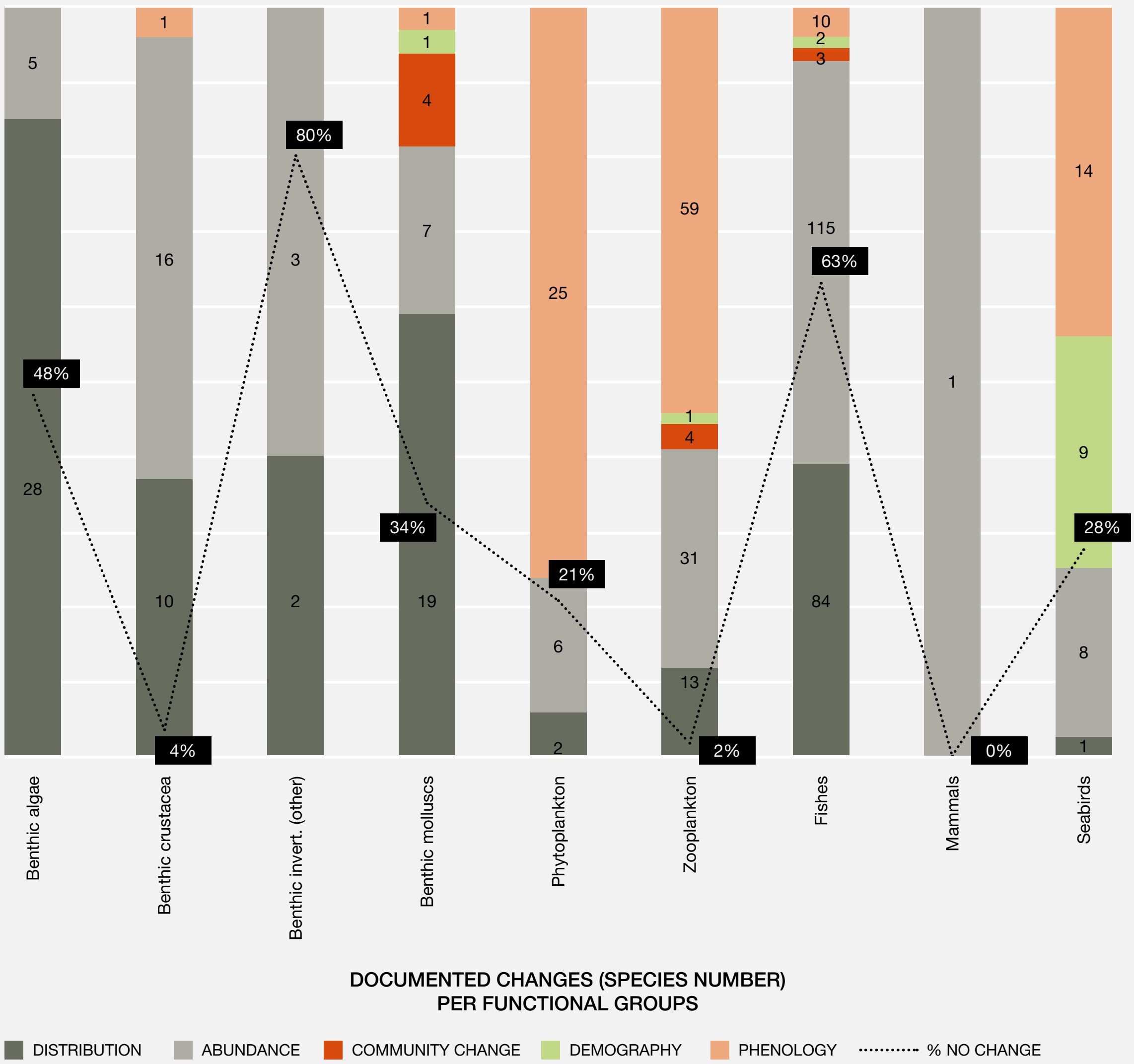
Shifts in range, in particular northward expansion of more than 140 km per decade on average across taxa (Poloczanska *et al.* 2013), have been shown **(Figure 3.34)**. This is exemplified by the subtropicalization of European pelagic fish communities (Montero-Serra *et al.*, 2015), by movements of calanoid copepods towards the north at rates of up to 23 km per year between 1958 and 2009 (Beaugrand *et al.*, 2009) and by shifts of the centre of the distribution for about 60% of 65 marine invertebrates studied in the North Sea (Hiddink *et al.*, 2015). Range shifts occur not only in latitude, but also along depth gradients (e.g. Dulvy *et al.* (2008) for fishes; Hiddink *et al.* (2015) for marine invertebrates). Range shift is, however, not fast enough to keep pace with climate change for many species (Hiddink *et al.*, 2015), so other effects of climate change, such as phenological changes, are also observed. Also, as shown **Figure 3.34**, the rate of change varies across taxa: northward expansion of benthic algae display an average range shift of 42 km per decade which is an order of magnitude slower than that documented for fishes (Perry *et al.*, 2005; Poloczanska *et al.*, 2013). Importantly, although documented in a few taxa only, such range shifts can provoke the loss of particular genetic clades (e.g. in the macroalga *Fucus vesiculosus*; Nicastro *et al.*, 2013) and impoverished genetic diversity at species level, with putative ecological and economic impacts (Parmesan, 2006).

In the 20th century almost all fish stocks of the North Atlantic have been depleted in abundance, with consequential impacts on stock biomass, size distribution, and diversity (reviewed in Rice *et al.*, 2016). Many fish stocks are currently overfished. However, in the 21st century, fishing has been reduced in most parts of the North East Atlantic shelves, and there is evidence of recovery in most of these areas, albeit at different rates for different species (Rice *et al.*, 2016). A combination of range shifts and fishing is responsible for genetic changes, such as declines in genetic diversity in fishes, as observed in the North Sea cod (Hutchinson *et al.*, 2003). Populations of most marine bird species have been declining since 2002 (Frederiksen, 2010), with the exceptions only of the northern gannet (*Morus bassanus*) and great skua (*Stercorarius skua*), both likely benefiting from increasing availability of fishery discards, and, for the gannet, from recovery from past persecution. These changes in abundance lead to local population and species decline, which affect a variety of fish and bird taxa, as detailed above, but also primary producers such as phytoplankton, with important consequences for trophic networks (McQuatters-Gollop *et al.*, 2007), and marine invertebrates including crustaceans, annelids, and molluscs (OSPAR, 2008; Wiens, 2016).

Another clearly documented change is biotic homogenization, due to species range shifts (e.g. for fishes assemblages, Magurran *et al.*, 2015) combined with the introduction of alien species. An estimated 237 species have been introduced into the North East Atlantic (Galil *et al.*, 2014), having steadily increased by about 173 species from 1970 to 2013. Many of these alien species were introduced deliberately (e.g. the Asian oyster (*Magallana gigas*), with which many other "hitch-hiking" species have been accidentally introduced). This is a consistent past

Figure 3 33 **Number of species for which changes in distribution, abundance or functioning (including demography, phenology, assemblages) have been documented since the 1950s (time series over more than 23 years), per functional groups.**

Data are shown separately for each taxonomic (functional) group. The dotted line provides the percentage of species with no change observed over all the trends considered. Source: Data for the North East Atlantic extracted from the Table S1 in Poloczanska *et al.* (2013).

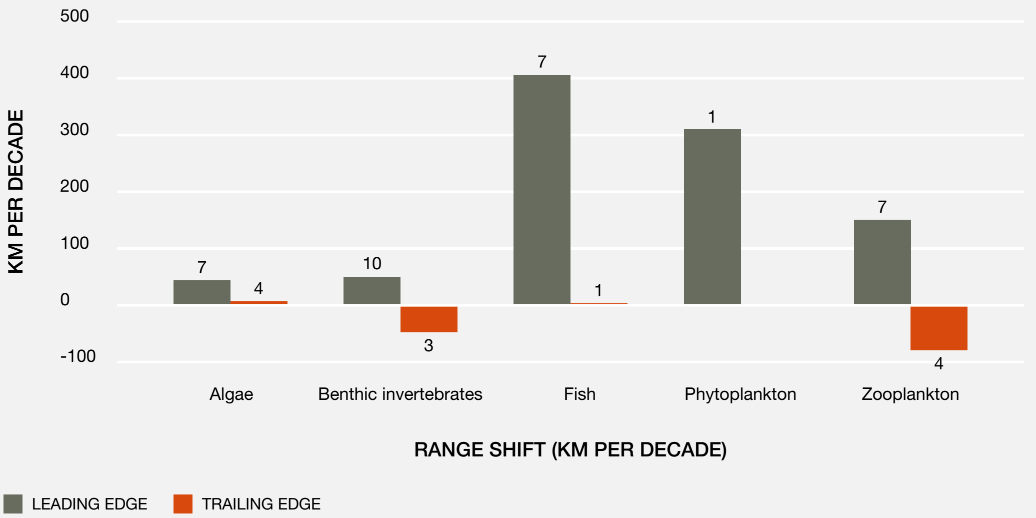


and current trend over a large range of taxa (Seebens *et al.*, 2017).

Changes in distribution and abundance also impact habitat-structuring species, such as seagrass and kelp forests, which are both natural carbon sinks and thus may contribute to carbon sequestration, or biogenic reefs, for example *Sabellaria spinulosa* or flat oyster reefs, both of which are included on the OSPAR list of threatened or declining habitats (OSPAR, 2008). Disease outbreaks have also been reported in cold-water corals, like the seafan *Eunicella verrucosa* (Hall-Spencer *et al.*, 2007), a structuring perennial species listed on the IUCN Red List of threatened species. The decline in extent and abundance of these diverse structuring species modifies ecosystem functioning as well as the contributions that they provide to people. For instance, a shift from kelp canopies to turf-forming seaweeds has a global impact on community structure and function (Smale *et al.*, 2013) as well as on fisheries (Bertocci *et al.*, 2015). These habitat-forming species are insufficiently monitored (e.g. for kelps see Araújo *et al.*, 2016), but current trends have already documented declines, as exemplified by *Cymodocea* meadows, with estimated declines of between 15% and 80% in extent along the Iberian Peninsula coasts. Changes in ecosystem functioning (e.g. food web and trophic network) have also been well-

Figure 3 34 **Range shift (northward expansion – leading edge; southern contraction – trailing edge) of taxonomic/functional groups in the North East Atlantic.**

Numbers above bars indicate the number of taxa for which data are available. Source: Data extracted from Table S6 by Poloczanska *et al.* (2013).



documented in some areas, e.g. in pelagic systems of the North Sea (e.g. copepods-fishes; Beaugrand, 2004; Kirby & Beaugrand, 2009).

Phenological changes (e.g. earlier timing of recruitment) are an important component of these changes in ecosystem functioning. They can affect populations through diverse mechanisms and with large impacts such as mismatches with food resource availability and increased mortality because of non-favourable environmental conditions (Thackeray *et al.*, 2010 and references therein). They have been established with confidence for several taxonomic groups (Edwards & Richardson, 2004; Kirby & Beaugrand, 2009; Poloczanska *et al.*, 2013; Thackeray *et al.*, 2010). For some taxa such as marine invertebrates (Thackeray *et al.* 2010), rates of advance in seasonal timing was shown to increase over recent decades.

Changes in patterns and processes, as detailed above, are indicative of a decline in biodiversity status, now and in the past, at species, community and ecosystem levels.

Although biodiversity decline and changes in ecosystem functioning are widespread, a few trends are indicative of partial recovery when compared with past-trends. With the exception of Atlantic cod, there are signs of improvement in fish stocks and biomass, especially compared with other Western European waters such as the Mediterranean Sea (Fernandes *et al.*, 2017). The number of assessed stocks that are above their maximum sustainable yield has dropped from 94% in 2007 to 41% in 2014 in European Union Atlantic and Baltic waters, which has been explained by an overall decrease in the level of fishing pressure (Daan *et al.*, 2005; EEA, 2015b). Moreover, with 3,203 marine protected areas extending over 171,174 km², 5.9% of the surface of the North East Atlantic benefits from protection. There are, nevertheless, discrepancies between sea areas (e.g. 14.7% Greater North Sea vs. 5.9% Bay of Biscay and Iberian coasts) and distance from the shore (52.1% of 0-1 nautical miles zone vs. 2.3% beyond 12 Nautical miles). The increase in network coverage is a positive current trend, but still below the Aichi Biodiversity Target 11 of 10% of marine habitats under protection (EEA, 2015a; OSPAR 2017) over the whole North East Atlantic area. In addition, only 10% of marine habitats that have been assessed have a favourable conservation status (EEA, 2015b), with contrasted features across areas. For instance, while the Macaronesian region reported 33% of favourable habitat conservation status, the other areas of the North East Atlantic reported 71% of unfavourable-bad assessments (EEA, 2015a). Finally, no fauna extinction has been documented so far, maybe due to major knowledge gaps for important taxonomic groups like marine invertebrates (McCauley *et al.*, 2015).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

The primary pressures responsible for past regime shifts in shelf ecosystems are overfishing, pollution and climate driven changes including Arctic ice melting and ocean warming. In terms of the importance of these direct drivers for past trends, they are graded as high impact **(Table 3.5)**.

Overall, several studies point with a high confidence to climate change, including ocean acidification as the main emerging driver in the North East Atlantic (Barceló *et al.*, 2016; Beaugrand *et al.*, 2013; Birchenough *et al.*, 2015; Fossheim *et al.*, 2015a; Hiddink & ter Hofstede, 2008; Montero-Serra *et al.*, 2015; Poloczanska *et al.*, 2016). Eighty-six percent of the changes documented by Poloczanska *et al.* (2013) are consistent with expectations based on climate change effects, although most often (82% of the cases examined), other drivers are acting simultaneously. These include natural resource exploitation with direct (e.g. overfishing) or indirect (e.g. trawling and demersal fishing activities on benthos) effects, land and water use (eutrophication, pollution, including plastics and microplastics), habitat changes (marine urbanization) and invasive species. There are also substantial cumulative impacts of this diverse set of drivers (Halpern *et al.*, 2015).

Between the past and current periods, the importance of the effect of climate change has not decreased. Conversely, the importance of changes due to natural resource exploitation has likely been decreasing (i.e. graded as moderate for current trends in **Table 3.5.** For example, in benthic communities bottom trawling is one of the main pressures (Rice *et al.*, 2016), but recoveries have been observed following cessation of this activity (Kaiser *et al.*, 2006). Similarly, overfishing remains high (50% of fish stocks in the North East Atlantic) but positive trends are now observed. For example, fishing effort decreased by 25% from 2000 to 2006 in the Greater North Sea (EEA, 2015c; OSPAR, 2010). The same can be said for pollution: coastal benthic communities have been strongly affected by nutrients and pollutants runoff and climate change (Rice *et al.*, 2016) but nutrient inputs are now reduced, even if still cause for concern (OSPAR 2010, 2017). However other categories of pollutants (e.g. xenochemicals, microplastics) might have substantial effect, but have not yet been assessed (see Chapter 4). Conversely, besides climate change, the impact of man-made structures on seabed and coastal habitats has been increasing. These include structures associated with urbanization of coastal areas, coastal land defences and a growing number of offshore structures (EEA, 2015c), and associated ecosystems and species. The importance of invasive alien species has been increasing in a recent past, with 44 high-impact species (de Castro *et al.*, 2017) **(Box 3.3; Table 3.5)**.

3.3.4.2 Baltic Sea

OVERVIEW OF THE SYSTEM

The Baltic Sea is a shallow brackish waterbody characterized by strong seasonal variability and decreasing gradients of salinity and temperature from south-west to north-east. It is an almost non-tidal sea that spans from the temperate, highly populated and industrialized south with intensive agriculture, to the boreal and rural north. It is a young, low diversity ecosystem inhabited by species of both marine and freshwater origin, migratory species and glacial relicts (Segerstråle, 1957). Despite being well-studied compared with other aquatic systems (Costello *et al.*, 2010), several ecosystem parts are still under-investigated (Ojaveer *et al.*, 2010).

PAST AND CURRENT TRENDS

International coordination of research in the Baltic Sea has been ongoing since the beginning of the 20th century, but long-term datasets are only available from the 1950s for benthos, plankton and fishes (Ojaveer *et al.* 2010). Due to the absence of long-term monitoring for many other taxa, several parts of the ecosystem are under-investigated and thus under-evaluated. Several biodiversity assessment tools have been created for the assessment of biodiversity, but most of them have only been applied in marginal areas of the Baltic Sea (Andersen *et al.*, 2014; Aunins & Martin, 2014). The overall health of the Baltic Sea is currently in a bad state, with significant decline in the status of biodiversity in large areas (BalticSTERN, 2013; HELCOM, 2009, 2010), as can be seen in the indicators in **Figure 3.35**. Only the Bothnian Sea and some coastal areas in the Bothnian Bay have an acceptable status in terms of different elements of biodiversity. The grey seal population is in good status in the whole Baltic Sea **(Figure 3.35)**.

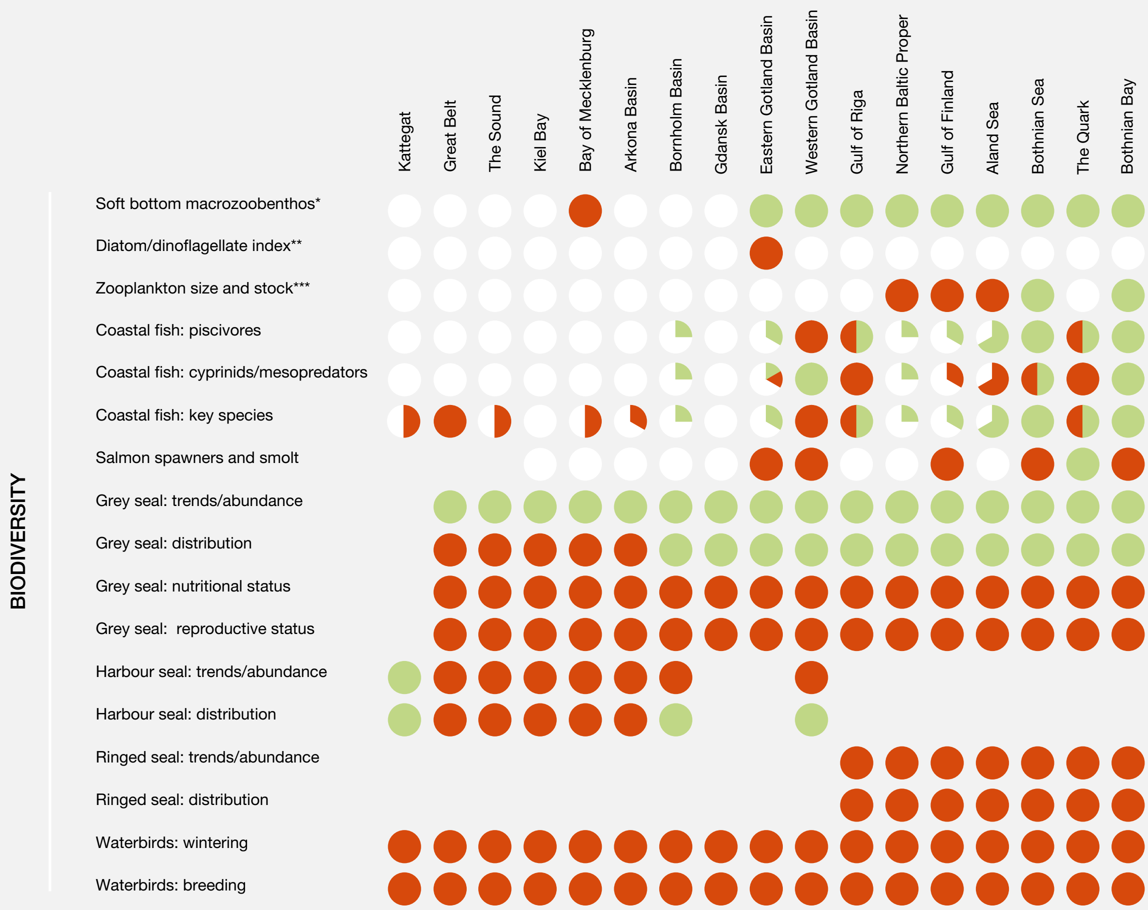
Regime shifts and fish trends

In general, fish communities of the Baltic Sea are very unstable due to substantial decline or lack of large predatory fish in the system. Several species are of concern in achieving the Baltic Sea Action Plan community level targets (HELCOM, 2009). Several currently threatened or declining fish species are negatively influenced by eutrophication and pollution (Fernandes *et al.*, 2017; HELCOM, 2009). Coastal fish species are declining in shallower areas, mainly due to increasing temperature (Snickars *et al.*, 2015). Latest assessments indicate a good biodiversity status for about half of the assessed coastal area (HELCOM, 2017f). In addition, reduced salinity reduces the food base for benthic feeding fish in deeper areas (Snickars *et al.*, 2015).

The open areas of the Baltic Sea have undergone several regime shifts in the 20th century (Österblom *et al.*, 2007). Such changes are primarily caused by the combination of weakened top-down pressure and increased primary production (Möllmann *et al.*, 2007). These ecosystem shifts are well observed in cod populations. The current decline of cod populations can be attributed to the large scale fishing industry and results in a significant increase in sprat populations (HELCOM, 2010), changes in zooplankton

Figure 3 35 **Status of biodiversity core indicators by sub-basin of the Baltic Sea.**

Green circles indicate good status, red circles indicate not good status, and empty circles indicate that the core indicator is applicable for the sub-basin, but has not been assessed. Absent circles indicated that the indicator is not applicable. For coastal indicators, pie charts show proportion of coastal assessment units per sub-basin in good status (green), not good status (red) and not assessed (empty). Source: HELCOM (2017e).



* Core indicator agreed to be tested in the HELCOM assessment
** Pre-core indicator agreed to be tested in the HELCOM assessment'
*** The indicator 'Zooplankton size and stock' is under testing for the Gdansk Basin

communities (Rönkkönen *et al.*, 2004) and thus reduced growth of the Baltic herring. In addition, changing climate conditions and lack of saline water inflows have created environmental conditions unsuitable for marine fishes (e.g. cod). Although, in some areas, signs of recovery have been observed for cod populations (Cardinale & Svedäng, 2011), recovery to safe biological limits has not yet been reached (HELCOM, 2010). Sturgeon, a very important commercial species for centuries, is now a red-listed species. A reintroduction programme has being developed with eggs from the St. John river in Canada (Kolman *et al.*, 2011). In the open sea, a good status in terms of fish biodiversity has not been achieved in any assessment area (HELCOM, 2017f).

Marine mammal trends

In the early 1900s strong hunting pressure followed by toxic pollution substantially decreased all populations of marine mammals in the Baltic Sea resulting in a "critically endangered status" for the Baltic Sea harbour porpoise (Hammond *et al.*, 2008; HELCOM, 2009, 2013) and an order of magnitude decrease in the number of seals (Harding & Härkönen, 1999). Although, the conservation status of marine mammals in the Baltic Sea was considered as unfavourable for most of the species assessed (EEA, 2015d), there are some signs of an increase of top predators, mostly seals and predatory birds, during recent decades (HELCOM, 2013, 2017d). Population size of grey seals is considered as favourable in several Baltic Sea areas **(Figure 3.35)** and this recovery is interfering with fishing activity and an unknown number of seals are drowning in fishing gear every year (Vanhatalo *et al.*, 2014). But the assessment of their nutritional and reproductive status is still not good **(Figure 3.35)**. In addition several migratory bat species populations are negatively impacted by wind turbine development (Voigt *et al.*, 2012). An expert evaluation of endangered species in the Baltic shows that a number of species are still at risk of extinction (HELCOM, 2013).

Marine bird trends

No clear trends are evident for marine bird populations, but populations are not considered stable in the Baltic Sea. Substantial long-term declines can be attributed to anthropogenic factors, through lower reproductive success. However, some bird species (e.g., cormorants) may benefit from certain anthropogenic activities (HELCOM, 2009). A cascading effect from overfishing, that targets predator fish, has also improved the food base for some birds, as more prey becomes available to them (e.g. auks) (HELCOM, 2009). In addition, climate change has impacted the range and population size of migrating species through changes in breeding areas (HELCOM, 2009, 2017b). In recent decades, over half of wintering water bird species have declined significantly and the reasons for their decline are not currently understood (BalticSTERN, 2013; HELCOM, 2017c).

Plankton trends

The species dominance and biodiversity of phytoplankton have significantly changed over the past 100 years (Feistel *et al.*, 2008; Hällfors *et al.*, 2013; HELCOM, 2009; Wasmund *et al.*, 2008). In recent decades, however, there have been few clear trends. Long-term increases in cyanobacteria blooms present a challenge to achieving good Baltic Sea Action Plan environmental status (HELCOM, 2009). During the past few decades, the dominant zooplankton taxa have undergone considerable changes, driven by natural shifts and human impacts. These changes are causing a cascading effect in the food web, affecting upper trophic levels (HELCOM, 2009).

Benthos and habitat forming species trends

Currently, macrobenthic communities are severely disturbed and degraded in several Baltic Sea areas (HELCOM, 2009; Norkko *et al.*, 2007) and long-term patterns indicate a “shifting baseline” (HELCOM, 2009). From 1994 to 2005 marine invertebrates in the Kattegat area decreased from 230 to 180 species and this decline continued until 2011, when some taxonomic groups were found to have only one third of the species recorded in 1994 (EEA, 2015a). In general, the dominance of perennial habitat-forming macrophytes, such as bladder wrack, eelgrass and charophytes, is gradually decreasing and currently being replaced by phytoplankton and fast growing annual phytobenthic species (Dahlgren & Kautsky, 2004; HELCOM, 2009, 2010; Korpinen & Jormalainen, 2008). However, some range expansion in several important macroalgal species has been observed in the area of the Northern Baltic Proper (HELCOM, 2009, 2013). For example, bladder wrack has increased its range in depth (HELCOM, 2009) and its status is considered of least concern in the most recent assessment (HELCOM, 2013). Eelgrass populations have undergone several restoration attempts after being almost destroyed by diseases in the 1930s. Long term trend indicates significant fluctuations in eelgrass distribution in the Baltic Sea, with higher instability in sheltered areas (Frederiksen *et al.*, 2004). In addition, mussel beds have undergone significant transformation and further decline is expected due to the range expansion of invasive species preying on mussels (Westerbom *et al.*, 2002; HELCOM, 2009; Ojaveer *et al.*, 2016). In open sea areas soft bottom invertebrate communities are in good condition in a large part of the Baltic Sea (HELCOM, 2017e, 2017f).

Invasive species trends

The number of non-indigenous species in the Baltic Sea is growing (HELCOM, 2009, 2017e, 2017g). Over half of those recorded have become established in at least one of the Baltic Sea countries (Ojaveer *et al.*, 2016).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Eutrophication, overfishing, and a significant decline in the abundances of marine mammal populations were the most important drivers of change in the Baltic Sea in the 20th century (Ojaveer *et al.*, 2010). Currently major environmental problems include eutrophication caused by increasing river runoff, overfishing, hazardous substances, risk of chemical or oil spills, invasive species, habitat loss due to anthropogenic factors, and climate change induced changes, i.e. in temperature and salinity (BalticSTERN, 2013; Costello *et al.*, 2010) **(Box 3.3, Table 3.5)**. Assessments of the status of widespread pressures like marine litter, including microplastics and underwater sound are currently unavailable, but need to be assessed (HELCOM, 2017e). Most areas are subject to multiple stressors (Andersen *et al.*, 2015).

Eutrophication

All open waters and coastal areas of the Baltic Sea, with the exception of some areas in the Bothnian Bay, are changing due to eutrophication (HELCOM, 2010). Altogether 97% of the surface area in the Baltic Sea is eutrophic (HELCOM, 2017e). The sea floor area where hypoxia occurs has increased 10-fold over the last 115 years (Carstensen *et al.*, 2014). In open waters, the increase of oxygen-deficient zone areas is the main driver of change in biodiversity and benthic community functioning (Carstensen *et al.*, 2014; HELCOM, 2009). Areas with eutrophication-induced coastal hypoxia are becoming more common both in deep and shallow water habitats (Conley *et al.*, 2011). In the northern Baltic Sea, hypoxic disturbance degrades the structure and function of seafloor communities and sediment nutrient cycling (BalticSTERN, 2013; Villnäs *et al.*, 2012). There are improvements in eutrophication status that are direct consequences of long-term efforts to reduce nutrient inputs (Andersen *et al.*, 2015; HELCOM, 2017e), but the overall target of a Baltic Sea unaffected by eutrophication has not yet been met (Svendsen *et al.*, 2015).

Overfishing

Overfishing is one of the main drivers of change in the Baltic Sea ecosystem, because low diversity systems are more prone to cascading effects caused by the decline of top predators (BalticSTERN, 2013). Technical improvements in fishing methods have increased landings since the second half of the 20th century in the overpopulated Baltic Sea area. In addition, construction and regulations in main watercourses have disturbed the natural reproduction of migratory fish species (BalticSTERN, 2013). Since the collapse of the cod stock in the 1980s, landings have been reduced, but due to a shifting regime the cod stocks have not recovered (HELCOM, 2010).

Invasive species

Fewer non-indigenous species are recorded in the Baltic Sea than in other European Seas (Galil *et al.*, 2014). Nevertheless, due to low native species diversity, underrepresentation of several ecosystem traits, and overall large disturbances in habitats, alien species are having severe impacts on the Baltic Sea ecosystem (BalticSTERN, 2013; Leppäkoski *et al.*, 2002). Ecological impacts caused by the invaders vary depending on how they differ from natives in their life form and resource usage (HELCOM, 2009).

Climate change

Climate change amplifies the effect of all other drivers of change (Snickars *et al.*, 2015). In the Baltic Sea eutrophication rates are increasing through increased nutrient fluxes from increased river runoff. Warmer temperature and an increase in extreme temperatures are making the areas better suited for the establishment of alien species. Moreover, increased riverine flows result in lower salinities with detrimental impacts on all species of marine origin.

In summary, the Baltic Sea is well studied and its ecosystems and biodiversity have been very degraded in the past. Management plans for recovery have been in place for some years, and although in general the status of biodiversity is still considered poor, some signs of recovery have been observed.

3.3.4.3 Mediterranean Sea

OVERVIEW OF THE SYSTEM

The Mediterranean Sea, covering approximately 2,500,000 km^2, is a remnant of the Tethys ocean, an ancient ocean from the Mesozoic era. The sea's main hydrologic features are: i) a microtidal regime; ii) scarce freshwater inputs compensated by inflow of Atlantic surface water; iii) highly saline (38 to 39.5‰) concentration basin with higher evaporation eastwards; iv) oligotrophy, with organic carbon inputs 15-80 times lower in the eastern than in the western basin and extremely low concentrations of chlorophyll-a in surface offshore waters (ca 0.05 µg l^{-1}); and v) with almost constant temperature from about 300-500 m downwards, with bottom temperatures about 12.8 - 13.5°C in the western basin and 13.5 - 15.5°C in the Eastern basin.

STATUS AND TRENDS

Despite covering only 0.82% of global oceanic surface, the Mediterranean sea is host to more than 17,000 described marine species, representing an estimated 7% of the world's marine biodiversity, including about 25 to 30% of endemic species (Coll *et al.*, 2010b; Mouillot *et al.*, 2011). Longitudinal and latitudinal patterns distinguish a dozen biogeographic regions, from the Alboran Sea to the Levantine Basin (Bianchi *et al.*, 2012), and a great number of unique ecosystems (Coll *et al.*, 2010b; Danovaro *et al.*, 2010). The apparent eastwards decrease in biodiversity follows a gradient of production, but its true extent is still not clear. Biodiversity is generally higher in coastal areas and on continental shelves. Biodiversity, excepting bacteria and archaea, decreases with increasing water depth, but to a different extent in different taxa. Danovaro *et al.* (2010) estimate the deep-sea biodiversity of the Mediterranean (excluding prokaryotes) at 2,800 species, of which two thirds remains undiscovered.

In recent habitat Red List assessments carried out for 47 benthic shallow (<200 m depth) habitats off the northern shores of the Mediterranean, 60% were considered data deficient. Of the remaining habitats 74% (14 habitats) were threatened (Gubbay *et al.*, 2016).

Some fish and invertebrate populations have been decimated in recent years. Of the 519 native marine fish species and subspecies in the Mediterranean Sea, more than 8% (43 species) were classified in threatened categories (critically endangered, endangered or vulnerable). Of the 15 critically endangered species, 14 are sharks and rays. Thirteen species are listed as endangered, nine of them sharks and rays (Abdul Malak *et al.*, 2011). Cartilaginous fishes in general are declining in abundance, diversity and range (Cavanagh & Gibson, 2007). In the red list assessment of Mediterranean Anthozoans 69 species (51%) were listed as data deficient, and from the remaning about 25% were found to be threatened with extinction (critically endangered, endangered or vulnerable), including two of the endemic species (Otero *et al.*, 2017).

Mediterranean phyto- and zooplankton blooms, including jellyfish and comb jellies, are regional, seasonal and species-specific phenomena. These blooms have likely benefited from overfishing, eutrophication, habitat modification, aquaculture, global warming and human-mediated dispersal (Boero, 2013). Documented increases in bloom frequency, duration, and spatial extent have negatively impacted food web structure, as well as economy and human health (Ferrante *et al.*, 2013) although in some cases, jellyfish can contribute to maintain water quality and prevent phytoplankton blooms exerting a top-down control of the trophic web (Pérez-Ruzafa *et al.*, 2002).

Concurrent expansion of the range of warm-water species (native, recent Atlantic thermophilic entries, tropical Erythraean aliens - that entered the Mediterranean through the Suez Canal) and contraction of that of cold-water species, disrupt the present biogeographic patterns within the basin and place cold-water species under threat (Bianchi *et al.*, 2012; Galil *et al.*, 2017). In the past decade Erythraean aliens have increasingly been recorded on the deeper shelf (> 80 m) and even on the upper slope (Innocenti *et al.*, 2017).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Recent increase of littoral residents, from 44 million in 2000 to 590 million expected in 2050 (Tosun, 2011), and tourists: 270 million in 2010 to 346 million expected in 2020, coupled with intensification of anthropogenic activities, is driving unprecedented changes in the Mediterranean Sea (Micheli *et al.*, 2013; EEA, 2015c). Habitat loss, environmental degradation and pollution are chronic and ubiquitous. Symptoms of complex and fundamental alterations to native populations, habitats and ecosystems proliferate, including increases in exotic species. The biota across wide swaths of the Mediterranean Sea, including marine protected areas, seagrass beds (Boudouresque *et al.*, 2009), algal mats, and biogenic reefs have already been severely altered (Airoldi and Beck, 2007) with direct ecological, economical and human health impacts (Galil *et al.*, 2015, 2017). Coastal lagoons are increasingly endangered by anthropogenic impacts (climate change, sea-level rise, massive introduction of invasive alien species, industrial scale aquaculture operations and fisheries) to the detriment of their role as a reservoir of genetic diversity (Pérez-Ruzafa *et al.*, 2011; Pérez-Ruzafa & Marcos, 2012).

Over half of all fish species are affected either directly or indirectly by fishing activities (Abdul Malak *et al.*, 2011; Vasilakopoulos *et al.*, 2014). Fishing, either through targeted or multi-species fisheries, is by far the most common threat to fish biodiversity, affecting 33% of native marine fish species, with an additional 18% threatened by by-catch. In the Mediterranean, 85% of the stocks are currently overfished and populations of many commercial species are characterized by truncated size- and age-structures (Colloca *et al.*, 2013). Overfishing has also led to a reduction of genetic diversity outside marine protected areas (Pérez-Ruzafa *et al.*, 2006). Larger coastal species and species that occur in areas subjected to prolonged or intensive fishing pressure are of particular concern (Abdul Malak *et al*., 2011). An analysis of the status of the Mediterranean fisheries (1970-2010), using various indicators (total landings, mean trophic level and fishing-in-balance index) confirmed that the fisheries resources of the Mediterranean are at risk from overexploitation. The pattern of exploitation and the state of stocks differed among the regions, with the eastern Mediterranean fisheries being in the worst shape, and declining (Tsikliras *et al.*, 2015).

The effectiveness of management initiatives implemented in the context of the European Common Fisheries Policy has been questioned with regard to the Mediterranean (Vasilakopoulos *et al.*, 2014; Cardinale & Scarcella, 2017). However, some of the analyses that compare the fishing activity in the North East Atlantic and in the Mediterranean do not take into account some of the differentiating characteristics of each region, and fail to discuss the role of marine protected areas as a complementary management tool (Pérez-Ruzafa *et al.,* 2017).

Marine protected areas provide benefits not only for recovering target fish stocks, but also to biodiversity (Pérez-Ruzafa *et al.*, 2017), maintaining assemblage structure and ecosystem equilibrium (Claudet *et al.*, 2008; García-Charton *et al.*, 2008; Lester *et al.*, 2009; Guidetti *et al.*, 2014; Sciberras *et al.*, 2015) preserving ecological interactions (Guidetti, 2006a, 2006b) and maintaining genetic diversity (Pérez-Ruzafa *et al.*, 2006). These effects can take place in a relatively short time (Pérez-Ruzafa *et al.*, 2017) and so the number of marine protected areas has been increasing significantly (see MAPAMED for trends in the Mediterranean, http://www.medpan.org/en/mapamed). There are 1,231 (7.14% of sea surface area) marine protected areas under legal designation in the Mediterranean, even if only 76 of those have no-go, no-take or no-fishing zones, that are the widest measures of protection for biodiversity (0.04% of sea surface area). A recent report (MedPAN & RAC/SPA, 2016) admitted that "… for the majority of sites little is known on whether management measures are implemented and if they are, whether these measures are effective to reach the sites' conservation targets." Surveys conducted in marine protected areas situated along the Levant coastline recorded large populations of mostly Erythraean exotic species (Sala *et al.*, 2011; Yokes & Baki, 2012; Guidetti *et al.*, 2014; Vergés *et al.*, 2014). These marine protected areas are "hot spots" of exotic biodiversity and serve as "seed banks" for secondary spread. A study by IUCN, WWF and MedPAN found "Uncertainty and lack of information regarding marine introduced species was high in the marine protected areas we surveyed, as in average half marine protected area (54.8%) managers did not know the status of the introduced species reported (there)." (Abdulla *et al.*, 2008).

The number of alien species, currently 740 multicellular species (**Figure 3.36**, with their distribution), is substantially greater for the Eastern than the Western Mediterranean Sea with new introductions registered on monthly basis (Galil *et al.*, 2015; Galil *et al.*, 2017). The most common vectors in the Mediterranean are the Suez Canal (60%) **(Figure 3.36)** and vessels (21%). The invasion of the "killer alga" *Caulerpa taxifolia* raised concern over its impact on *Posidonia* meadows (Bulleri & Piazzi, 2014), on the trophic chain (Alomar *et al.*, 2016; Deudero *et al.*, 2011; Felline *et al.*, 2014; Terlizzi *et al.*, 2011), nutrient cycles (Gennaro *et al.*, 2015), sediments (Balata *et al.*, 2015), and sessile and motile biota.

In the eastern Mediterranean algae-dominated rocky habitats, including *Cystoseira* meadows, have been decimated by large populations of herbivorous fish introduced through the Suez Canal. The two voracious grazers, *Siganus luridus* and *S. rivulatus* have transformed lush rocky reefs into "barrens" (Giakoumi, 2014; Sala *et al.*, 2011; Vergés *et al.*, 2014).

The individual and cumulative impacts of these invasions adversely affect the conservation status of native species and critical habitats, as well as the structure and function of ecosystems and the availability of natural resources (Galil, 2007). Some species are noxious, poisonous, or venomous and pose clear threats to human health (Galil *et al.*, 2015).

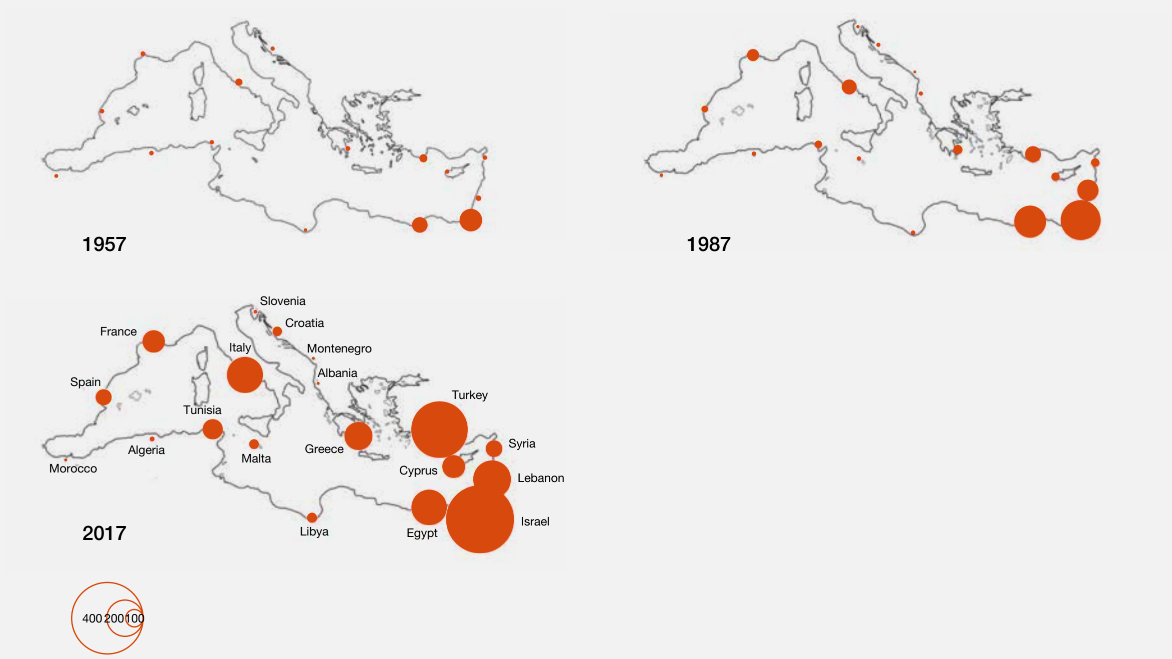
3.3.4.4 The Black and Azov Seas

OVERVIEW OF THE SYSTEM

The Black and Azov Seas are connected to the Mediterranean Sea by the Bosporus and the Dardanelles Straits and the Sea of Marmara. The area of the Black Sea

Figure 3 36 **Number of alien species recorded in the coastal waters of the Mediterranean Sea in 1957, 1987, and 2017.**

Introductions through the Suez Canal account for the larger numbers in the Levantine Basin. Source: Galil *et al.* (2017), unpublished.



is 422,000 km, with a maximum depth of 2,210 m and the mean depth is 1,240 m (Dobrovolskii and Zalogin, 1982). It is very stratified (Vershinin, 2003, 2016), with about 90% of its volume as anoxic water, saturated with hydrogen sulphide accumulated from decaying organic matter. The thin oxygen rich upper layer is about 10-15% of total water volume and only about 100-150 m thick, but supports most of the unique biodiversity of the Black Sea (BSC, 2008; Filippov, 1968; Murray *et al.*, 1989; Yakushev, 1999). The deeper waters are inhabited mostly by protozoa, bacteria, and some multi-cellular invertebrates, though overall knowledge about its biodiversity is very limited (BSC, 2008). Recent publications estimate the number of Black Sea species at about 5,000 (Gomoiu *et al.*, 2012).

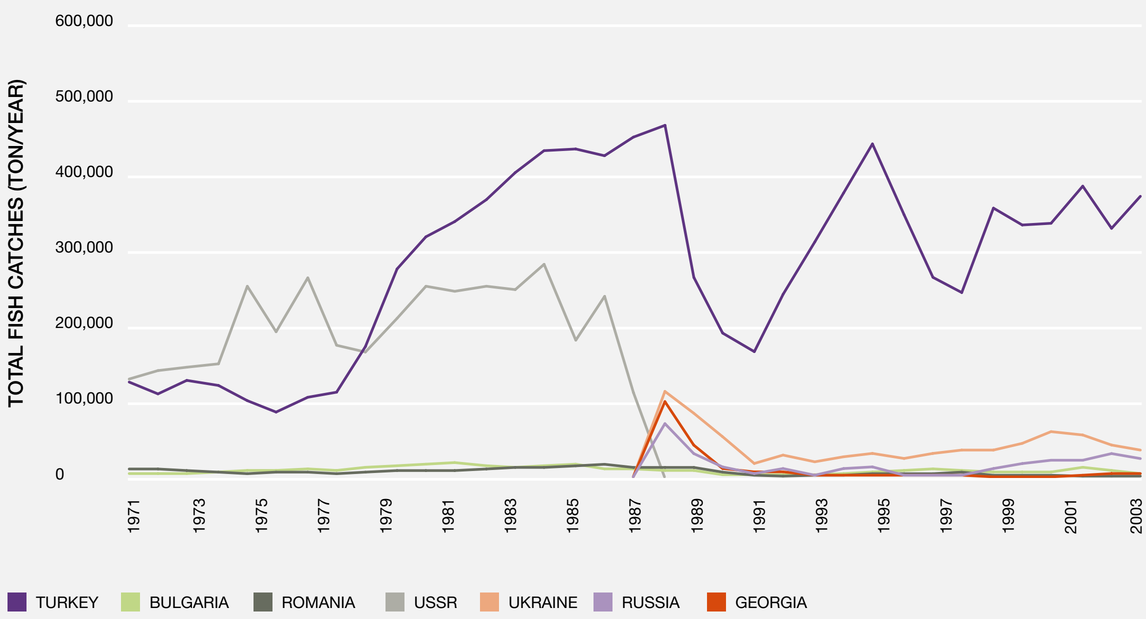
Two major rivers flow into the Sea of Azov: the Don and Kuban, and salinity is at its lowest (about 1‰) near the mouth of the Don (Kotlyakov, 2004). Flora and fauna are composed of different biogeographic groups with a predominance of eurythermic and euryhaline species. Only for the last 6,000-7,000 years the Black Sea has been connected to the Mediterranean basin and freshwater organisms gave place to marine life. Relicts contribute less than 5% of current species, whereas about 85% of the current species originate from the Mediterranean. Now there are about 700 species of phytoplankton, 150 of zooplankton, 300 macroalgae, 1,500 benthic invertebrates and about 180 fish species and three marine mammals in the Black Sea (Vinogradov, 1958; Sorokin, 2002; Vershinin, 2003).

PAST AND CURRENT TRENDS

During the 1980s and early 1990s, the Black Sea ecosystem was in a severely degraded condition, being rated with highest concern in five out of seven environmental categories, and the worst of any of the European seas (Stanners & Boudreau, 1995). The deterioration of this ecosystem was the result of two main drivers: a) eutrophication caused by increase of phosphate and nitrate input from large rivers leading to changes in the silicon/phosphorous and silicon/nitrogen balance (Nesterova & Terenko, 2009); and b) invasion by the ctenophore *Mnemiopsis leidyi*. This ctenophore, a competitor of planktivorous fishes, reached very high biomass levels (>1 kg m^{-2}) (Kideys, 2002), devastating the food chain of the entire Black Sea basin. After the ctenophore bloom, there were sharp decreases in anchovy catch and in the biomass of non-gelatinous zooplankton across the Black Sea which lead to a simplification of the food web that consisted mainly of phytoplankton, gelatinous zooplankton and ctenophores and bacteria **(Figure 3.37)** (Shiganova *et al.*, 2000; Stelmakh *et al.*, 2012; Vinogradov *et al.*, 1995).

Extinction of about half of the native bivalve species was brought about by the invasion of the Pacific gastropod *Rapana venosa*, starting in 1947. Black Sea populations of *Ostrea edulis* and *Flexopecten ponticus* are now on the brink of extinction (Sorokin, 2002; Vershinin, 2016; Zaitsev & Mamaev, 1997). The populations of predators such as dolphins, mackerel and tuna have declined because of

Figure 3 37 **Total fish catches in the Black Sea, according to FAO data (ton/year). Source: Living Black Sea (2016).**



pollution and overfishing. Fishing has been refocused on the sprats *Sprattus and Clupeonella*, whose population had also dramatically decreased by the early 1990s (Tokarev & Shulman, 2007).

Since the mid-1990s there have been some signs of ecosystem recovery. Western Black Sea coastal waters improved due to reduced nutrient inputs, especially phosphorus (Kresin *et al.*, 2008), mainly due to the economic recession after the dissolution of the Soviet Union. This led to fewer microalgal blooms, recovery of some algal populations, increasing plankton biodiversity, decreasing opportunistic and gelatinous species, re-appearance of some native fodder zooplankton and fish species, and increasing edible zooplankton biomass (Ogus, 2008). After 1992, several eutrophication indices also improved in the eastern and deep Black Sea, indicating a more widespread recovery of the Sea (Kideys, 2002). Then, the ctenophore *Beroe ovata*, a specialized predator of *Mnemiopsis* was also introduced into the Black Sea leading to a sharp decline of *Mnemiopsis* followed by a sharp decline of *Beroe* itself. The *Mnemiopsis* population crash and reduction of eutrophication led to increases in non-gelatinous zooplankton, egg densities of anchovy, as well as increases in the biomass of two native gelatinous cnidarians (*Rhizostoma pulmo* and *Aurelia aurita*) and anchovy landings. In the early 2000s the concentration of zooplankton returned to the level before the invasion of *Mnemiopsis leidyi*. In 2004 in the north-eastern part of the Sea the number of species was comparable with numbers before the invasion of *Mnemiopsis*. The total number of fish roe and especially fish larvae, however, remains below the level of the 1960s (Tishkov, 2009).

In the Azov Sea in 1950 to 1970 the construction of storage reservoirs and implementation of water management led to a significant decrease in river inflow (Bespalova, 2016) and subsequent increase in salinity (Kuksa, 1994). There was a migration of Black Sea species to the Azov Sea and the native freshwater and brackish water ecosystems changed, with a decrease of commercial fish spawning in the estuary systems. Pollution by heavy metals, organochlorine pesticides, and petroleum hydrocarbons increased, leading to the reduction of productivity (Bespalova, 2016; Kotlyakov, 2004). Annual migration of *Mnemiopsis leidyi* led to a decrease in zooplankton biomass (Khrustalev *et al.*, 2001; Mirzoyan *et al.*, 2002) that caused damage to the anchovy and sprat populations, resulting in the loss of commercial catch of these species.

The first Black Sea Red Book (Dumont *et al.*, 1999) included 160 endangered species. Of those, sturgeons are the most endangered, along with species that inhabit shallow coastal waters such as turbot, sharks, seals, shrimp and oysters. Several marine mammals and seabirds were also considered to be threatened when their population size and distribution was assessed, with the potential to become extinct in the near future (Eremeev *et al.*, 2011). The habitats at risk include some in the water column, lagoons, estuaries and deltas, and wetlands and saltmarshes. In a recent assessment of 63 shallow water habitat types in the Black Sea, 86% of the habitats were considered data deficient (Gubbay *et al.*, 2016). Excluding those, 67% of habitats were classified as threatened, including 11% as critically endangered.

Phytoplankton and zooplankton ecological communities are currently recovering, but the communities of higher trophic level species (benthonic species, fish) have not yet recovered. Commercial stocks of anchovy are at a relatively high level, and stocks have recovered, but populations of the majority of anadromous and catadromous fishes, such as sturgeons **(Table 3.4)** are still low and 70% of the industrial fish catching consists of small pelagic fishes (Lukoyanov, 2013).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Increased temperature of the upper mixed and the cold intermediate layers due to climate change contributes to naturalization of thermophilic species from the Mediterranean Sea and thins the upper, oxygen-rich layer of water in the Black Sea. Increase of temperature also causes increased evaporation from the seawater surface and reduced inflow from rivers.

Invasions as a result of introduction from ballast water have caused profound changes in the Black Sea. There are 156 species naturalized in this basin (Shiganova, 2000; Shiganova *et al.*, 2000). Invasive species from the coastal Atlantic waters of North America, belonging to eurybiont marine organisms, have the greatest influence.

Twenty countries in Western, Central and Eastern Europe discharge industrial and household wastewaters into the Black Sea basin. Moreover, the main pressure falls on the north-west shallow part of the Black Sea, where the main spawning grounds and habitats of algae and benthic species, are located. Drainage of agricultural lands and increase in mineral fertilizer flows led to the eutrophication of waters and changes in the structure of communities. Nutrients coming from the Danube river remained significant, but stable, in recent years (EEA, 2015c). Rice agriculture has a strong impact on Azov Sea biodiversity (water balance and pollution of seawater). Water pollution by oil and oil-products killed marine animals in the Azov and Black Seas (Diagelets *et al.*, 2014).

Fish stocks have deteriorated dramatically over the past three decades. The diversity of commercial fish caught

Table 3 4 **Average fish catching in the Azov district in the 20th century, ton/year.**

Fish	Natural regime	After river regulation	
	1930-1940	1975-1982	1988-1989
Anadromous:			
Acipenser guldenstadti	463	73	71
A. stellatus	684	17	7
Huso huso	276	15	5
Alosa caspia tanaica	1,508	97	47
Vimba vimba	233	15	11
Pelecus cultratus	3,696	475	376
Catadromous and freshwaters:			
Lucioperca lucioperca	10,224	432	410
Abramis brama	20,353	912	1,960
Rutilus rutilus heckeli	770	18	11.6
Cyprinus carpio	895	2	6
Silurus glanis	1,200	2	0
Esox lucius	70	0	4
Others	2,730	2	20
Total:	43,102	2,060	3,033

has decreased over this period from about 26 species to only six, although the volume of fish caught has actually increased, after a near collapse in 1990. This is almost entirely due to significant anchovy fishing by Turkey, accounting for almost 80% of the total catch. Illegal fishing is also increasing, affecting biodiversity as well as the fishing industry (EEA, 2015c). Fishing gear is also responsible for a decrease in non-target species. For example, dolphins are being stranded in lost or abandoned fishnets, even inside marine protected areas (Nicolaev *et al.*, 2013; Radu & Anton, 2014; Zaharia *et al.*, 2014).

3.3.4.5 Arctic Ocean

OVERVIEW OF THE SYSTEM

The Barents, the White, the Kara, the Laptev, the East-Siberian, the Chukchi, and the Bering Seas together form the Arctic Seas of Europe and Central Asia. The region is a part of the Arctic biogeographic realm except some areas on its south-western and south-eastern margins which are temperate (Spalding *et al.*, 2007). The most distinctive feature of the region is its ice-associated ecosystems.

PAST AND CURRENT TRENDS

As the Eurasian Arctic Ocean is among the less studied marine regions of the world (Jorgensen *et al.*, 2016) and monitoring data are sparse, the majority of observed variations are for the Barents, the White, the western Kara, the Bering, and the Chukchi Seas. While studies that speculate or attempt to forecast impacts of current climate change on Arctic marine biota are numerous, documented impacts are much more scarce (Wassman *et al.*, 2011).

The generally observed and well documented trend of northward species' range shifts (including invasive species) has been defined in the western and the eastern parts of Eurasian Arctic as a processes of "Atlantification" and "Pacification" respectively (Fossheim *et al.*, 2015b; Jørgensen *et al.*, 2016a). In particular, the invasive snow crab is rapidly spreading in the eastern Barents and the Kara Sea (Pavlov & Sundet, 2011; Zalota & Spiridonov, 2015), and other "warm-water" decapods are shifting north-eastward from respective biogeographical borderlines drawn decades earlier (Zimina *et al.*, 2015). Consequences of this process could be unpredictable and different for the different ecosystems. For example, in the Chukchi Sea more nutritious copepods with high fat content could increase; while in the Barents Sea less nutritious boreal copepods could replace their Arctic relatives (CAFF, 2017). At the same time there are observations showing increasing primary and secondary productivity in the Barents Sea (Dalpadado *et al.*, 2014).

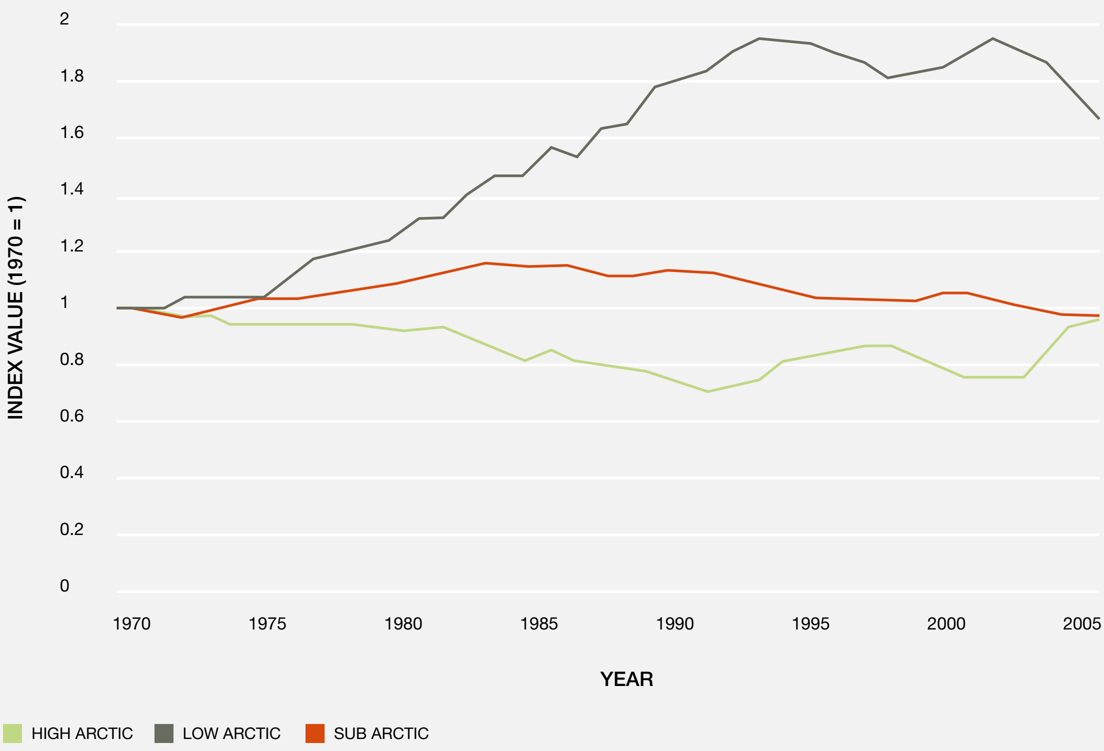
There are also different trends in species and abundance of Arctic fish in the northern Barents Sea (Johannesen *et al.*, 2017). Overall there was a negative trend in the number of Arctic fish species from 2004-2015 but, while some species declined across the area, others declined only in the southern part and increased in the north, indicating displacement, while others did not show any significant change.

There are also changes in Arctic vertebrates' demography, abundance, distribution, phenology and community structure related to these processes (McRae *et al.*, 2012) **(Figure 3.38)**. Several marine mammal species are currently recovering from commercial exploitation (see also paragraph 3.4.3), which could mask reductions in carrying capacity associated with habitat loss in the short-term (Laidre *et al.*, 2015).

There is limited evidence of a decrease in benthic species biomass and diversity with increased pelagic grazing and recycling in the water column across the region (Kędra *et al.*, 2015). In contrast, there are observations showing increase in biomass and diversity of the benthic communities in the Chukhchi Sea where Pacific species of polychaetes, crustaceans, mollusks, and bryozoans have been found in recent years (Sirenko & Gagaev, 2007), later research conducted in this region showed that, despite the presence of Pacific species in the area (e.g. northward shift and increased biomass of Walleye Pollock were observed in the Bering and the Chukchi Seas; Overland & Stabeno, 2004), local benthic communities remained relatively stable (Sirenko, 2009).

Shrinking of multi-year ice cover and related increases of open waters and shelf seas caused a major decline in the productivity of sea-ice algae (Pabi *et al.*, 2008; Wassman *et al.*, 2011). Shifts in range and seasonal movement patterns have altered predator-prey relationships, resulting e.g. in changes in diet of sea birds (Meltofte *et al.*, 2013). Some arctic species have to travel more and expend more energy to find food. This can affect the condition of individuals and populations (CAFF, 2017). In the Barents Sea, the Chukchi Sea, and the Bering Sea, ecosystems are transforming from mostly ice-associated to more pelagic systems with changes in functional diversity (Wiedmann *et al.*, 2014) and structure of food webs (Kortsch *et al.*, 2015).

Figure 3 38 **Index of abundance of Arctic vertebrate species from 1970 to 2007 grouped by high, low and sub-Arctic. Source: Mc Rae *et al.* (2012).**



ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

The primary driver of the observed biodiversity change in the Arctic marine ecosystems is ongoing climate change, and in particular warming (Huntington *et al.*, 2005) and the decrease of sea ice. Current trends show that some species that are dependent on sea ice for reproduction, resting or foraging, are experiencing a reduction in range as sea ice retreats earlier and the open water season is prolonged (CAFF, 2017). This has been shown for many species, such as ducks breeding on the Siberian tundra and wintering at sea, which have now shortened their migration in response to declines in winter sea ice cover. Changes in sea ice conditions are probably also linked to changes of abundance and health of marine mammals, such as declines in the abundance of hooded seals, reduced body condition of Barents Sea harp seals, and changes in prey composition of bearded seals. Early sea ice retreat also reduces suitable breeding and pup rearing habitat for ringed seals. This negatively affects polar bears, which feed on ringed seals, as these conditions make them much more difficult to catch. The bears are thus shifting to prey on ground-nesting seabirds nests (Prop *et al.*, 2015), potentially causing a decline on these bird populations.

Multi-year sea ice is disappearing and is being replaced by first-year sea ice. This is expected to cause shifts in ice algal communities with cascading effects on the ice-associated ecosystem. Decline in ice amphipod abundance was already seen around Svalbard since the 1980s, coinciding with declining sea ice conditions (CAFF, 2017).

Although climate change and its effects are the major drivers of change in the Arctic (Wassman *et al.*, 2011), other drivers are also contributing **(Box 3.3; Table 3.5)**. For many years both local communities and international fleets have harvested several species of fish, seabirds and marine mammals and some stocks of fishes, large whales and seals were reduced to a small fraction of their original population sizes. Their current trends are, therefore, still subject to recovery from past overexploitation, complicating the interpretation of observed trends and attribution to environmental drivers (CAFF, 2017). Sea ice has been limiting the areas for industrial-scale fisheries until now but as the ice retreats, there is potential for expansion of this activity into previously unfished areas. In the Barents Sea, declines in benthic biomass have been linked to the intensity of bottom trawling and this is likely also important in other parts of the Arctic (CAFF, 2017).

So far, there are few examples of invasive marine species becoming established in the Arctic. However, in the Barents Sea two large non-native crab species, the snow crab and the king crab, have become abundant and are affecting benthic communities (CAFF, 2017; Oug *et al.*, 2011).

Finally, population sizes and trends of many migratory Arctic birds are influenced by overharvest, disturbance, and habitat loss outside the Arctic (Meltofte *et al.*, 2013).

3.3.4.6 North West Pacific Ocean

OVERVIEW OF THE SYSTEM

The Russian Far Eastern seas, consisting of the western part of the Bering Sea, Okhotsk Sea and northern part of the Sea of Japan and the adjacent waters of the Pacific Ocean **(Figure 3.39)**, have deep basins separated from the open ocean by chains of islands: Aleutian, Kuril and Japan Islands, that stretch from the Bering Strait to the coast of the Korean Peninsula (34° to 66° N). These are young basins with extensive development of recent metamorphic, volcanic and seismic processes. Natural hazards such as landslides in the coastal zone and continental slopes, earthquakes and volcanic eruptions that can cause tsunamis are widespread. This is one of the most highly productive regions of the global ocean with record levels of primary production equivalent to 70% of all Russian marine biological resources (Antonov *et al.*, 2013) and important fishing areas with valuable marine animals and algae **(Figure 3.40)**.

In these waters, there are 37 species of marine mammals: 27 cetaceans, eight pinnipeds, the polar bear and the sea otter (Artyukhin *et al.*, 1999; Burdin *et al.*, 2009; Hunt *et al.*, 2000; Geptner *et al.*, 1976; Sokolov, 1986; Yablokov *et al.*, 1972). The pelagic fishes in Russian waters of the Far Eastern seas and the Pacific Ocean comprise about 450 species, among which 114 species are identified in the Sea of Japan, 258 species in the Sea of Okhotsk, 170 species in the Bering Sea, and 319 species in the Russian waters of the Pacific Ocean. The average density of pelagic fauna in this area was calculated from about 20 years of trawl catches between 1980 and 2009, as an average of 16.8 tons/km^2 and a total resource of about 70–80 million tons (Ivanov & Sukhanov, 2015) **(Figure 3.40)**.

The Sea of Japan is one of the most diverse seas in Europe and Central Asia. A total of 33,629 species have been reported to occur in these waters. The state of knowledge was extremely variable, with taxa containing many inconspicuous, smaller species tending to be less well known. The total number of species is estimated as 155,542, including 121,913 of identified but undescribed species reached (Fujikura *et al.*, 2010).

PAST AND CURRENT TRENDS

After the dissolution of the USSR, production of commercial fish sharply decreased but since the beginning of the 21st century fishing volume has steadily increased. In 2012

Figure 3 39 General chart of the North Western Pacific area. Source: Google (n.d.).

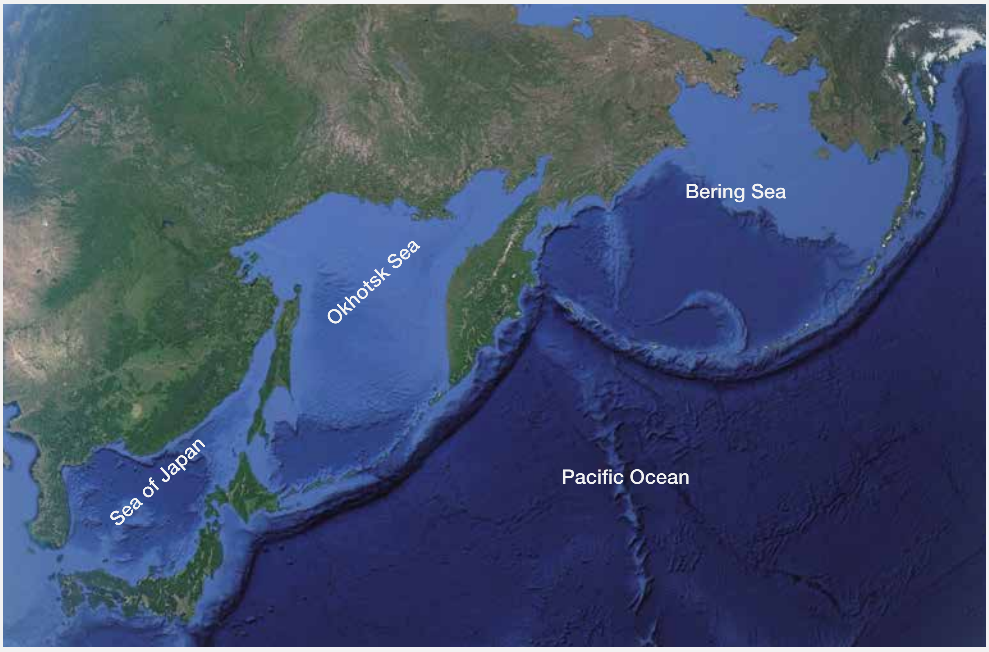
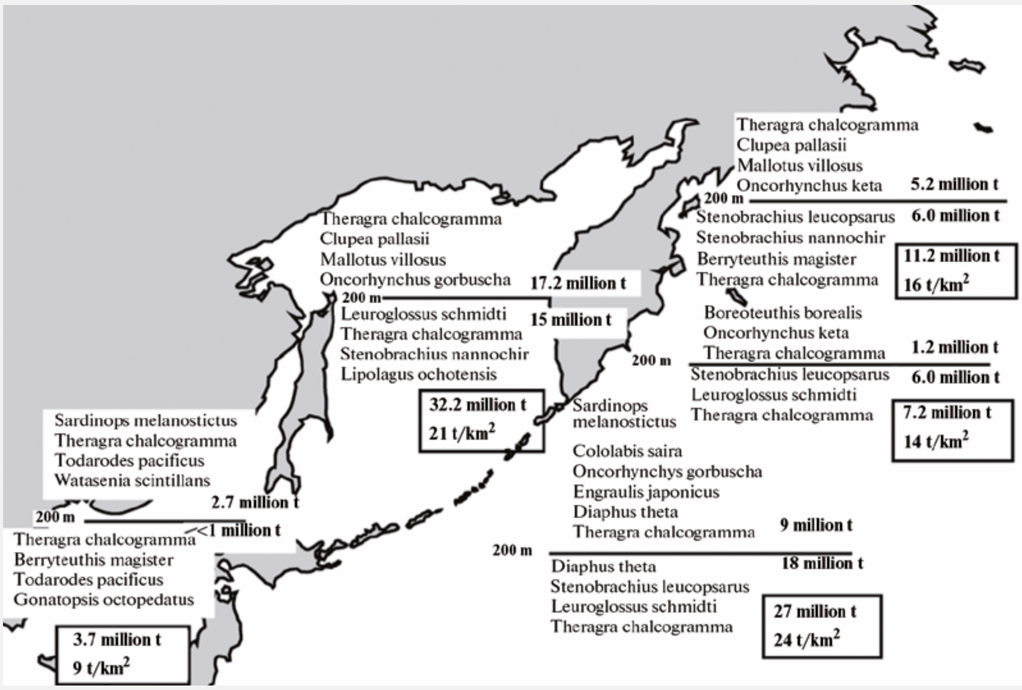


Figure 3 40 Mean annual composition of the most abundant nekton species and total nekton biomass in different regions of the Far Eastern Seas: numerator — in the epipelagic layer (0–200 m), denominator — in the mesopelagic layer (200–1000 m), in frame — total biomass (106 t) and concentrations (t/km²) of nekton. Source: Shuntov & Temnykh (2013). With permission of Springer.



the official catch was equal to 1.7 million tons (Antonov *et al.*, 2013) **(Figure 3.41)**. The volume of poaching is unknown. From 2006 to 2012 there was significant growth in catch, mainly of pollock, cod, herring, bluefish and lemonemy (*Laemonema longipes*) and the composition of the 2012 catch can be seen in **Figure 3.41** (Shevchenko & Datsky, 2014).

From 1930 through the 1970s benthic communities of the Amur Bay have changed dramatically because of pollution: the number of polychaetes has decreased between 5-10 times, brittle stars 2-3 times, the average biomass of benthos by one third. Stocks of Gray's mussels have diminished, and the number and growth rate of scallops have drastically decreased. The stocks of commercial seaweeds (*Ahnfeltia*) decreased – from 86.5 to 40 thousand tons from 1961 to the present time (Belan, 2003). The number of polychaetes, tolerant to low oxygen conditions increased (Belan, 2003). Mass mortalities of small fish have occurred (Yablokov *et al.*, 2014).

The Okhotsk-Korean population of grey whales is one of the most vulnerable in the world. It is included into the Red List of threatened species as "critically endangered" (IUCN, 2015) and is in the Russian Red Book. The reason for its decline in the past was whaling, while in the present day intensive exploitation of oil and gas deposits on the shelf near Sakhalin Island threaten destruction of the population on its the summer-autumn feeding grounds (Adrianov, 2011). The far Eastern seas are important for the Russian economy due to the discovery of large oil and gas reserves on the Far Eastern shelf. However, after an agreement between NGOs and an oil company, mitigation plans for the company exploitation where agreed and followed and the number of whales increased from about 115 animals in 2004 to 174 in 2015 (Martin-Mehers, 2016).

In the waters of the Gulf of Peter the Great 32 potentially harmful species of microalgae capable of producing biotoxins were discovered (Adrianov & Tarasov, 2007). Recently blooms of strains of microalgae that are highly pathogenic and highly virulent have appeared and accumulations of dangerous microorganisms in filter-feeding organisms may lead to a threat to human health (Adrianov & Tarasov, 2007) **(Figure 3.42)**.

312 invasive species were found in Peter the Great Bay, including 104 southern migrants, most of them were transported in ballast waters. In the last 12 years 19 new tropical and subtropical species were detected (Adrianov, 2011). The expansion to the north of not only individual species, but entire complexes of the southern biota is one of the consequences of climate change (IPCC, 2014b).

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Fishery is the main pressure on the North West Pacific Ocean's biological diversity. The total catch every year reaches several million tons of fish and invertebrates. Before 1990, the Soviet Union provided more than half of the world's total catch of pollock (about 2.5 million tons) (FAO, 2011). Excessive fishing of species such as crab, cod, pollock and others, and the by-catch of non-target fish lead

Figure 3 41 **The composition of marine fish catch of the Far East seas in 2012 (tonnes; %). Source: Shevchenko & Datsky (2014).**

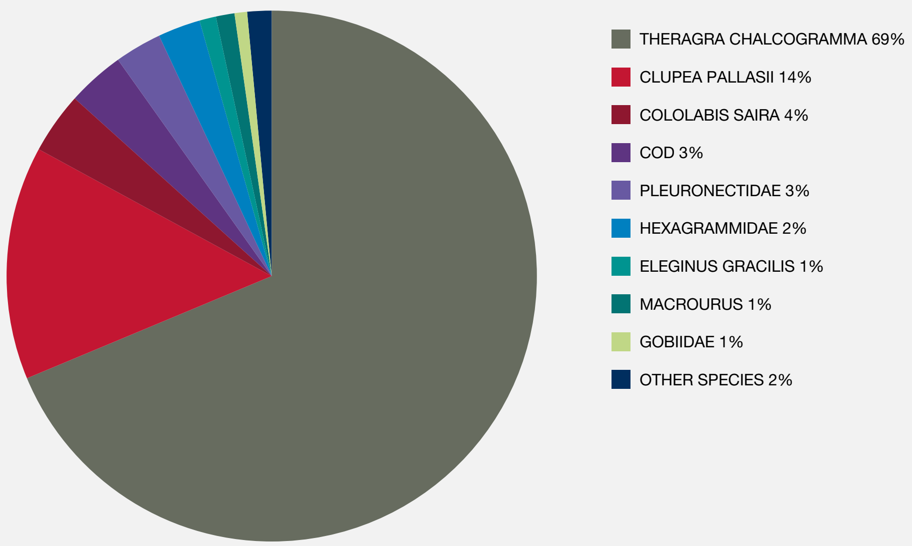
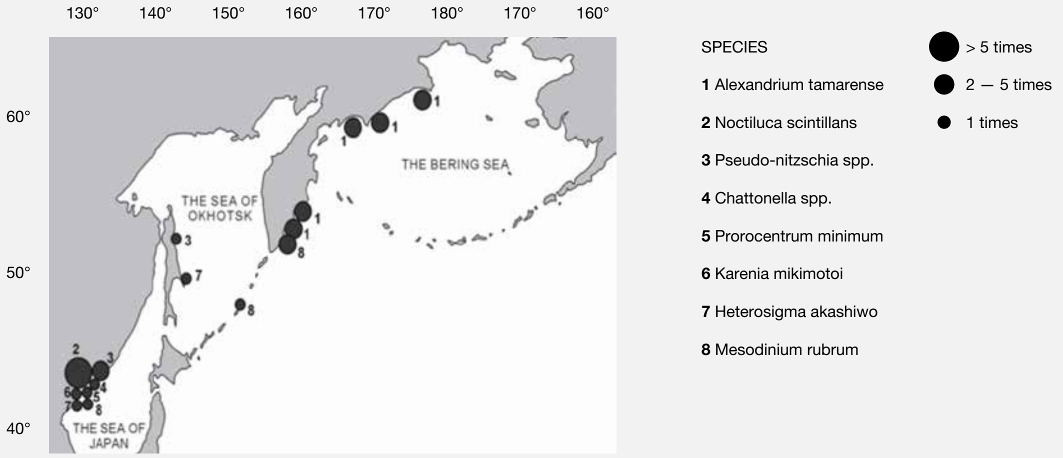


Figure 3 42 **Harmful algal blooms in the Far East seas of Russia in 1980–2005. Source: Orlova *et al.* (2002).**



to the loss of fishing activities, e.g. the loss of Far Eastern crab fisheries (Adrianov, 2011).

A fast reduction of sea ice (4% of the sea area per decade) was recorded in the Okhotsk Sea in the period of 1957-2012 (Roshydromet, 2014). Thirty-three years of observations (1979-2011) showed that the air temperature above the water surface in the Sea of Japan had increased by 0.27°C. In the last 50 years the average temperature of surface waters in the Peter the Great Bay have increased by nearly 0.6°C and the amount of precipitation in the Far Eastern Seas has decreased (Roshydromet, 2014). This creates favourable conditions for invasive species (Adrianov, 2011). An assessment performed by PICES (The North Pacific Marine Science Organization) (Kestrup *et al.*, 2015) found 208 NIS (Non-indigenous Aquatic Species) for the North West Pacific, introduced mostly by ballast water, hull fouling, the aquatic animal and plant trade or aquaculture.

Areas of the North West Pacific are impacted by pollution by oil products from oil and gas extraction on the shelf. Draining of fuel in ports and along the transportation routes, and dumping of decommissioned ships in the coastal zones is a very significant source of pollution in these waters. Their effects on marine biota are severe, including oil films on the surface poisoning birds and other animals, and disrupting photosynthesis and oxygen exchange with the atmosphere (Yablokov *et al.*, 2014).

Excessive run-off of nutrients (nitrogen, phosphorous) from land causes eutrophication leading to hypoxia and the degradation of water ecosystems (Yablokov *et al.*, 2014). Also, marine farming of fish and invertebrates harms the ecosystems at the local level degrading habitats and increasing pollution from organic waste, leading to the deterioration of water quality and a drop in farm productivity. The area affected by pollution can be tens of times greater than the area of the farm (Vyaznikova, 2014).

3.3.4.7 Deep-sea in Europe and Central Asia

OVERVIEW OF THE SYSTEM

The deep-sea is usually defined as those parts of the ocean deeper than 200 m (Gage & Tyler, 1991) beyond the edge of the continental shelf. It is the largest biome on earth, covering approximately 60% of the Earth's solid surface. In the Europe and Central Asia region, the deep-sea covers an area greater than 15 million km^2, encompassing 8 pelagic and 37 benthic biogeographic provinces (UNESCO, 2009) and 11 hydrothermal vent provinces (Rogers *et al.*, 2012). Due to its limited accessibility, it is the least understood, yet one of the richest ecosystems on the planet supporting a high diversity of habitats (e.g. deep-sea pelagic habitats, continental slopes, abyssal soft sediments plains, seamounts, mid ocean ridges, deep-sea canyons and trenches, and smaller habitats such as hydrothermal vents, cold seeps, or cold water coral reefs) and species, as well as a set of supporting and regulating functions and services (Thurber *et al.*, 2014).

PAST AND CURRENT TRENDS

The Millennium Ecosystem Assessment recognized more than 10 years ago that enormous deep-sea species richness remains undiscovered (MEA, 2005), and this is still true today (Mengerink *et al.*, 2014). While there is a solid understanding of biodiversity changes in many coastal ecosystems, trends in the deep sea are poorly described (MEA, 2005), and even basic ecological information (e.g., species ranges, population subdivision, population genetic diversity, dispersal capability and demographic parameters) is lacking for the vast majority of species (Taylor & Roterman, 2017).

However, changes in biodiversity and abundance have been reported as a result of deep-sea fishing activities, oil spills, climate change, and other activities (Koslow *et al.*, 2016). Also declines in cold-water coral and deep-sea sponge abundance and community structure have been widely reported, including off Norway, in the Barents Sea, the Azores, and other regions (Clark *et al.*, 2016; Pham *et al.*, 2014a).

Recent changes in climate (5-16 years) in the deep-sea changed benthic species diversity, abundance and faunal composition (Glover *et al.*, 2010). This biodiversity loss in deep-sea ecosystems has been shown to produce exponential reductions of ecosystem functions (Danovaro *et al.*, 2008) (see Section 3.2).

Although trends are based on a very limited portion of the deep-sea (Koslow *et al.*, 2016), they indicate increased habitat degradation, and declines in biodiversity, abundance and probably ecosystem functioning (Baldrighi *et al.*, 2017). This may also mean that the achievement of important Aichi Biodiversity Targets may be compromized. Targets 5, 6 and 10 under the Strategic Goal B of the Strategic Plan for Biodiversity 2011-2020, and Target 11 under Strategic Goal C may require additional attention and management measures in this context. This may include more effective fisheries management, and an increase of protected areas in the deep-sea and other area-based conservation measures.

ATTRIBUTION OF BIODIVERSITY TRENDS TO DIRECT DRIVERS

Although humans utilized the oceans for millennia, only recently, through technological developments, deep-sea exploitation has begun. The past century has seen a significant increase in human activities that directly affect deep-sea ecosystems, including fishing, waste disposal, oil and gas extraction and bio-prospecting (Morato *et al.*, 2006; Pham *et al.*, 2014b; Ramirez-Llodra *et al.*, 2011; Sandrea & Sandrea, 2010; Synnes, 2007). Added to these pressures are indirect effects caused by global climate change (Ramirez-Llodra *et al.*, 2011).

Bottom fishing has been the major driver of past ecosystem changes in the deep-sea (Clark *et al.*, 2016). It has modified seafloor morphology and its physical properties (Puig *et al.*, 2012), produced overfishing of many stocks, and produced extensive damage to benthic communities, many of them of Vulnerable Marine Ecosystems (VME) (Clark *et al.*, 2016; Hall–Spencer *et al.*, 2002; Pham *et al.*, 2014a).

Global landings of marine deeper water species have increased over the last 50 years (Morato *et al.*, 2006; Watson & Morato, 2013). Many of these fisheries have been overfished or depleted (reviewed in Norse *et al.*, 2012). Bailey *et al.* (2009) and Godbold *et al.* (2013) analysed scientific trawl data from 1977 to 2002 in the Porcupine region of the North East Atlantic deep sea and found a significant decrease of 36% in fish biomass in fished depths and considerably deeper.

Decline in deep-sea benthic invertebrate diversity (reviewed by Clark *et al.*, 2016) has been observed as a consequence of deep-sea fishing in the Barents Sea, and other regions.

Although evidence has been found from the geological record that past climate change has impacted deep-sea faunas, the evidence that recent climate change or climate variability has altered deep-sea benthic communities is still limited (Glover *et al.*, 2010). This mainly reflects the lack of observations and monitoring of this vast seafloor habitat.

Additionally, new industrial activities in the deep-sea are emerging, including the extraction of gas hydrates, carbon sequestration, and mining. Future deep-sea mining (Petersen *et al.*, 2016) has the potential to disturb hundreds of thousands of km^2 of seabed and pelagic environment, with uncertain consequences (Levin *et al.*, 2016). The recent discovery of microplastics in deep-sea sediments suggests that this emergent form of pollution is more far reaching than previously anticipated (Van Cauwenberghe *et al.*, 2013).

3.3.4.8 Progress towards goals of Multilateral Environmental Agreements

AICHI BIODIVERSITY TARGET 11 AND SUSTAINABLE DEVELOPMENT GOAL 14, TARGET 14.5

Subtarget "At least 10 per cent of coastal and marine areas are conserved (in marine protected areas)"

The definition of marine protected area varies significantly (e.g. Costello & Ballantine, 2015), which causes divergence in the numbers presented as percentage of marine protected area coverage both globally and regionally. In Europe and Central Asia, the coverage of marine protected areas was calculated as 4% of its marine area (within the "exclusive economic zone" of 200 nautical miles) by Brooks *et al.* (2016) and as 5.3% calculated by the present assessment with 2017 numbers from the Convention on Biological Diversity (CBD, 2017).

Within Europe and Central Asia, significant differences occur in terms of coverage both between the different regional seas and the coverage of coastal waters and off-shore, within the exclusive economic zone of coastal states. Marine protected area networks cover more than 5.9% of the European Union marine area but only about 3% of Russian Federation marine waters. On the other hand, in European Union countries more than 16% of coastal marine areas now have some form of protection but, beyond 12 nautical miles from the shore, an area representing 80% of the European Union's total sea area, only 3% are protected.

In the framework of regional agreements such as OSPAR (see below), HELCOM (see below), the Bucharest and Barcelona Conventions, and the Arctic Council there have been significant advances regarding the area covered by marine protected areas, including in "areas beyond national jurisdiction", and the integration of these marine protected areas in regional networks.

The OSPAR network comprises 448 marine protected areas, covering 5.9% of the OSPAR maritime area, including 16.7% of its coastal waters; 2.3% of the exclusive economic zones (EEZs) of OSPAR countries; and seven marine protected areas situated in areas beyond national jurisdiction covering 8.9% of this OSPAR area (OSPAR, 2017a). Marine protected area coverage also varies geographically, covering 14.7% of the Greater North Sea but only 1.9% of the Arctic OSPAR area.

The HELCOM marine protected area network from the Baltic Sea was the first in the world, already in 2010, to reach the target of conserving at least 10% of coastal and marine areas. But although today this network covers 11.8% of the Baltic Sea, protection is not evenly distributed between sub-basins or between coasts and open sea, and the aim remains to reach the 10% target in all offshore sub-basins (HELCOM, 2017e).

In the Mediterranean 1,231 marine protected areas and "other effective area-based conservation measures" now cover 7.14% of the Sea area, through a large variety of conservation designations, but with the "no-go", "no-take" or "no-fishing" zones accounting only for 0.04% (MedPAN and RAC/SPA, 2016). Coverage is very uneven in geographic terms: over 72.77% of the surface covered is located in the western Mediterranean. Designations cover 9.79% of European Union waters mostly due to the Natura 2000 at sea network. To reach the Aichi Biodiversity Target 11 of 10% of marine areas protected, an additional 71,900 km^2 (2.86% of the Mediterranean) will have to be designated. To also fulfill the representivity goal, these new designations should target currently under-represented features and subregions (MedPAN and RAC/SPA, 2016).

The extent of protected areas in the Arctic's marine environment has almost quadrupled since 1980 and represents today 4.7% of the Arctic marine area (CAFF, 2017). The marine protected area is dominated by several very large areas and some parts of the Arctic marine ecosystem are still poorly protected. In 2013, the Arctic Council adopted a resolution to identify "Areas of heightened ecological and cultural significance" similar to the Convention on Biological Diversity's "ecologically and biologically significant areas" criteria. Through this process, 98 areas were identified covering about 76% of the Arctic marine area. These areas were identified primarily on the basis of their ecological importance for fish, birds or marine mammals (CAFF, 2017). Approximately 5% of "areas of heightened ecological importance" lie within the present protected areas.

An effort to achieve the Aichi Biodiversity Target 11 of 10% has led to a significant increase in number and extent of marine protected areas of different kinds in Europe and Central Asia in recent years (e.g. in OSPAR it went from 159 in 2010 to 448 in 2016 and from 1.06% of the areas in 2010 to 5.9 in 2016 (OSPAR, 2017a) and in the Mediterranean 397 new marine protected areas were designated between 2012 and 2016). The general trend in marine protected area designation is therefore very positive. In 2017, 15 coastal nations have already more than 10% of their marine waters protected (CBD, 2017).

Global conservation targets based on area alone will, however, not optimize protection of marine biodiversity, and the emphasis should be on better marine protected area design, adequate management and compliance to ensure that they achieve their desired conservation value. Edgar *et al.* (2014) showed that the conservation benefits of marine protected area increased significantly with the accumulation of five key features: no fishing allowed, well enforced, old (>10 years), large (>100 km^2), and isolated by deep water or sand. These were also shown to be key features in the Mediterranean (Giakoumi *et al.*, 2017), although here some small but well managed marine protected areas were also effective in conservation.

Subtarget "Protected areas are ecologically representative and well connected and include areas of particular importance for biodiversity and ecosystem services"

Since there is so much difference between coverage of marine protected area in open seas and in coastal waters, ecological representativeness is still not achieved in Europe and Central Asia. In OSPAR progress was made in recent years towards an ecologically coherent and well-managed network, but further work is required to achieve this goal (OSPAR, 2017a). This network is well distributed in the Greater North and Celtic Seas, but substantial gaps remain in Arctic Waters and the wider Atlantic Ocean. Also 19 of the 54 OSPAR listed features (i.e. species or habitats) are already protected by more than one marine protected area in those parts of the North East Atlantic where they are considered to be at risk. This includes all five listed invertebrates, three of the seven bird species, one of the two reptile species, one of the three marine mammal species, five of the 22 fish species and four of the 15 types of habitat.

The HELCOM assessment of ecological coherence (HELCOM, 2016) showed that the areal representation of different types of broad-scale habitats and the replication of a set of indicative species and biotope were at an acceptable level for supporting a coherent marine protected area network. However, connectivity, which measures how well the network supports the migration and dispersal of species, is not yet optimal.

Subtarget "Protected areas are effectively and equitably managed"

For many of the marine protected areas in waters of Europe and Central Asia, management plans either do not exist; or knowledge on the implementation of protective measures or the effectiveness of these measures to reach the sites' conservation targets is insufficient (MedPAN and RAC/SPA, 2016). Only a small percentage is known to have reached or to be moving towards the objectives they were set up to attain. The resources needed to adequately implement the existing regulations and to manage pressures inside and outside of marine protected areas are still very often not in place.

Information on management is available for 61% of OSPAR marine protected areas, with a further 16% partially documented. But management measures have been implemented for only 12% of OSPAR marine protected areas, with partial action for a further 54%. The situation is similar for monitoring, implemented only for about 14% of these marine protected areas (OSPAR, 2017a). So only 11% of OSPAR marine protected areas were found to be moving towards or have achieved their conservation objectives.

Implementation of management actions for OSPAR marine protected areas in "areas beyond national jurisdiction" have started by OSPAR member countries, but successful management requires cooperation with international organisations with competence for the management of human activities, such as fishing, shipping and deep-sea mining. A mechanism to help cooperation between the relevant organisations has been started between OSPAR and the Northeast Atlantic Fisheries Commission, referred to as "the collective arrangement" (OSPAR, 2017a). On-going negotiations within the United Nations on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction (so called "BBNJ process") is expected to result in a new implementing agreement under the United Nations Law of the Sea that will finally allow marine protected areas in "areas beyond national jurisdiction" to be adequately managed.

HELCOM is now working towards the development of a method to assess the management effectiveness of HELCOM marine protected areas and of the network. Such an assessment will determine the environmental positive effects of the marine protected area management (HELCOM, 2017e).

Many sites of the current system of marine protected area and "other effective area-based conservation measures" in the Mediterranean Sea do not have regulations in place to curb existing pressures or enough means to enforce them. Information about management measures and their effectiveness in maintaining or restoring biodiversity is also lacking. Resources allocated to management are not sufficient for the requirements, thereby compromising successful conservation (MedPAN and RAC/SPA, 2016).

EUROPEAN UNION MARINE STRATEGY FRAMEWORK DIRECTIVE

Progress towards the European Union Marine Strategy Framework Directive goals

The European Union Marine Strategy Framework Directive, approved in 2008, has as its main objective to achieve good environmental status in all waters of the European Union by 2020 (EEA, 2015c). This status is described through 11 descriptors including: biodiversity, non-indigenous species, commercially exploited fish, food-webs, eutrophication, sea-floor integrity, hydrographical conditions; contaminants in the environment, contaminants in seafood, marine litter, and energy, all relevant for determining the status of marine biodiversity and ecosystem functioning. The Directive aims to maintain or restore biodiversity and to attain a marine environment that is healthy, clean, and productive in all the European Union Seas and Ocean areas, and those it shares with its neighbors. Its implementation should also make significant contributions to achieving the goals of the European Union Biodiversity Strategy for the marine environment.

The first assessment of Europe's seas at European Union-wide scale (EEA, 2015c) used data from the first Marine Strategy Framework Directive and Habitats Directive's reporting completed in 2012 and other sources. 80% of the species and habitats assessments under the Marine Strategy Framework Directive were categorized as "unknown" status, but a more complete picture is available for the marine habitats and species protected by the Habitats Directive. Even among assessments of the conservation status of species and habitat types of conservation interest, only 7% of marine species and 9% of marine habitat types show a "favourable conservation status". Moreover 27% of species and 66% of assessments of habitat types show an "unfavourable conservation status" and the remainder are categorized as "unknown". Additionally, 58% of the assessed commercial stocks did not have "good environmental status", while the status of 40% of commercial fish stocks was not assessed due to lack of data.

There are many "unknowns" when it comes to European Union member State reporting and in commercial fish stock statistics data from mandatory reporting. This highlights the difficulty associated with obtaining data to assess the health status of even the seas that are under European Union responsibility, where relatively rich information exists. However, by comparing information available from European, regional, and national sources, a common pattern of change can be seen: ecological extinctions are being observed across species belonging to different functional groups including species such as monk seals in the Black Sea, bluefin tuna in the eastern North Sea, sharks in the Mediterranean Sea and North East Atlantic Ocean and habitat-forming species like oysters in the North Sea and sea grasses in the Baltic and Mediterranean Seas. Even if there are a few examples of species where the declining trends appear to be halted, such as for bluefin tuna (*Thunnus thynnus*) in certain areas (EEA, 2015c), patterns of degradation are observed across all of the ecosystem components, and across all of the information sources considered. The observed loss of biodiversity affects ecosystem functioning and may cause irreversible loss of ecosystem resilience, putting in jeopardy ecosystem health. Based on different assessments considered the European Union's marine ecosystems could therefore not be considered to be in a healthy state, as would be the objective of the Marine Strategy Framework Directive.

The European Environment Agency (2015e) considered in addition that European Union marine areas could also not be considered clean, even though some improvements in eutrophication are already visible, for example in the Black and Baltic Seas. It stated, however, that they could be considered productive, thus fulfilling one of the three main goals of the Marine Strategy Framework Directive.

Even if this Directive is only valid in the European Union, member States are required to use existing regional cooperation structures to co-ordinate among themselves and to make every effort to coordinate their actions with those of third countries in the same region or subregion. This cooperation has been taking place through OSPAR, HELCOM, the Barcelona and Bucharest Conventions for more than 30 years, and is also done in the framework of the Arctic Council.

Box 3 1 Summary of past and current trends in biodiversity and ecosystems and their attribution to direct drivers of change.

The table and figure of this box summarize past and current trends in biodiversity and ecosystems for terrestrial and inland surface water units of analysis and marine areas in Europe and Central Asia and the attribution of these trends to direct drivers of change. **Table 3.5** presents the assessed information in terms of trends in areal extent and biodiversity status. Biodiversity status summarizes the biodiversity information assessed in Sections 3.3 and 3.4. **Figure 3.43** summarizes the trend information on biodiversity status.

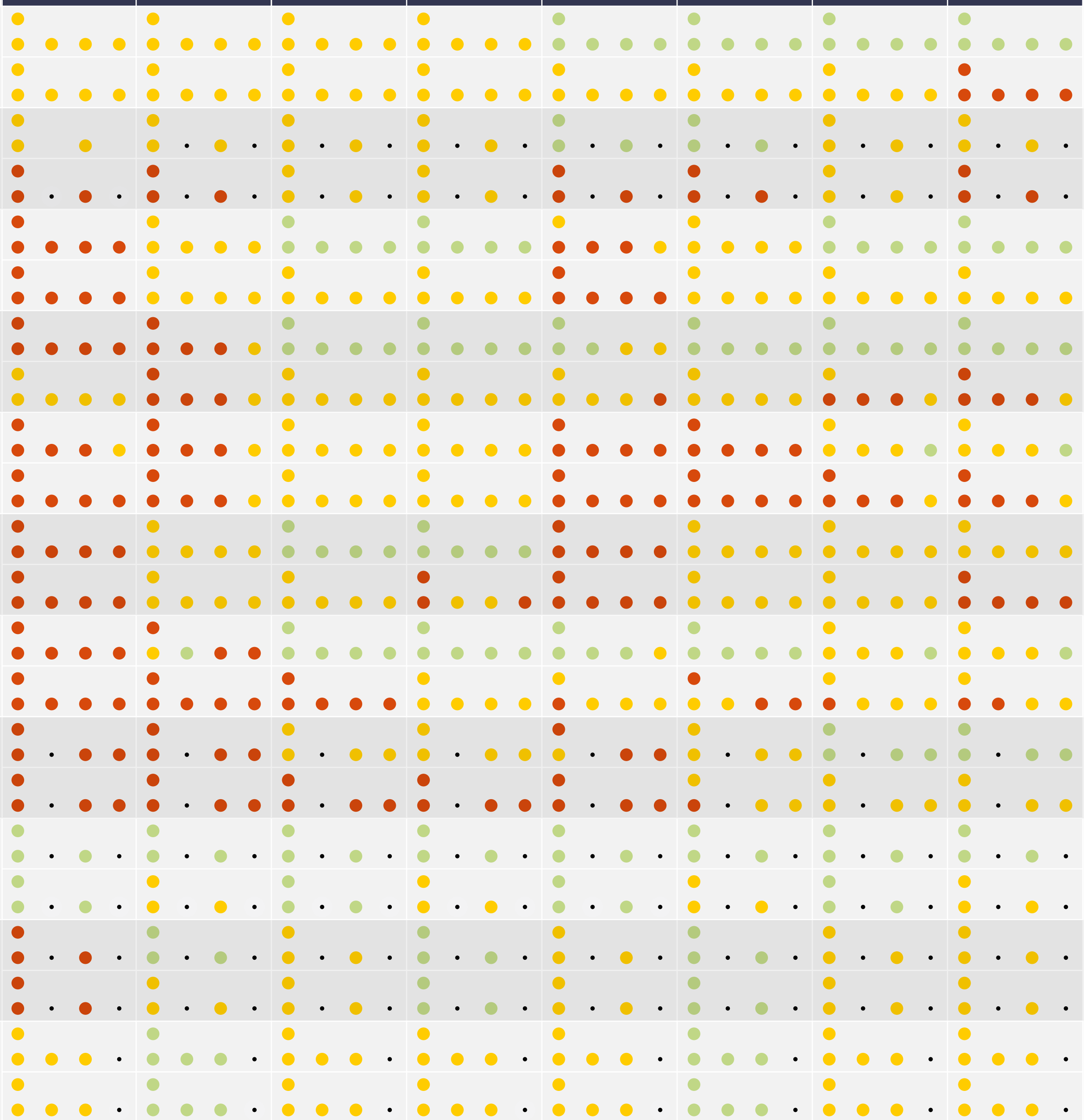
Table 3 5 Summary of past and current trends in biodiversity and ecosystems in terms of spatial extent and biodiversity status for terrestrial and inland surface water units of analysis and in terms of biodiversity status for marine systems, and summary of the attribution of these trends to direct drivers of change.

● HIGH IMPACT ● MODERATE IMPACT ● NO OR MARGINAL IMPACT

Unit of analysis	Indicator	GENERAL TREND								CLIMATE CHANGE							
		Past				Present				Past				Present			
		ECA				ECA				ECA				ECA			
		WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
TERRESTRIAL																	
Snow and ice-dominated systems	Extent	↘				↘				Moderate				High			
Snow and ice-dominated systems	Extent	↘	↘	↘	↘	↘	↘	↘	↘	Moderate	Moderate	Moderate	Moderate	High	High	High	High
Snow and ice-dominated systems	Biodiversity status	↘				↘				Moderate				High			
Snow and ice-dominated systems	Biodiversity status	↘	↘	↘	↘	↘	↘	↘	↘	Moderate	Moderate	Moderate	Moderate	High	High	High	High
Tundra	Extent	↕				↕				Moderate				High			
Tundra	Extent	↕	•	↕	•	↕	•	↕	•	Moderate	•	Moderate	•	High	•	High	•
Tundra	Biodiversity status	↘				↘				Moderate				High			
Tundra	Biodiversity status	↘	•	↘	•	↘	•	↘	•	Moderate	•	Moderate	•	High	•	High	•
Alpine and subalpine systems	Extent	↓				↘				Moderate				Moderate			
Alpine and subalpine systems	Extent	↓	↓	↓	↓	↘	↘	↘	↘	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Alpine and subalpine systems	Biodiversity status	↘				↘				Moderate				Moderate			
Alpine and subalpine systems	Biodiversity status	↘	↘	↘	↘	↘	↘	↘	↘	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Temperate and boreal forests and woodlands	Extent	↘				↗				Marginal				Moderate			
Temperate and boreal forests and woodlands	Extent	↘	↘	↘	↘	↗	↗	↕	↕	Marginal	Marginal	Marginal	Moderate	Moderate	Moderate	Moderate	High
Temperate and boreal forests and woodlands	Biodiversity status	↘				↘				Marginal				Moderate			
Temperate and boreal forests and woodlands	Biodiversity status	↘	↘	↘	↘	↘	↘	↘	↘	Marginal	Marginal	Marginal	Moderate	Moderate	Moderate	Moderate	High
Mediterranean forests, woodland and scrubs	Extent	↓				↓				Moderate				High			
Mediterranean forests, woodland and scrubs	Extent	↓	↓	↓	↓	↓	↓	↓	↓	Moderate	Moderate	Moderate	Moderate	High	High	High	High
Mediterranean forests, woodland and scrubs	Biodiversity status	↘				↘				Moderate				Moderate			
Mediterranean forests, woodland and scrubs	Biodiversity status	↘	↘	↘	↘	↘	↘	↘	↘	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Tropical and subtropical dry and humid forests	Extent	↓				↕				Marginal				Marginal			
Tropical and subtropical dry and humid forests	Extent	↓	↓	↓	↓	↔	↕	↕	↕	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal
Tropical and subtropical dry and humid forests	Biodiversity status	↓				↕				Moderate				High			
Tropical and subtropical dry and humid forests	Biodiversity status	↓	↓	↓	↓	↕	↕	↕	↕	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High	High
Temperate grasslands	Extent	↓				↕				Marginal				Moderate			
Temperate grasslands	Extent	↓	↓	↓	↓	↘	↘	↕	↗	Marginal	Marginal	Marginal	Marginal	Moderate	Moderate	Moderate	High
Temperate grasslands	Biodiversity status	↓				↕				Marginal				Moderate			
Temperate grasslands	Biodiversity status	↓	↓	↓	↓	↓	↘	↕	↕	Marginal	Marginal	Marginal	Marginal	Moderate	Moderate	Moderate	High
Deserts	Extent	↗				↗				Moderate				High			
Deserts	Extent	↕	•	↗	↗	↕	•	↗	↗	Moderate	•	Moderate	Moderate	High	•	High	High
Deserts	Biodiversity status	↘				↘				Moderate				High			
Deserts	Biodiversity status	↘	•	↘	↘	↘	•	↘	↘	Moderate	•	Moderate	Moderate	High	•	High	High
Permafrost peatlands	Extent	↔				↔				Marginal				Marginal			
Permafrost peatlands	Extent	↔	•	↔	•	↔	•	↔	•	Marginal	•	Marginal	•	Marginal	•	Marginal	•
Permafrost peatlands	Biodiversity status	↔				↘				Marginal				Moderate			
Permafrost peatlands	Biodiversity status	↔	•	↔	•	↘	•	↘	•	Marginal	•	Marginal	•	Moderate	•	Moderate	•
Boreal peatlands	Extent	↓				↘				Marginal				Moderate			
Boreal peatlands	Extent	↓	•	↓	•	↘	•	↘	•	Marginal	•	Marginal	•	Moderate	•	Moderate	•
Boreal peatlands	Biodiversity status	↓				↘				Marginal				Moderate			
Boreal peatlands	Biodiversity status	↓	•	↓	•	↘	•	↘	•	Marginal	•	Marginal	•	Moderate	•	Moderate	•
Temperate peatlands	Extent	↘				↔				Marginal				Marginal			
Temperate peatlands	Extent	↘	↘	↘	•	↔	↔	↔	•	Marginal	Marginal	Marginal	•	Marginal	Marginal	Marginal	•
Temperate peatlands	Biodiversity status	↘				↔				Marginal				Marginal			
Temperate peatlands	Biodiversity status	↘	↘	↘	•	↔	↔	↔	•	Marginal	Marginal	Marginal	•	Marginal	Marginal	Marginal	•

ECA=Europe and Central Asia, WE=Western Europe, CE=Central Europe, EE= Eastern Europe, CA=Central Asia. ↑/↓ denote strong and consistent increase/decrease in the indicator; ↗/↘ denote moderate and consistent increase/decrease in the indicator; ↔ stable indicator; ↕ variable trend in the indicator.

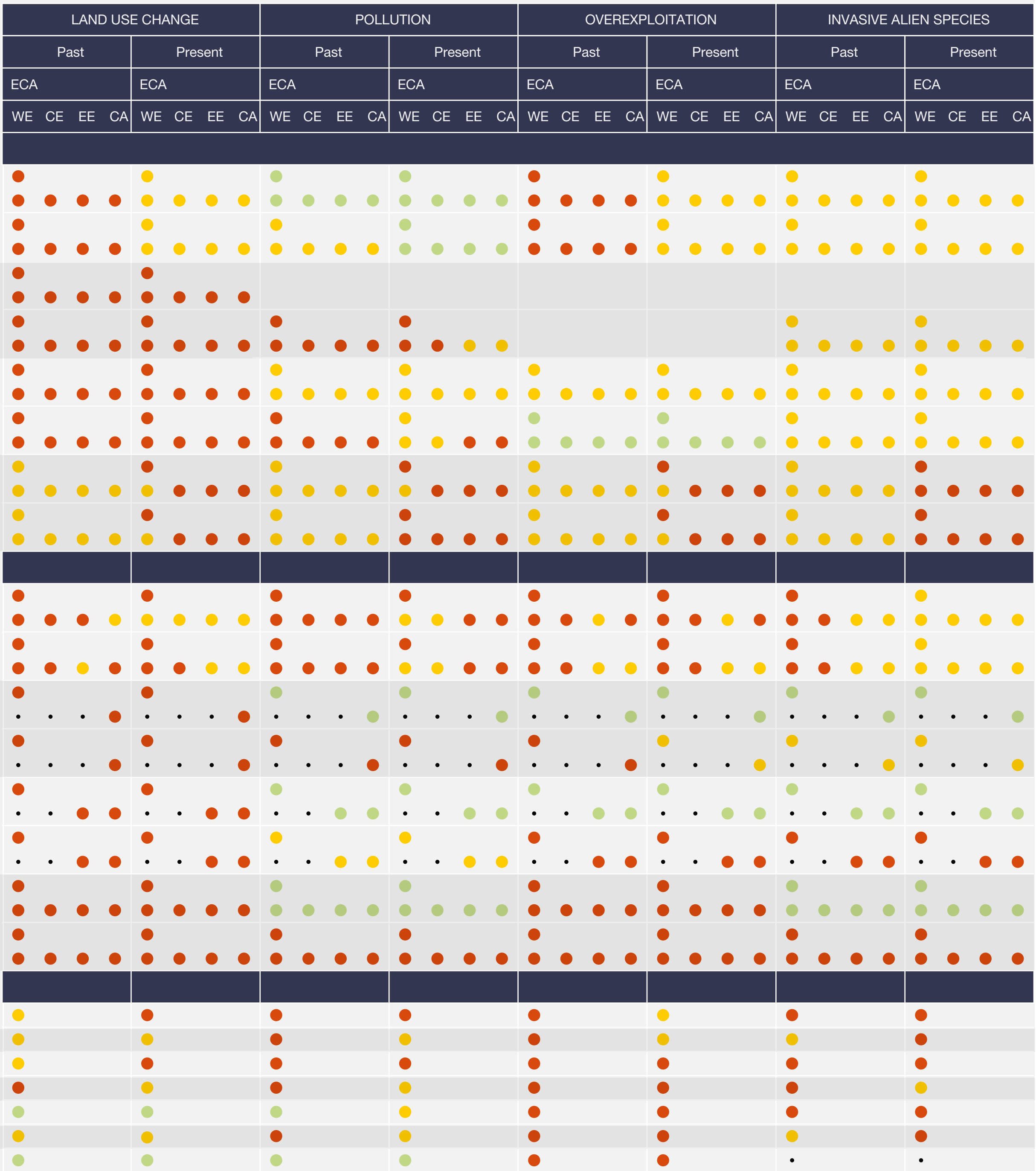
LAND USE CHANGE								POLLUTION								OVEREXPLOITATION								INVASIVE ALIEN SPECIES							
Past				Present				Past				Present				Past				Present				Past				Present			
ECA				ECA				ECA				ECA				ECA				ECA				ECA				ECA			
WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA



Box 3 1

Table 3 5

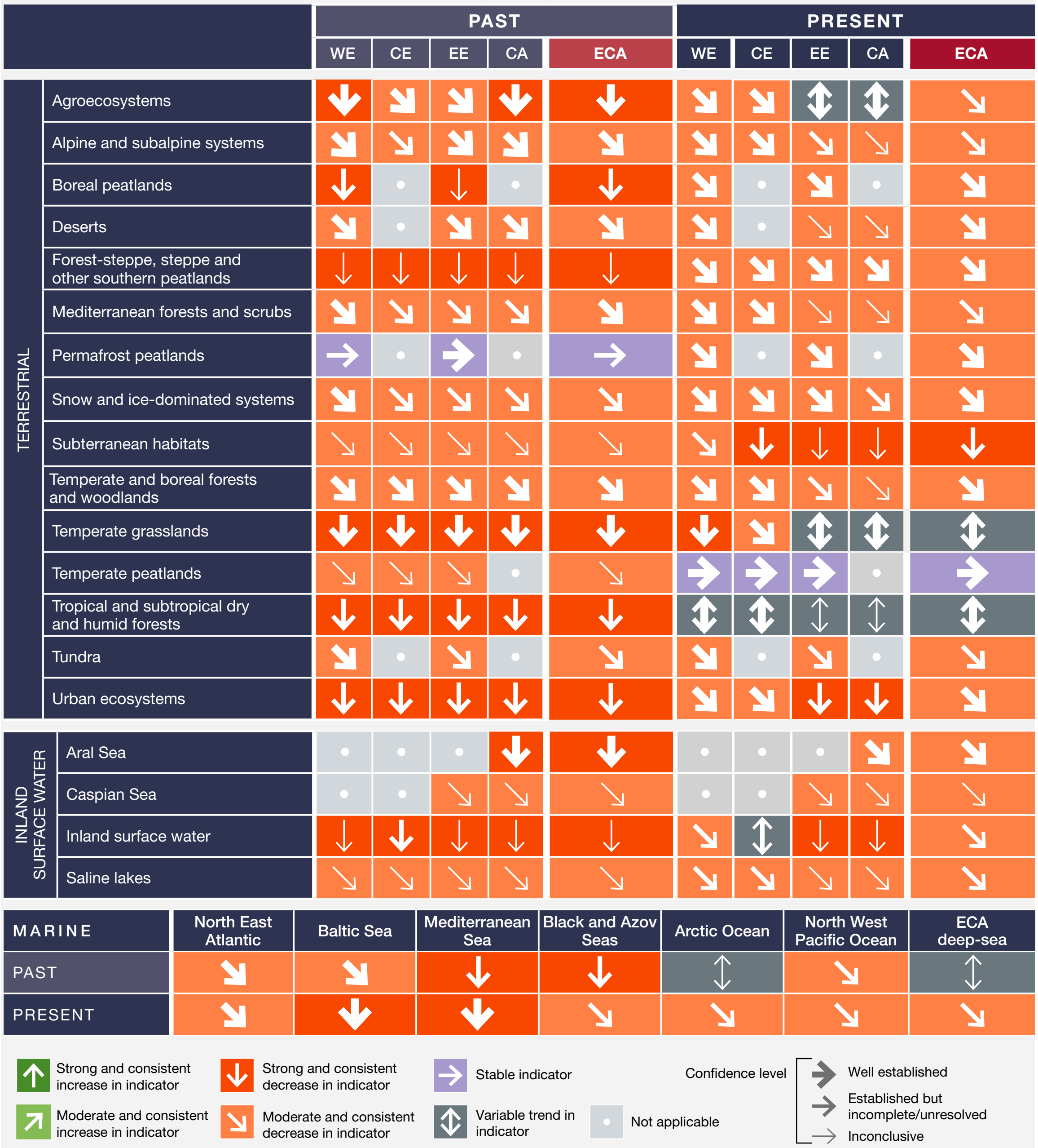
		GENERAL TREND								CLIMATE CHANGE							
		Past				Present				Past				Present			
		ECA				ECA				ECA				ECA			
Unit of analysis	Indicator	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
TERRESTRIAL																	
Forest-steppe, steppe and other southern peatlands	Extent	↓				↘				🟡				🟡			
Forest-steppe, steppe and other southern peatlands	Extent	↓	↓	↓	↓	↘	↘	↘	↘	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Forest-steppe, steppe and other southern peatlands	Biodiversity status	↓				↘				🟡				🟡			
Forest-steppe, steppe and other southern peatlands	Biodiversity status	↓	↓	↓	↓	↘	↘	↘	↘	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Agricultural areas	Extent	↗				↔											
Agricultural areas	Extent	↔	↗	↑	↑	↔	↗	↘	↘								
Agricultural areas	Biodiversity status	↓				↘				🟢				🟡			
Agricultural areas	Biodiversity status	↓	↘	↘	↓	↘	↘	↕	↕	🟢	🟢	🟢	🟢	🟡	🟡	🟡	🟡
Urban areas	Extent	↓				↘				🟡				🟡			
Urban areas	Extent	↓	↓	↓	↓	↘	↘	↘	↘	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Urban areas	Biodiversity status	↓				↘				🟡				🟡			
Urban areas	Biodiversity status	↓	↓	↓	↓	↘	↘	↓	↓	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Subterranean habitats	Extent	↘				↓				🟡				🟡			
Subterranean habitats	Extent	↘	↘	↘	↘	↘	↓	↓	↓	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
Subterranean habitats	Biodiversity status	↘				↓				🟡				🟡			
Subterranean habitats	Biodiversity status	↘	↘	↘	↘	↘	↓	↓	↓	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡
INLAND SURFACE WATER																	
Freshwater	Extent	↓				↘				🟢				🟡			
Freshwater	Extent	↓	↓	↓	↓	↘	↕	↓	↓	🟢	🟢	🟢	🟢	🟡	🟡	🟡	🟡
Freshwater	Biodiversity status	↓				↘				🟢				🟡			
Freshwater	Biodiversity status	↓	↓	↓	↓	↘	↕	↓	↓	🟢	🟢	🟢	🟢	🟡	🟡	🟡	🟡
Aral Sea	Extent	↓				↘				🟡				🟡			
Aral Sea	Extent	•	•	•	↓	•	•	•	↘	•	•	•	🟡	•	•	•	🟡
Aral Sea	Biodiversity status	↓				↘				🟡				🟡			
Aral Sea	Biodiversity status	•	•	•	↓	•	•	•	↘	•	•	•	🟡	•	•	•	🟡
Caspian Sea	Extent	↕				↔				🟡				🟡			
Caspian Sea	Extent	•	•	↕	↕	•	•	↔	↔	•	•	🟡	🟡	•	•	🟡	🟡
Caspian Sea	Biodiversity status	↘				↘				🟡				🟡			
Caspian Sea	Biodiversity status	•	•	↘	↘	•	•	↘	↘	•	•	🟡	🟡	•	•	🟡	🟡
Saline lakes	Extent	↘				↘				🟡				🔴			
Saline lakes	Extent	↘	↘	↘	↕	↘	↘	↘	↓	🟡	🟡	🟡	🟡	🔴	🔴	🔴	🔴
Saline lakes	Biodiversity status	↘				↘				🟡				🔴			
Saline lakes	Biodiversity status	↘	↘	↘	↘	↘	↘	↘	↘	🟡	🟡	🟡	🟡	🔴	🔴	🔴	🔴
MARINE																	
North East Atlantic	Biodiversity status	↘				↘				🔴				🔴			
Baltic Sea	Biodiversity status	↘				↓				🔴				🔴			
Mediterranean Sea	Biodiversity status	↓				↓				🔴				🔴			
Black and Azov Seas	Biodiversity status	↓				↘				🟡				🟡			
Arctic Ocean	Biodiversity status	↕				↘				🟡				🔴			
North West Pacific Ocean	Biodiversity status	↘				↘				🟡				🟡			
ECA deep-sea	Biodiversity status	↕				↘				🟡				🟡			


LAND USE CHANGE
POLLUTION
OVEREXPLOITATION
INVASIVE ALIEN SPECIES
Past
Present
ECA
WE CE EE CA

Box 3 1

Figure 3 43 **Summary graph of the assessment of past (~1950–2000) and current (~2001–2017) trends in biodiversity status of marine, inland surface water and terrestrial ecosystems for the four subregions and the whole of Europe and Central Asia.**

The figure summarizes the trends in biodiversity status of the assessed units of analysis (habitat types). Biodiversity status represents the expert assessment of available indicators of habitat intactness, species richness and the status of endangered species. The trends are presented by unit of analysis and subregion for terrestrial and inland surface-water ecosystems, and by sea or ocean area for marine ecosystems. WE=Western Europe, CE=Central Europe, EE= Eastern Europe, CA=Central Asia, ECA=Europe and Central Asia.



3.4 PAST AND CURRENT TRENDS BY TAXONOMIC GROUP

3.4.1 Introduction

Europe and Central Asia hosts more than 10% of the world's vascular plant species, and about 25% of animal and plant groups comprehensively assessed by IUCN are unique to this region. Between 20 and 120 species have gone extinct regionally and an additional 44 to 67 have gone extinct globally since the 1500s[7] (data summarized from the IUCN Red List of Threatened Species - Species Information System, March 2017). These numbers are an under-estimation considering that only about 86,000 species have been assessed by the IUCN, less than 4% of species of plants and animals described today (estimated to be 2.3 millions according to Jenkins *et al.*, 2013). In addition to the extinctions recorded at large scale, numerous extinction events were recorded at the country level. The following statistics are based on a subset of taxonomic group that has been comprehensively assessed[8]. There is a high risk of extinction for 13% of species occurring in Europe and Central Asia in these selected groups and for which data is available (94% of the 2,493 species in these taxonomic groups). 13.5% of the species in the region are endemic, and 27.9% of these species are threatened. The Central and Western European subregions hold the highest percentages of species threatened (13.3%) and endemic (10.6%), and the highest percentage of endemics threatened (35.1%), with these percentages primarily driven by the many threatened endemic species in the Mediterranean hotspot and the Macaronesian Islands **(Figure 3.44)**.

Eastern Europe and Central Asia have lower percentages of species threatened (<10%) and endemic (<5%), and a smaller proportion of endemics threatened (<10%). For mammals, birds, and amphibians, global assessments of extinction risk against the Red List Categories and Criteria have been undertaken multiple times over the last three decades to derive Red List Indices as indicators of the rate at which species groups are sliding towards extinction, and these can be combined with species distribution data to produce geographically downscaled Red List Indices (i.e., regional contributions towards the global Red List Index; Rodrigues *et al.* 2014). Specifically, changes in aggregate extinction risk of all regions' and subregions' species can be calculated, showing how adequately species are conserved relative to their potential contribution to global species conservation. The contribution to increasing global extinction risk varies among the subregions, with Central and Western Europe contributing the most, followed by Central Asia and Eastern Europe **(Figure 3.45)**.

Below we discuss status and trends for most major taxonomic groups. These trends and their attribution to different direct drivers are summarized in **Table 3.11**. Insufficient data were available to assess status and trends of marine species except for mammals, birds and fishes. Status and trends in community composition and biomass stocks of marine plankton are dealt with in the marine units of analyses section, whereas the lack of status and trends of other taxonomic groups, including non-planktonic marine invertebrates, algae and protozoans, are discussed in the knowledge gaps section.

3.4.2 Birds

Status and trends

There are an estimated 887 extant bird species in Europe and Central Asia, 25 endemic (BirdLife International, 2016), and 71 threatened with extinction (categories vulnerable, endangered and critically endangered; BirdLife International, 2016). Analysis of changes of categories in the IUCN Red List between 1988 and 2008 suggests that Eastern Europe was the subregion with the greatest declines (the most changes towards higher threat categories), and Central Asia was the subregion with the smallest declines (Brooks *et al.*, 2016). No species within the region has gone extinct since 1980, but three species are possibly extinct or nearing extinction in the Western, Central and Eastern European subregions (BirdLife International, 2016).

Areas of high bird richness include Russia, Turkey, the Mediterranean, Israel, the Black Sea and the Caucasus (BirdLife International, 2015, 2016; **Figure 3.46 A**). The highest rates of endemism, and highest numbers of threatened species (Jenkins *et al.* 2013; BirdLife International, 2016; **Figure 3.46 B**) are found in the Mediterranean and Macaronesian islands, as well as the Caucasus (BirdLife International, 2015, 2016), and Central Asia.

There is strong evidence for a moderate *overall decline of bird populations* in the region (BirdLife International, 2017). A recent report (BirdLife International, 2015) shows that out of the 533 species breeding in the EU-27 countries, 153 have declined since 2001, while 136 show a long-term decline (since 1980, **Table 3.6**). Most of the large-scale,

7. The lower value are the documented number of extinctions, the upper value is obtained by including also all species classified by IUCN as possibly extinct.

8. Mammals, birds, chameleons, amphibians, sharks and rays, selected bony fish groups (angelfishes and butterflyfishes, tarpons and ladyfishes, parrotfishes and surgeonfishes, groupers, wrasses, tunas and billfishes, hagfishes, sturgeon, blennies, pufferfishes, seabreams, porgies, picarels), freshwater caridean shrimps, cone snails, freshwater crabs, freshwater crayfish, lobsters, reef-building corals, conifers, seagrasses, and plant species occurring in mangrove ecosystems. Species assessed by IUCN in other taxonomic groups may not be a random sample, but likely a subset of species deemed at higher risk of extinction, therefore extrapolating their extinction risk to all species may bias the percentage of species endangered.

long-term research studies (Gregory *et al.*, 2007; Jørgensen *et al.*, 2016b; Reif *et al.*, 2008; Vickery *et al.*, 2014) as well as many smaller studies (e.g. Vilkov 2013) also report declines in either species richness or populations. However, different species groups and regions exhibit different trends, and knowledge gaps exist. Notably, population sizes are unknown for many species, particularly in Eastern Europe and Central Asia (BirdLife International, 2017).

A large proportion of species in decline are associated with marine habitats (BirdLife International, 2015). Terrestrial species show contrasting trends among functional groups. Decline is strongest for migratory birds (BirdLife International, 2008; Vickery *et al.* 2014) and habitat specialists (Le Viol *et al.*, 2012). The latter, coinciding with an increased frequency of generalist species, leads to a decrease in functional diversity. This trend, often referred to as "biotic homogenization", is maybe the typical change in terrestrial avian communities across groups and locations (Le Viol *et al.*, 2012).

Genetic diversity is often studied at the population level (Eeva *et al.*, 2006; Liu *et al.*, 2013) and no clear large-scale trend patterns have been detected as this is still a young field of exploration. Possible threats to avian genetic diversity include habitat fragmentation, hybridization with feral (Randi, 2008) or introduced or invasive species (Muñoz-Fuentes *et al.*, 2007).

Figure 3 44 **Overview of extinction risk of species in the Europe and Central Asia region. Source: IUCN (2017c).**

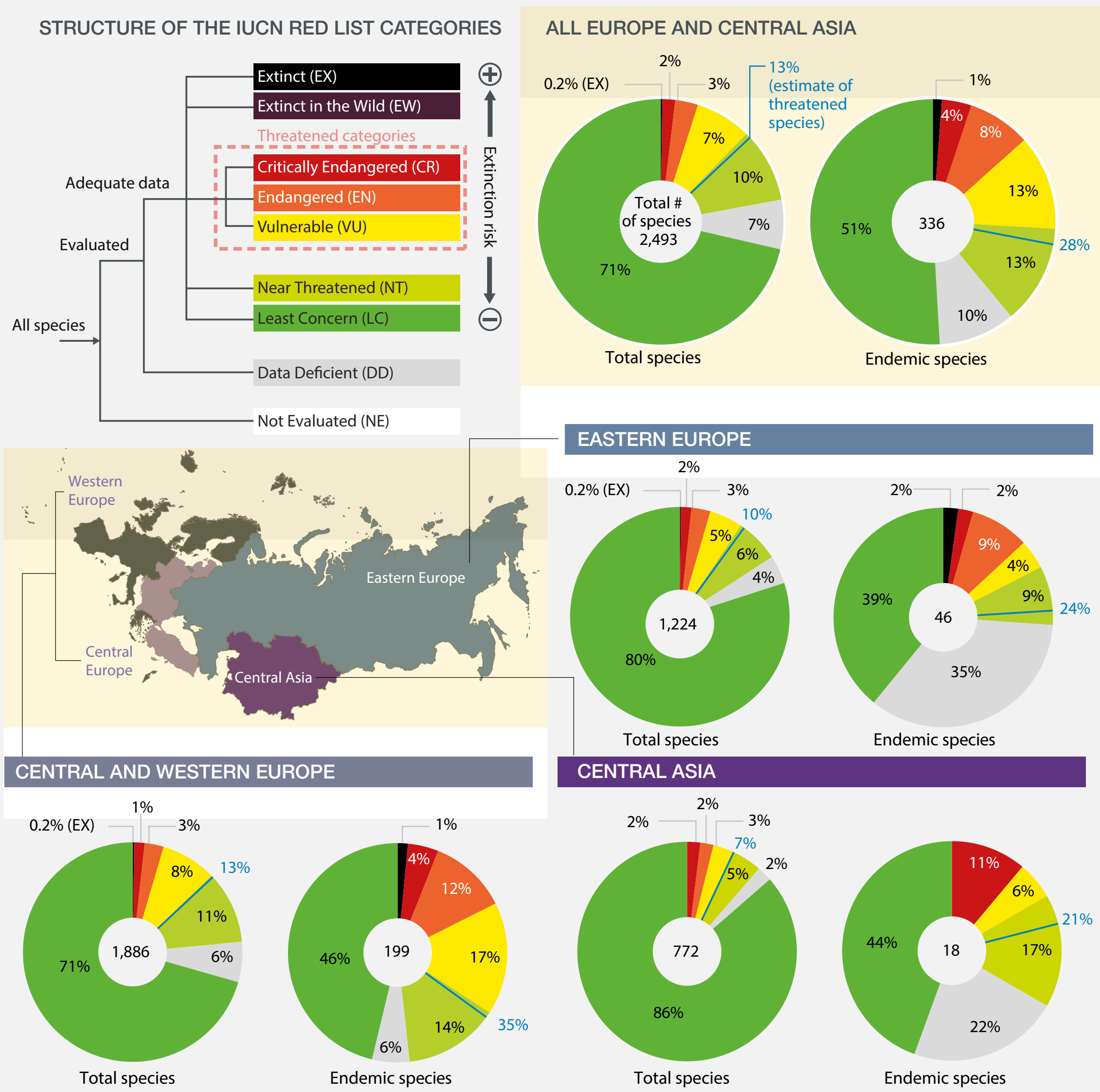


Figure 3 45 **Red List Indices of species extinction risk weighted by the fraction of each species' distribution occurring within Europe and Central Asia and its subregions.**

The position on the vertical axis indicates the aggregate extinction risk facing species in the region overall, while the slope indicates how rapidly this extinction risk is changing. For the region as a whole, the risk of extinction of species has increased over the last 20 years. Species in the Central and Western Europe subregions are least well-conserved relative to the region's potential contribution to global species conservation, and are declining fastest in status. Source: Data from Brooks *et al.* (2016).

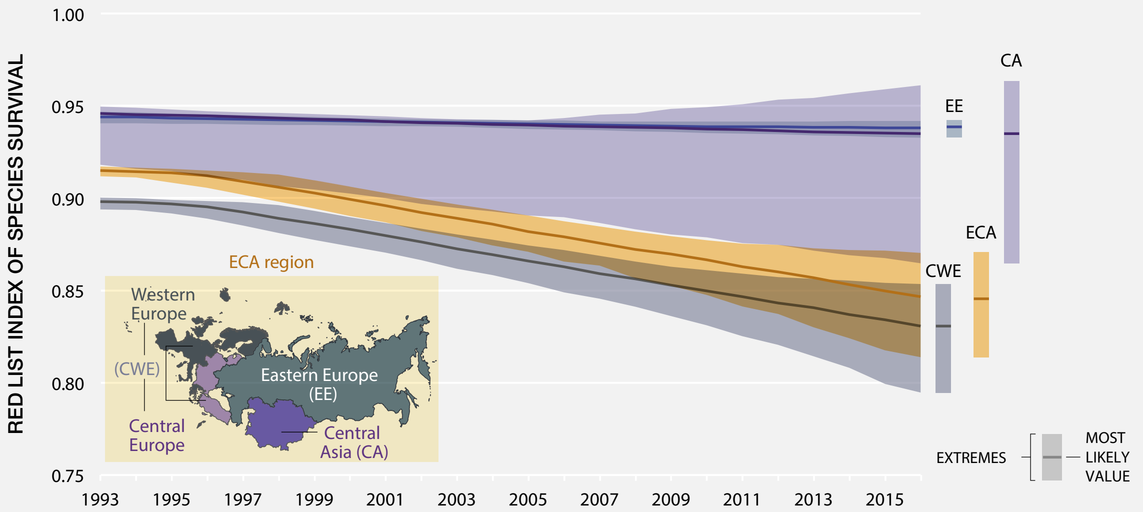


Table 3 6 **Long-term and recent trends of bird species breeding in EU-27 countries (EEA, 2015a). Short-term covers the time period 2001-2012, and long-term the period 1980-2012. The total number of species is 456.**

Trend	Long-term	Short-term
Declining	136	153
Increasing	150	133
Stable	49	96
Fluctuating	6	12
Uncertain	55	23
Unknown	79	58

Drivers of change

Exploitation (hunting, poaching, and bycatch from fisheries) was found to be the largest threat to vulnerable or endangered species by the IUCN (BirdLife International, 2015). Although the exact numbers of birds killed are difficult to evaluate due to lack of data, the order of magnitude in the entire Mediterranean region is several millions of birds killed each year (Arizaga & Laso, 2015; Brochet *et al.*, 2016; Casas *et al.*, 2009; Sokos *et al.*, 2013), while hunting and poaching seem also to be significant in Central Asia (BirdLife International, 2016; Chemonics International, 2001a).

Land and water use is an important driver as it affects multiple species at once. As such it is often reported both in scientific literature and indigenous and local knowledge sources (Roué and Molnár 2016). Overall, decreases in the extent of specific habitats and urban expansion contribute to biotic homogenization (Le Viol *et al.*, 2012; McKinney, 2006). Recent agricultural changes have had a dramatic effect on bird diversity (Donald *et al.* 2001, also see section on Agricultural areas). Amongst forest birds, several changes have been documented, mostly showing a decrease in old forest specialists, deciduous forest specialists, and cavity-nesters. All these changes can be related to the intensification of forestry practices, which often entail dense monocultures that are harvested before structural elements can benefit many bird species (Gil-Tena *et al.*, 2007; Lõhmus *et al.*, 2016; Sirkiä *et al.*, 2010; Smith *et al.*, 2008). However, no large-scale consensus on land use related trends in forest birds seems to exist (Gregory *et al.*, 2007; Ram *et al.*, 2017).

There is clear evidence that bird communities are locally affected by pollution from industrial activities (Eeva *et al.*, 2012) or pesticide use in agricultural fields, directly (Wegner *et al.*, 2005) or indirectly (Hallmann *et al.*, 2014). Light pollution in urban environments has been shown to affect the timing of reproductive events (Dominoni & Partecke, 2015), but there is not yet any clear evidence of an impact on abundance or community composition.

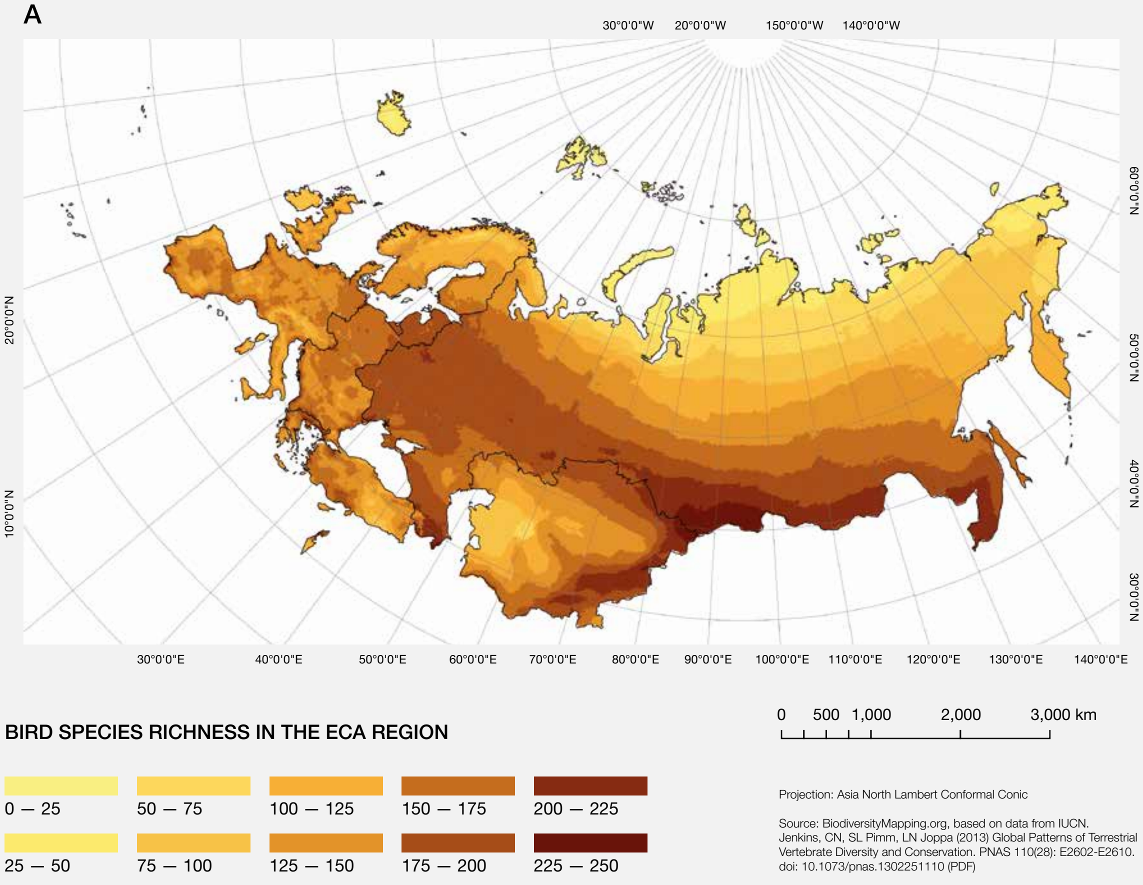
Invasive alien species and invasive native species (e.g. rats, domestic cats), have been shown to threaten the reproductive success of many birds, particularly colonial seabirds (BirdLife International, 2015), and have been linked with declines of some species (e.g. Skorka *et al.*, 2010).

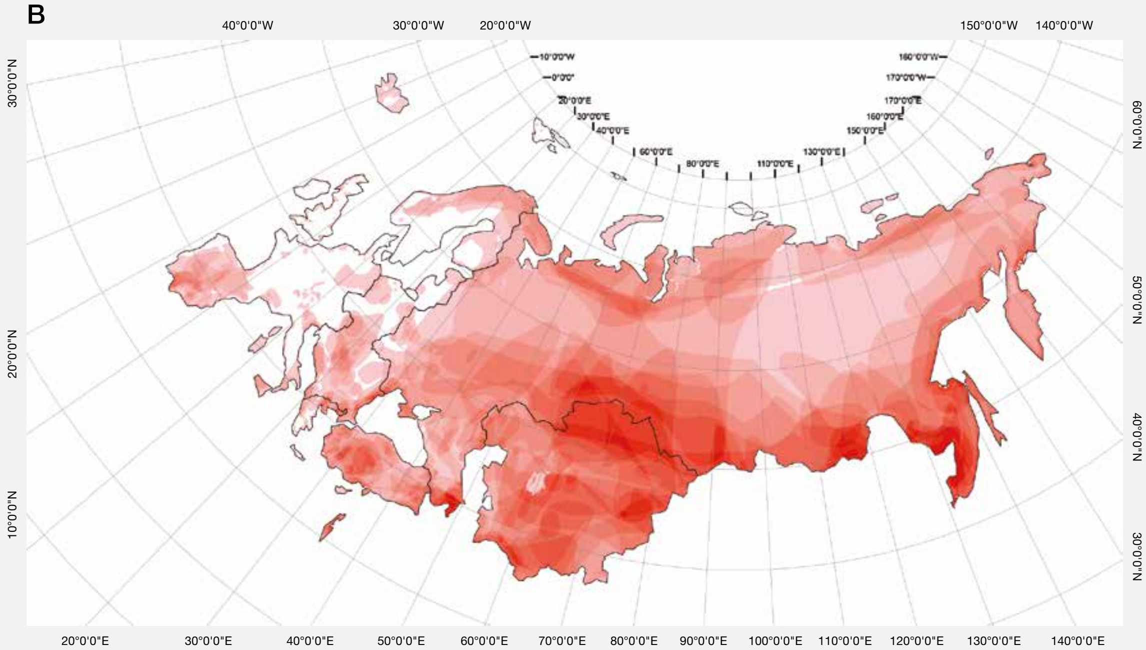
Climate-driven community changes and range expansions or contractions have been reported in many studies (Estrada *et al.*, 2016), and both scientific studies and reports from indigenous herders suggest that local bird declines have been caused by climate change (Roué & Molnár, 2017; Vilkov, 2013). However, evidence of direct impacts of climate change on population decline remains weak.

Other important drivers include direct mortality caused by power lines and wind turbines, although the consequences of population decline are only documented for a few, rare species (BirdLife International, 2015).

In many cases, it is the combination of drivers that put bird species at risk. Seabirds, for instance, have declined strongly due to a multiplicity of threats. Conservation

Figure 3 46 **A Bird species richness in Europe and Central Asia (ECA). Note low resolution of data for eastern parts of the region due to lack of sources.**
B Number of threatened species of birds in Europe and Central Asia. Source: Adapted from Jenkins *et al.* (2013); BirdLife International (2016). 10km resolution, Lambert Conformal Conic projection.





NUMBER OF THREATENED BIRD SPECIES IN THE ECA REGION

Number of bird species per 10 km²

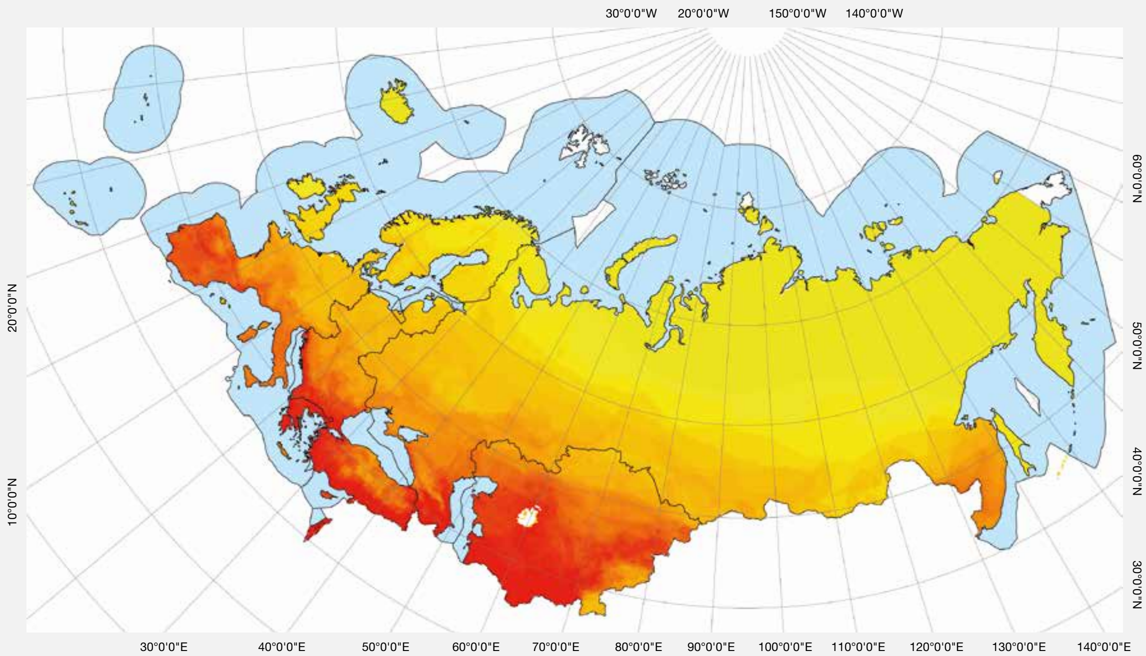
HIGH: 12 LOW: 1

0 500 1,000 2,000 3,000 km

Projection: Asia North Albers Equal Area Conic

Source: BiodiversityMapping.org, based on data from IUCN. Jenkins, CN, SL Pimm, LN Joppa (2013) Global Patterns of Terrestrial Vertebrate Diversity and Conservation. PNAS 110(28): E2602-E2610. doi: 10.1073/pnas.1302251110 (PDF)

Figure 3 47 **Species richness of reptiles across Europe and Central Asia. Source: IUCN (2017c).**



0 500 1,000 2,000 3,000 km

REPTILE SPECIES RICHNESS

High: 62 Low: 0

Projection: Asia North Lambert Conformal Conic

Source: Data from IUCN 2017, published in Roll, Uri, et al. Nature ecology & evolution (2017).

efforts reducing multiple pressures (e.g. the European Union Habitats Directive, national legislations) have been shown to have positive effects on bird populations (Gamero, 2016).

3.4.3 Mammals

Status and trends

There are 538 species of mammals in the IUCN database that are extant in the region. Of these, 66 are threatened with extinction (categories vulnerable, endangered and critically endangered). Their number could be up to 124 (23% of the total) if all data deficient species where found to be vulnerable or worse (IUCN, 2016). Globally, the net annual change in IUCN extinction risk categories for mammals from 1996 to 2008 has been -13, meaning that, on average, 13 species moved one category closer to extinction (Brooks *et al.*, 2016). The Europe and Central Asia contribution to the global trend is -0.47, which is equivalent to having one species endemic to the region moving one category closer to extinction every two years (Brooks *et al.*, 2016).

A notable decline in Europe and Central Asia in recent decades is that of the *Saiga tatarica*, an antelope inhabiting the steppes and semi-desert regions in Russia, Kazakhstan, Uzbekistan and Western Mongolia, which deteriorated from vulnerable in 1996 to critically endangered in 2008. This followed a greater than 95% decline in population size from approximately one million in the early 1990s to an estimated 50,000 by 2008, primarily owing to poaching. An epidemic of pasteurellosis in 2015 caused a further population collapse by 50% in two weeks, with an estimated mortality of >70% (Milner-Gulland & Singh, 2016).

However, species that have received conservation attention are generally improving their conservation status. There are 87 mammal species in the Annex II, IV and V of the European Union Habitats Directive. European Union member States are required to take steps towards their conservation and report on the conservation status of these species every six years. Species in these annexes generally improved their conservation status between 2006 and 2012 relative to the previous six years **(Table 3.7)**. Mammal species had more populations with stable or genuinely improved conservation status than otherwise in all biogeographic areas in the European Union except Boreal, and Marine Mediterranean (EEA, 2015a).

Remarkable recoveries due to conservation efforts include the one of the European bison, *Bison bonasus*, which was extinct in the wild after World War I and reduced to a captive population of 54 animals. Conservation efforts started in 1929 with a captive breeding programme followed by reintroductions in Białowieża National Park in Poland; Russia and several other locations in Europe. Today there are more than 2,700 wild bison, in several populations, mostly stable or increasing in numbers. Other remarkable recoveries are that of the European beaver (*Castor fiber*), the European hamster (*Cricetus cricetus*) (EEA, 2015a) and large terrestrial carnivores (Chapron *et al.*, 2014). Among the latter group, are once critically endangered large felids

Table 3 7 **Number of mammal species in each biogeographic area of European Union countries whose conservation status was stable, or genuinely improved or worsened between the 2001-2006 assessment period and the 2007-2012 period. Total indicates the total number of species or biogeographic region assessments of mammals in the European Union and include also assessments with non-genuine changes (e.g. because of taxonomic revisions or improved knowledge), or unknown or unreported trends. The biogeographic areas are Alpine (ALP); Atlantic (ATL); Boreal (BOR); Continental (CON); Macaronesian (MAC); Mediterranean (MED); Pannonian (PAN); Marine Atlantic (MATL); Marine Baltic (MBAL); Marine Mediterranean (MMED). No genuine changes were recorded for the Macaronesian and Marine Macaronesian regions and are not reported here. Species of the Black Sea and Steppic region were only assessed in 2012 and are excluded here. Species with non-genuine changes in assessment, are not reported here.**

	ALP	ATL	BOR	CON	MAC	MED	PAN	MATL	MBAL	MMED
Stable	9	11	3	27	3	11	13	3	2	1
Improved	8	17	1	15	3	5	1	2	3	0
Worsened	14	15	5	22	1	5	13	1	1	1
Total	364	213	111	416	14	222	119	156	22	75

such as the Iberian lynx (*Lynx pardinus*) whose population tripled from 2002 (52 mature individuals) to 2012 (156), the Amur tiger (*Panthera tigris altaica*), from 20-30 animals in the 1930s to 500 and stable in 2016, and the Amur leopard (*Panthera pardus orientalis*), whose population has doubled since 2000. Among marine mammals, the Baltic seal (*Pusa hispida ssp. botnica*) rebounded from 3,000 individuals in the 1970s affected by hunting pressure and impaired fertility due to organochlorine pollution, to over 25,000 today thanks to hunting regulations afforded by the European Union and national legislations, habitat protection and improved water quality (Härkönen, 2015).

Drivers of change

National and international legislation affording legal protection and law enforcement are the main drivers of large carnivore recoveries in Western and Central Europe (Chapron *et al.*, 2014). Habitat protection and law-enforcement by government and non-government agencies are the main drivers in Eastern Europe (Government of the Russian Federation, 2015).

The main threats to terrestrial mammal species in the region are land-use change (including changes to intense cropland and pastures, logging, and extractive activities), affecting 186 species; followed by hunting and trapping, affecting 123 species; and invasive species, affecting 73 species; it should be noted that these threats are not mutually exclusive (Joppa *et al.*, 2016). Nearly all marine mammals are impacted by persistent organic pollutants, especially polychrorinated byphenils (PCBs), despite being banned by the Stockholm Convention in 2004, their concentrations in sediments and in the marine food-chains have remained high, due to low compliance to the Convention requirements of safe storage and elimination of PCB stockpile and limited decontamination of sediments, landfills, building and equipment (Stuart-Smith & Jepson, 2017). As a result, high PCB concentrations in European cetaceans from 1990 to 2012 were associated with long-term population declines and low or zero rates of reproduction, consistent with severe PCB-induced population-level effect (Jepson *et al.*, 2016). Climate change is an emergent threat for mammals that is potentially overlooked in the region (Pacifici *et al.*, 2015 **Table 3.11**).

3.4.4 Reptiles

Status and trends

Reptile species richness across the region follows a latitudinal gradient. It is highest in southern Turkey and along the eastern Mediterranean coast to Israel, with further hotspots in parts of the Iberian peninsula and southern France, the Balkans, southern Transcaucasia, the southern deserts of Central Asia and southern and far east Russia (**Figure 3.47**, Sillero *et al*., 2014; Roll *et al*., 2017). At the subregional level, species richness is highest across Western Europe, with 213 species recorded and 212 assessed **(Table 3.8)**. This is due to the subregion combining separate faunas: the Macaronesian fauna of Portugal and Spain, the western Mediterranean fauna and the fauna of the eastern Mediterranean of Israel.

Species richness of small-range endemics is highest in the Caucasus, southern Balkan Peninsula, central and southern Iberian Peninsula, southern Turkey, and southern Central Asia. There are also a number of important refugia, i.e. places supporting a relict population of a previously more widespread species. These are both mesophyllic (Caucasian Black Sea coast of Russia, Georgia, Turkey & Southeast Azerbaijan & southern Far East Russia; Tuniyev, 1990, 1997) and xerophyllic (Spain, Portugal, Italy, Greece, Turkey, Armenia, Azerbaijan, Georgia, Russia and Central Asia; Tuniyev, 1995).

Areas of high diversity at the level of genera and families are: the Balkan Peninsula for turtles; south Turkey and Kopet Dag for skinks; Central Asia for agamas; south Mediterranean and southern Central Asia for geckos; the Caucasus, southern Balkan Peninsula and Iberian Peninsula, Mediterranean and Aegean Sea islands for lacertids; southern Central Asia for boas; and the Caucasus and north-east Turkey for vipers.

In this assessment we compiled a dataset of all 408 extant species of reptiles occurring in Europe and Central Asia from the Reptile Database (Uetz, 2017) and IUCN Red List of Threatened Species (IUCN, 2017c). Of these, 289 have published assessments of extinction risk on the IUCN Red List. Sixty-three species are assessed as threatened with extinction (categories vulnerable, endangered and critically endangered; **Table 3.8**). Thus between 21.7% (assuming that no data deficient species are threatened with extinction) and 26.6% (assuming that all data deficient species are threatened with extinction) of species within the region are threatened with extinction. Best estimates of extinction threat generally assume that data deficient species fall into non-data deficient categories in the same proportions as non-data deficient species (IUCN, 2017a), indicating here that about 22.8% of reptile species in Europe and Central Asia are threatened with extinction. This level of threat is similar to the one of reptiles globally (18.8% - Böhm *et al.*, 2013) and across Europe (Western, Central and Eastern Europe, including the Russian Federation up to the Urals and excluding the Caucasus) (19.7% - Cox & Temple, 2009; χ^2=2.31, df=2, p=0.315). However, recent studies suggest that globally data deficient reptiles are neither widespread nor common, suggesting there may be an underestimation of extinction risk (Meiri *et al.*, 2018).

Extinction threat is lowest for snakes and highest for turtles and tortoises **(Table 3.8)** which is comparable to global patterns (Böhm *et al.*, 2013). Extinction risk across all assessed species is highest in Western Europe. More than one third of reptiles endemic to Europe and Central Asia subregions are at risk of extinction and this threat is highest across Central Asia **(Table 3.8)**. Not all species have been assessed yet for the IUCN Red List, however, there are a number of ongoing assessments.

One Canary Island endemic, *Gallotia auaritae,* is listed as possibly extinct or likely extinct (Martin, 2009; Mateo Miras & Martínez-Solano, 2009). There is evidence for at least two extinctions from Europe and Central Asia: the Persian toad agame *Phrynocephalus persicus* is thought to have gone extinct from Azerbaijan and now solely exists outside Europe and Central Asia in Iran (Anderson *et al.*, 2009). In Israel, the Nile crocodile (*Crocodylus niloticus*) was lost in the early 20th century, probably due to hunting (Dolev Pervolutzki, 2004; Masterman, 1921). Of the more speciose genera, those with most threatened species include the narrow-endemic vipers (genus *Vipera sensu lato*, 22 species, 45% threatened, six not evaluated), toad-headed agamas of Eastern Europe and Central Asia (genus *Phrynocephalus*, 13 species, 31% threatened, three not evaluated); species of mostly Mediterranean wall lizards, often very common, but with small ranges (genus *Podarcis*, 23 species, 30% threatened, three not evaluated); and the Caucasian – Asia Minor rock lizards (genus *Darevskia*, 26 species, 23% threatened, three not evaluated).

Compared with data on extinction risk, data on reptile population trends are sparse. Deriving trends from IUCN Red List data is difficult since not all species have yet been assessed and many have only ever been assessed once. Only one species has a documented change in global extinction risk, the globally distributed leatherback sea turtle, *Dermochelys coriaceae*, critically endangered in 2004

Table 3 8 **Global IUCN Red List status of reptiles occurring within the Europe and Central Asia assessment region, for species with a published assessment (Total = 289). N is the number of species recorded in the assessment region. IUCN categories: DD: data deficient; LC: least concern; NT: near threatened; VU: vulnerable; EN: endangered; CR: critically endangered. Source: IUCN (2017c).**

Group	DD	LC	NT	VU	EN	CR	Total	N	% threatened	% lower bound	% upper bound
Reptiles	14	186	26	21	25	17[1]	289	*408*	22.9	21.8	26.6
Lizards	6	120	17	13	16	12[1]	184	*246*	23.0	22.3	25.5
Snakes	7	63	7	4	7	4	92	*141*	17.7	16.3	24.0
Amphisbaenians	0	2	0	0	0	0	2	*5*	-	-	-
Turtles/tortoises	1	1	2	4	2	1	11	*16*	70.0	63.6	72.7
By region											
Western Europe	3	105	18	11	14	9[1]	160	*212*	21.7	21.3	23.1
Central Europe	4	88	11	6	9	5	123	*156*	16.8	16.3	19.5
Eastern Europe	2	55	9	6	4	2	78	*119*	15.8	15.4	18.0
Central Asia	5	51	1	4	2	3	66	*109*	14.5	13.4	20.9
Endemics											
Endemic ECA	7	52	17	11	17	14[1]	118	*145*	37.8	35.6	41.5
Western Europe[2]	2	25	11	4	8	6[1]	56	*71*	33.3	32.1	35.7
Central Europe[2,3]	3	16	5	2	6	4	36	*45*	36.4	33.3	41.7
Eastern Europe[3,4]	0	11	5	3	4	2	25	*28*	36.0	36.0	36.0
Central Asia[4]	3	9	0	3	1	3	18	*21*	46.7	38.9	55.6

1. *Gallotia auaritae*, endemic to the Canary Islands, is listed as critically endangered (possibly extinct)
2. Four species endemic to Western Europe and Central Europe
3. Eleven species endemic to Central and Eastern Europe
4. Two endemic species shared between Eastern Europe and Central Asia

and vulnerable in 2013. Of the 289 species with published IUCN Red List assessments, 98 species show declining populations and only five show an increasing trend across their global range: three least concern species (*Cyrtopodion scabrum, Hemidactylus turcicus, Podarcis siculus*) and two critically endangered species of the Canary Island endemic *Gallotia* (*Gallotia bravoana*, *G. intermedia*), which have been subject to conservation action (control of predators). Populations for 119 species are considered stable, and the status of the remaining 61 is unknown.

The Living Planet database currently contains 66 population time series representing 23 species of reptiles for Europe and Central Asia (LPI, 2016). These are exclusively from Western and Central Europe (49 and 17 time series, representing 22 and three species, respectively). Most Central European population time series focus on marine turtles in Turkey and Cyprus. In Western Europe, data are also available for snakes and lizards. The loggerhead turtle (*Caretta caretta*) is increasing across available time series, while the few time series available for *Testudo hermanni* (not threatened on the IUCN Red List), three species of vipers (*Vipera aspis*, least concern; *V. berus*, not evaluated; *V. ursinii*, vulnerable) and *Hierophis viridiflavus* indicate declining population trajectories. Increases in sea turtle populations have been noted in other parts of the eastern Mediterranean too, for example in Israel (Casale & Margaritoulis, 2010).

Other data sources suggest declines for *Testudo kleinmanni* in Israel, the only country in Europe and Central Asia where this species is thought to occur (Dolev Pervolutzki, 2004). There is also direct evidence from the literature that some snake populations are in decline in specific Western European localities (e.g., UK: *Coronella austriaca*; Italy: *Vipera aspis, Vipera ursinii;* France: *Vipera aspis, Hierophis viridiflavus, Zamenis longissimus*; Reading *et al.*, 2010).

Annexes II, IV and V of the European Union Habitats Directive list 91 reptile species and 7 subspecies. Most species were only assessed once for the European Union Habitats Directive or did not have enough information for a conclusive definition of their status. In many cases it is therefore not possible to determine a trend **(Table 3.9)**. Only few genuine changes in conservation status were recorded between the two reporting periods. However, only one species and one subspecies were recorded to have a worsening status between the two assessment periods of 2001-2006 and 2007-2012: *Podarcis lilfordi* in the Mediterranean, though in places this species is still very common; and *Lacerta vivipara pannonica*. In terms of spatial planning, however, a recent study suggests that the Natura 2000 network mostly covers widespread reptile species, while narrow-range endemics are under-represented in Natura 2000 and national protected area networks (Abellán & Sánchez-Fernández, 2015).

Drivers of change

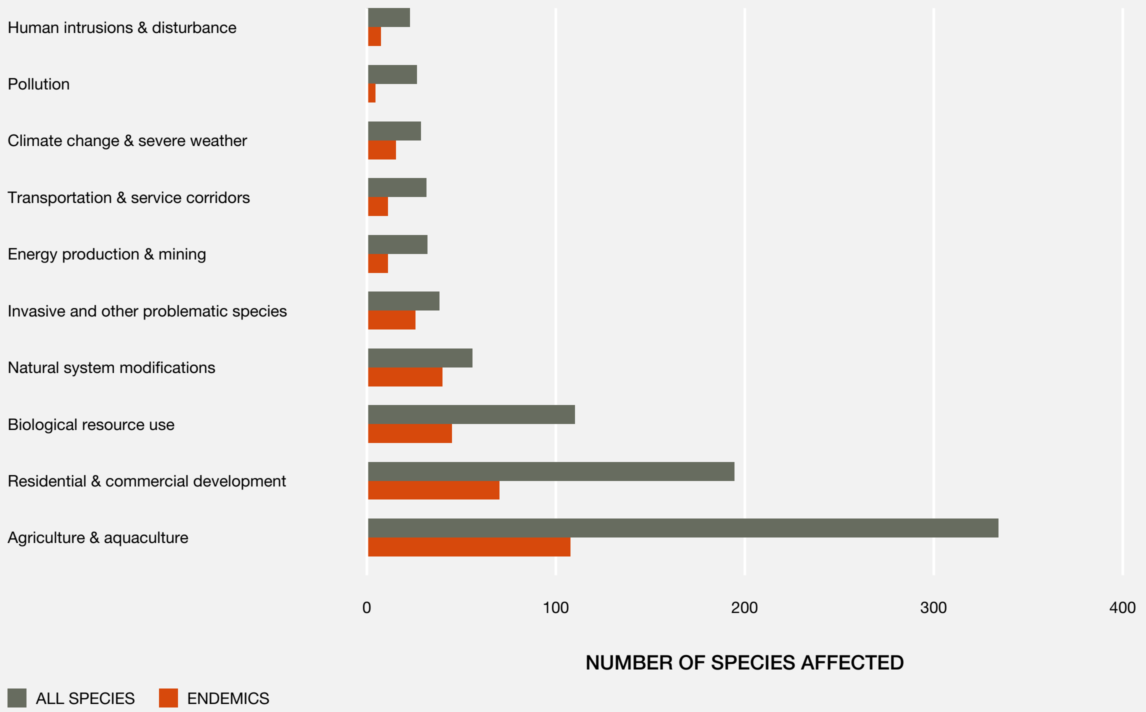
The main threats to reptiles in Europe and Central Asia, according to the IUCN Red List, are agriculture, residential/commercial development, and biological resource use **(Figure 3.48)**. These threats primarily cause habitat fragmentation and loss.

The major threat of habitat loss affects in particular relic forest species, and species of the steppe and semi-desert ecosystems, which are often not able to persist on agricultural and other transformed lands. *Eremias pleskei* (Armenia, Azerbaijan, Turkey and Iran) is listed as critically endangered, based on a population decline of more than 80% over ten years. Its natural sandy habitat has virtually disappeared due to human disturbance (Tuniyev *et al.*, 2009). For habitat specialists, such as the critically endangered *Phrynocephalus horvathi* and *Acanthodactylus*

Table 3 9 **Number of reptile species in each biogeographic area of European Union countries whose conservation status was stable, or genuinely improved or worsened between the 2001-2006 assessment period and the 2007-2012 period. The biogeographic areas are Alpine (ALP); Atlantic (ATL); Boreal (BOR); Continental (CON); Mediterranean (MED); Pannonian (PAN); Marine Atlantic (MATL); Marine Mediterranean (MMED). Species of the Black Sea and Steppic area were only assessed in 2012 and are excluded here. Non-genuine changes were mainly due to taxonomic revisions or improved knowledge.**

	ALP	ATL	BOR	CON	MED	PAN	MATL	MMED
Stable	2	4	1	10	4	5	0	2
Improved	2	2	0	0	0	1	0	1
Worsened	5	2	3	0	1	2	0	1
Non-genuine changes /Unknown/ Not Assessed	86	34	10	112	128	34	22	22

Figure 3 48 **Main threats affecting reptiles in Europe and Central Asia according to species assessments published in the IUCN Red List (all species, grey; endemic species, orange). Source: IUCN (2017c).**



beershebensis which are found on highly specific soils, habitat conversion can have a major impact (Ananjeva & Agasyan, 2009; Werner *et al.*, 2006). The disappearance of steppe vipers of the "ursinii-renardi" complex throughout most of the previously occupied habitats in Europe and Central Asia is associated with ploughing of steppes for agriculture (Tuniyev, 2016). Dam building has been detrimental to species such as *Rafetus euphraticus* in Turkey, causing drastic habitat alteration (Taskavak *et al.*, 2016).

Significant threats include the illegal capture of commercially valuable species for the pet trade (all representatives of the vipers and turtles, and some species of lizards) in Turkey, the Caucasus and Central Asia. *Trionyx triunguis* softshell turtles have been reported as bycatch and have been killed, and nests destroyed, by fishermen who may perceive them as competitors; they are also affected by pollution, resulting in a listing of the Mediterranean subpopulation in Israel, Lebanon, Syria and Turkey as critically endangered (European Reptile & Amphibian Specialist Group, 1996). There are also reports of reptile poaching in Israel, which affects species such as *Uromastyx aegypticus* (Yom-Tov, 2003). Prosecution of snakes continues in the area, especially in Turkey, the Caucasus and southern regions of Russia, and is associated with low levels of environmental education.

Invasive predator species play a particularly important role for island species, such as the Canary Island genus *Gallotia* (four of the eight species are critically endangered). Climate change is likely to play a major role in the region in the future. Climate change has led to an increase in summer temperatures and length of the dry summer period in the western Caucasus, resulting in a reduction of habitats of mesophylic Colchis reptile species (*Darevskia derjugini*) and an increase in the number of eastern Mediterranean snakes (*Hierophis caspius, Platiceps najadum*) on the Black Sea Coast (Tuniyev, 2012).

Other threats, such as pollution, are less prominent in the IUCN Red List data; however, a recent risk evaluation of pesticide use to protected European reptiles suggests that ten species, including all six Habitats Directive Annex II turtles, are at above-average pesticide risk (Wagner *et al.*, 2015).

3.4.5 Amphibians

Status and trends

Europe and Central Asia is highly diverse with, for example, thirty-five percent of the world's newt and salamander species (26 species of the family Salamandridae) present in Europe, extending from Iceland in the west to the Urals in the east and from Franz Josef Land in the north to the Mediterranean in the south.

A total of 74 amphibian species are known in Western, Central and Eastern Europe, with the highest numbers occurring in France, Italy, Spain and the Balcans (20-30 species each) (Corbett, 1989). Fifty-nine percent of amphibian species (Temple & Cox, 2009) have declining populations. In the western Palearctic (i.e. European region and part of Asia with Turkey and the Caucasian region), species richness decreases with increasing latitude for amphibians and reptiles (Meliadou & Troumbis, 1997).

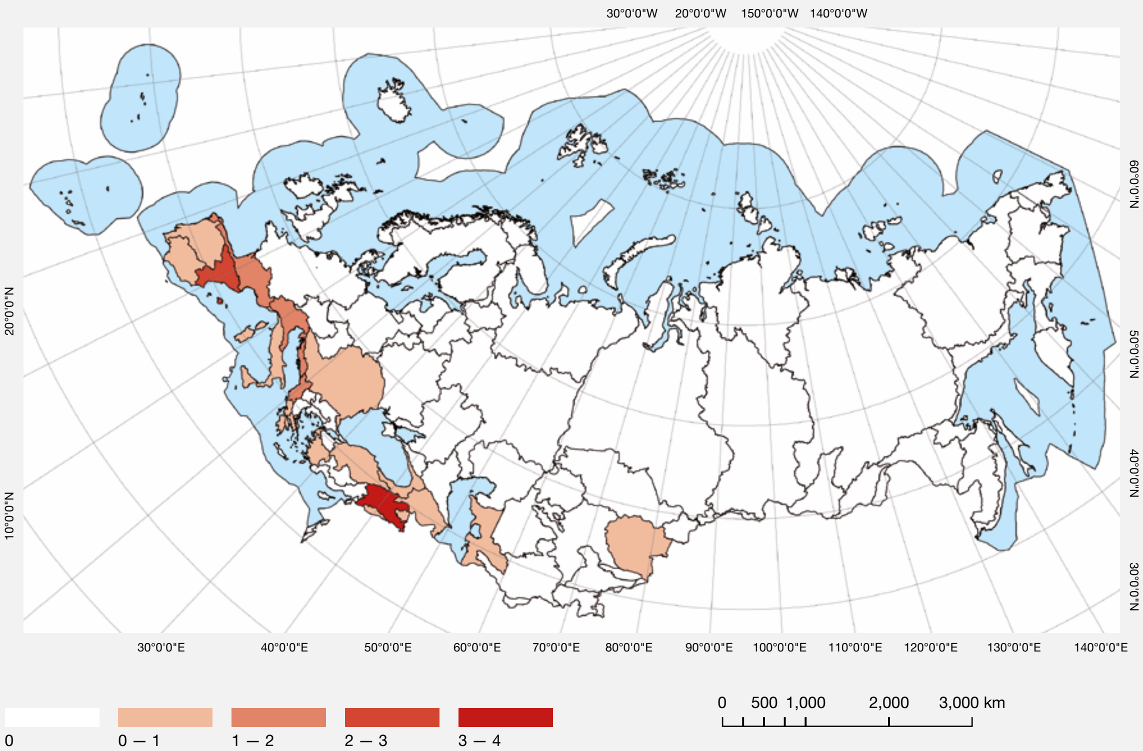
Amphibians represent the third most endangered group of vertebrates in the European Union, with 23% of species (19 species out of the 83 assessed) considered as threatened (Temple & Cox, 2009) **(Figure 3.49)**. According to the Habitats Directive, more than two-thirds of the amphibian species assessed by European Union countries by biogeographical region (104) have an unfavourable conservation status. About 59% of European amphibian populations are declining with a further 36% stable and only 2% on the increase. These declines seem to have worsened over the past 25 years and amphibians are now more threatened than either mammals or birds (Beebee & Griffiths, 2005).

The recent Red list of European amphibians (Temple & Cox, 2009) has highlighted that about 23% of European amphibians (85 species in total) are threatened and show declining populations. This is even more significant given that 74% of European amphibians are endemic (only found in Europe) and that these endemic species tend to be more threatened within Europe.

Drivers of change

The three main causes for amphibians decline in the region are: 1) that fewer habitats available for these species, and what remains is often in small and isolated patches; much of the habitat has become less suitable through destruction or transformation, e.g. urbanization with roads, drainage and water pollution (Hamer & Mcdonnell, 2008) and with the

Figure 3 49 **Number of globally threatened amphibian species by freshwater ecoregion. Source: Abell *et al.* (2008); WWF & TNC (2017).**



Projection: Asia North Lambert Conformal Conic
Source: Robin Abell, Michele L. Thieme, Carmen Revenga, Mark Bryer, Maurice Kottelat, Nina Bogutskaya, Brian Coad, Nick Mandrak, Salvador Contreras Balderas, William Bussing, Melanie L. J. Stiassny, Paul Skelton, Gerald R. Allen, Peter Unmack, Alexander Naseka, Rebecca Ng, Nikolai Sindorf, James Robertson, Eric Armijo, Jonathan V. Higgins, Thomas J. Heibel, Eric Wikramanayake, David Olson, Hugo L. López, Roberto E. Reis, John G. Lundberg, Mark H. Sabaj Pérez, and Paulo Petry. 2008. Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation. BioScience. Vol. 58 No. 5: 403-414.

loss of areas managed by traditional means (Hartel *et al.*, 2010), more intense fish farming and recreational activities; 2) Climate changes, which threaten species particularly in areas where water and humid habitats are already scarce and expected to become even drier (Araújo *et al.*, 2006); 3) Introduction of alien species, including the chytrid fungus, which is a particularly virulent disease affecting the skin and nervous system of adult amphibians and the mouthparts of their larvae, and responsible for amphibian declines worldwide (fatal for many species) (Duffus & Cunningham, 2010; European Commission, 2009). These three factors may also interact to exacerbate each other. In addition, there is rising concern that the impact of pesticides on amphibians has been underestimated and that pesticides could locally be a cause of amphibian population declines (Brühl, *et al.* 2013). While amphibians are generally declining, in the absence of the above mentioned drivers they can be well represented in traditionally managed landscapes by stable populations and species rich communities (Hartel *et al.*, 2010).

3.4.6 Fishes

3.4.6.1 Marine fishes

Status and trends

There are considerably more species of fish in all marine areas surrounding Europe and Central Asia than those known to consumers from markets. For example, reported species richness is around 100 in the Caspian Sea (Mitrofanov & Mamilov, 2015), 833 in the Far Eastern seas of Russia (Volvenko, 2014), 650 in the Mediterranean Sea (United Nations, 2016), 200 in the Black Sea (Bologa & Sava, 2012), and 100 in the Baltic Sea (HELCOM, 2009). Species richness tends to be comparatively higher in coastal areas, along the continental slope, and towards the south **(Figure 3.50)**. Due to the high mobility of fish and the open nature of marine waters, there are intense, complex, competitive interactions within fish communities, which naturally leads to large differences in the population biomasses of different species (Fung *et al.*, 2013).

In Europe and Central Asia, 26% of marine fish species have known trend data. Of those, 72% are stable, 26% have declining populations and 2% have been increasing over the last decade (IUCN, 2017c). In a comprehensive assessment of threats to European marine fish species, Nieto *et al.* (2015) found that 59 species (7.5%) were threatened. All 15 critically endangered species amongst these are Chondrichthyes (sharks, rays, and similar). The low resilience of these organisms is due to their life-history traits (slow reproduction and small number of offspring). Indeed, poor conservation status is most common for Chondrichthyes and other species with large body size, which also infers slow reproductive rates (Fernandes *et al.*, 2017b). Among the largest species, many migrate over large distances. Of species with assessed stock, including those considered overfished, Fernandes *et al.* (2017) found only a small proportion to be threatened. Considering trends in the sizes of species populations, 8.4% were found to be declining, mainly due to overfishing, but also coastal development, energy production and mining, and pollution. Increasing trends were found for 1.7% of populations. For about 69% of marine fish species data for European Union waters is insufficient to estimate trends (Nieto *et al.*, 2015).

Good data on trends is available for the North East Atlantic shelf seas, which permits application of trend analyses that take into account that fish populations can naturally fluctuate over wide ranges (Greenstreet *et al.*, 2012). These reveal recovery of a statistically significant number of fish species classed as sensitive (based on their recruitment pattern) in the Celtic Sea, but not yet in the North Sea (OSPAR, 2017b). Yet, in both of these highly fished areas the number of recovering species has increased over time (OSPAR, 2017b) as a result of changes in fisheries management.

Considering the strong relationship between conservation status and body size (Fernandes *et al.*, 2017) and the slow recovery dynamic of overall fish community size structure (Fung *et al.*, 2013), the state of marine fish communities can be assessed based on the "typical length" (Lynam & Rossberg, 2017) of fish caught in surveys. Using this measure, OSPAR (2017b) showed that demersal fish communities continue to deteriorate in some parts of North East Atlantic shelf, e.g. in the southern parts of the North Sea and along the continental slope **(Figure 3.51)**, while in other areas recovery can be observed. This illustrates the surprisingly localized impact of varying exploitation patterns on the status of marine fish communities. For pelagic fish communities, trends in either direction tend to be less apparent (OSPAR, 2017b). For the Baltic Sea, good status of piscivores and of cyprinids/mesopredators (in terms of total biomass) is reported by (HELCOM, 2017a).

For status and trends of fish biodiversity in the Mediterranean Sea, indigenous and local knowledge offers important information that is unavailable from scientific surveys. Combined survey data and interviews with local fishermen in the Spanish Mediterranean Sea and Gulf of Cadiz, Coll *et al.* (2014) documented overall declines in abundances and maximum sizes of fish. Potential extirpations, notably of Chondrichthyes, were reported as well. Small fish were reported to have proliferated, potentially due to a trophic cascade effect. A meta-analysis by Vasilakopoulos *et al.* (2014) of 42 stocks of nine species in 1990–2010 covering the entire European Mediterranean and Black Seas comes to similar conclusions: exploitation rates have been increasing, and stocks are shrinking and are being harvested too early in their lifecycle. In the Black

Figure 3 50 **Species richness of European marine fishes. Source: Nieto *et al.* (2015).**

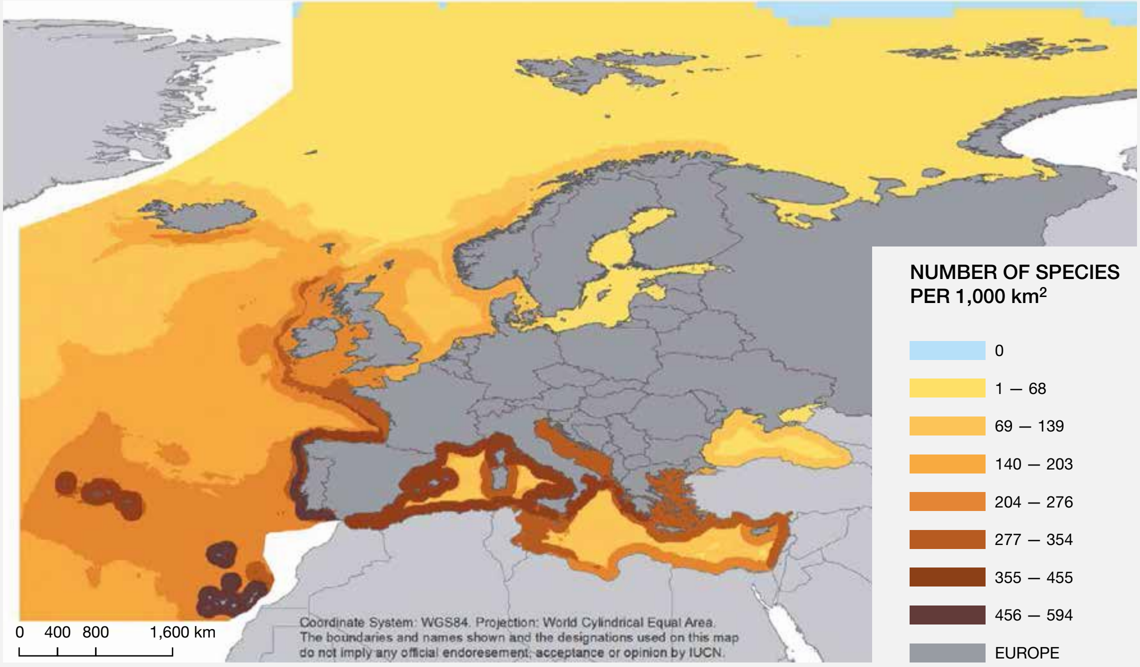
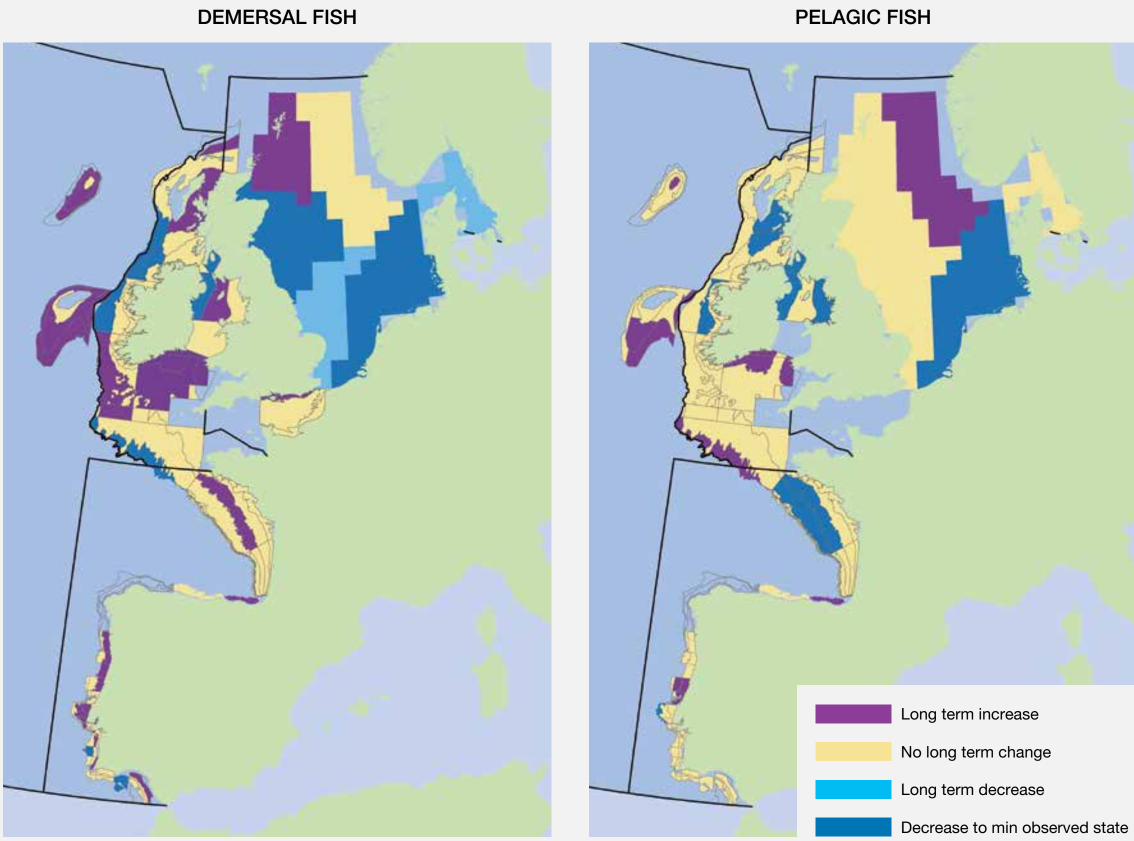


Figure 3 51 **Spatial pattern of trends in the "typical length" of fish caught in surveys. Source: OSPAR (2017).**



Sea, two sturgeon species were recently declared extinct (Yankova *et al.*, 2014).

For the North-West Pacific a digital database covering the years 1977-2010 is available (Volvenko, 2014), but coverage has been argued not to be sufficient even to reveal specific trends. In data from pelagic trawl surveys, Ivanov and Sukhanov (2015) document a pronounced decline of pelagic fish biomass and diversity in the Russian Waters of Far Eastern Seas from the 1980s to the mid 1990s, and a pronounced recovery in the subsequent period until 2009, without providing a clear attribution.

Drivers of change

Overfishing is still the main threat to marine fish across Europe and Central Asia. Throughout the region, the expansion of industrial fishing after the Second World War and the resulting over-exploitation of fish led to pressures on biodiversity at community level, except in the Arctic Ocean where only specific stocks appear to be affected (CAFF, 2013). However, during the last few decades changes in management practices have led to improvement in the status of stocks and release of pressures on fish-communities as a whole, especially throughout the North East Atlantic Shelf Seas. In other parts of Europe and Central Asia, institutional barriers to coordinated action and the relatively high costs involved in regular stock assessments have so far prevented demonstrable recovery of fish communities.

Other drivers are also responsible for the negative trend identified, especially different forms of pollution in enclosed seas (Black, Mediterranean, Baltic, Caspian and Aral Seas); coastal developments degrading and sometimes extirpating coastal habitats important as nurseries; energy production; and mining. These are sometimes exacerbated by climate change. In the Black Sea, for example, ecosystem disruptions by eutrophication and invasive species continue to impact fish communities (Bologa & Sava, 2012). In rivers feeding the Caspian and Aral Seas construction of dams has led to drastic reductions in the abundance and extinction of some migratory fish (Mitrofanov & Mamilov, 2015).

3.4.6.2 Freshwater fishes

Status and trends

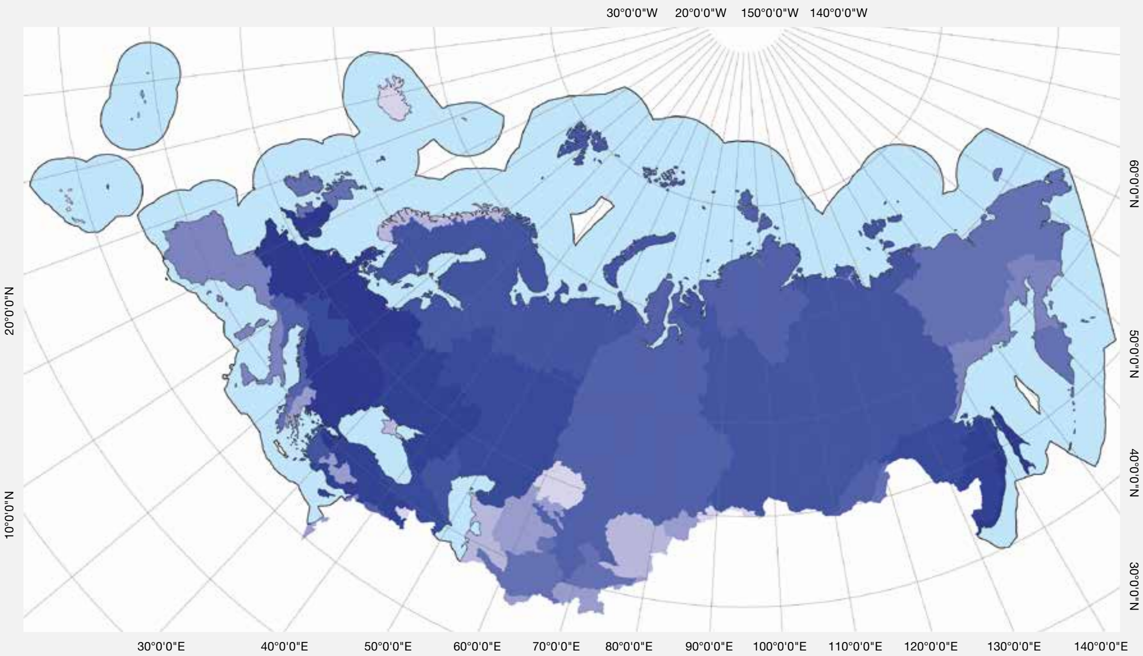
The European Union contains 546 native species of freshwater fish of which, according to IUCN assessments, at least 37% are threatened and 4% are considered near threatened (Freyhof & Brooks, 2011). This is currently the second most threatened taxonomic group assessed, after freshwater molluscs. The highest diversity of fish species can be found in the Danube River with 103 species, followed by the Volga River with 88 species **(Figure 3.52)**. Southern Europe is the region with the highest number of local endemic species, with natural ranges limited to one or few streams, springs or rivers, and several of them have only recently been discovered. They are therefore still not well known to conservationists and national or regional governments (Freyhof & Brooks, 2011). Central Asia is home to approximately 120 fish species of which 30 are on the Red List (Karimov *et al.*, 2009; Milner-Gulland *et al.*, 2006). Several fish species naturally entered the floodplains from the north (Siberia) and west (Western Asia). Many Eurasian fish species have formed sub-species in Central Asia (e.g. Amudarya trout, Aral roach, Aral asp, Samarkand khramulya, Aral bream) and contribute to high endemic diversity (e.g. Aral Sea basin) (Berg, 1949; Nikolsky, 1971; Turdakov, 1963).

There are no other groups of freshwater fishes in Europe and Central Asia that show higher threat levels than anadromous species (e.g. sturgeons, herrings of the genus *Alosa*, salmonids and some whitefishes of the genus *Coregonus* and *Stenodus*) (Freyhof & Brooks, 2011). Trends also highlight a crisis with, for example, a sixfold decline in Baltic salmon catches between 1990 and 2009 (Mannerla *et al.*, 2011).

Although these figures are at a European level and such detailed data are difficult to access for Central Asia, it is expected that these trends and the observed decline of about 17% of European freshwater fishes populations are also true in Central Asia. In Europe, only 1% of freshwater fish species populations are on the increase, against 17% declining and 6% considered stable (Freyhof & Brooks, 2011). However, there is a lack of reliable data on trends, and therefore the actual percentage of species that is declining is probably largely underestimated. In fact, population trends for 76% of all fish species in Western Europe, Central Europe and western parts of Eastern Europe still remain unknown because almost no population trend data exist from most countries (Freyhof & Brooks, 2011). Thus, monitoring data for freshwater fish species diversity and abundance is urgently needed in order to accurately measure population trends and improve the accuracy of future Red List assessments. The highest number of threatened freshwater fish species is found in the south of the European subregions **Figure 3.53**).

Villéger and co-authors (2014) have also shown that among current European fish assemblages, functional homogenization (reduction in diversity of functional traits over space and time) exceeds taxonomic homogenization (reduction in species diversity) six-fold. In addition, non-native species originating from other parts of Europe played a stronger role in this homogenization process than non-native species from outside Europe, while extinction did not play a significant role.

Figure 3 52 **Distribution of freshwater fish species richness across Europe and Central Asia. Source: Abell *et al.* (2008); WWF & TNC (2017).**



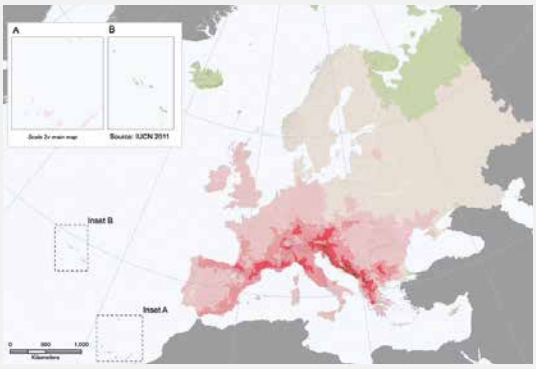
NUMBER OF FISH SPECIES BY FRESHWATER ECOREGION

1 — 9
10 — 19
20 — 27
28 — 33
34 — 39
40 — 46
47 — 56
57 — 68
69 — 83
84 — 114

0 500 1,000 2,000 3,000 km

Projection: Asia North Lambert Conformal Conic
Source: Abell, R., M.L. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya, B. Coad, N. Mandrak, S. Contreras Balderas, W. Bussing, M.L.J. Stiassny, P. Skelton, G. R. Allen, P. Unmack, A. Naseka, R. Ng, N. Sindorf, J. Robertson, E. Armijo, J.V. Higgins, T.J. Heibel, E. Wikramanayake, D. Olson, H.L. López, R.E. Reis, J.G. Lundberg, M.H. Sabaj Pérez, and P. Petry. 2008.
"Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation."
BioScience 58: 403-414. Digital media at: www.feow.org

Figure 3 53 **Distribution of threatened freshwater fish in Europe (as defined by the European Environment Agency, including Russia up to the Urals). Source: Freyhof & Brooks (2011).**



NUMBER OF THREATENED SPECIES PER HYDROSHED BASIN

45 — 78
23 — 43
12 – 22
5 – 11
1 – 4

Drivers of change

A main threat for freshwater fish species in Europe and Central Asia is the destruction or modification of their habitat. This includes a change in the river continuum with the construction of dams and weirs that fragment populations. This has direct consequences for the remixing of upstream-downstream genetic pools and for free seasonal migrations. In addition, it leads to a deep modification of flow patterns transforming lotic habitat into lentic ones and, as a result, changing species assemblages, functional diversity and homogenization of freshwater fish communities. Water abstraction is one of the most important threats to European freshwater fishes, especially in the Mediterranean basin where illegal water abstraction is widespread (Freyhof & Brooks, 2011). Many countries in southern parts of Western and Central Europe still lack effective enforcement of legislation that could limit the damages of excessive water abstraction to biodiversity. The increased frequency and intensity of droughts are worsening the situation.

Another important threat is pollution of industrial, agricultural and domestic origin (e.g. hormone distruptors from polimery and paint industries that cause reproductive disorders, in particularly in aquatic organisms). In lakes, for example, the percentage of land used for agriculture in the catchment (which leads to anthropogenically enhanced productivity) is associated with several changes in fish communities such as increase in species richness and abundance and a decrease in their community average body size (Brucet *et al.*, 2013). At least eight of the 13 globally extinct species of European freshwater fishes were victims of water pollution and lake eutrophication, mainly during the late 19th and in the 20th centuries (Freyhof & Brooks, 2011). However, due to European Union regulation, the water quality of rivers and lakes has improved in recent decades and this has helped to improve conditions for many fish species. In Central Asia and the Caucasus, however, about one third of untreated sewage goes directly into regional rivers. Pollution as a result of change in land use is still relevant in these regions, in particular the increase in siltation due to agricultural practice and destruction of riparian vegetation, which used to act as an important buffer zone to freshwater ecosystems.

Climate change is also affecting fish populations, particularly in the coldest and the most arid parts of Europe and Central Asia. Jeppesen and co-authors (2012) published long-term (10–100 years) series of fish data from 24 European lakes. Along with a temperature increase of about 0.15–0.3°C per decade, considerable changes have occurred in either fish assemblage composition, body size or age structure during recent decades, with a shift towards dominance of warm water species. These changes took place despite a general reduction in nutrient loading. Similar responses to warming were found in river fish (Daufresne *et al.*, 2009). Arctic charr has been particularly affected. In the arid conditions of Central Asia, agriculture relied on the extensive use of irrigation. From the 1950s to the 1980s, about 40 reservoirs (total water volume more than 57 km^3), more than 150,000 irrigation canals, more than 100,000 drainage canals and 10 lakes for residual water storage (with an area of about 7,000 km^2) were created. These large-scale constructions impacted local fish communities. Dams on the rivers blocked passage to spawning areas for migratory fishes. As a result, fringebarbel, sturgeon and Aral barbell vanished from local waters. All fish populations in the floodplain (such as common carp, asp, sabrefish, bream, roach, pike-perch) have established new stocks in all newly constructed man-made reservoirs and lakes. Also, the abundance of riverine fishes such as shovelnoses (three species), pike-asp, zarafshon dace and minnow dramatically decreased due to a change in flow and a reduction of turbidity in the river sections downstream of the reservoirs (Berg, 1949; Kamilov, 1973; Nikolsky, 1938; Turdakov, 1963).

Another key threat in Central Asia is water salinization (Jeppesen *et al.*, 2015). For example, in the three decades from 1961 to 1991 the Aral Sea's salt concentration increased from 10.2 ppt to 35 ppt (Pavlovskaya, 1995). Freshwater fishes cannot adapt to these levels of salinity and many therefore became extinct. The discharge of drainage waters from irrigated fields and industries has also led to salinization and chemical pollution of rivers. Parts of many Central Asian rivers have been contaminated by phenols, oil products, heavy metals, pesticides and nitrogen compounds (Pavlovskaya, 1995).

In recent years there have been many examples of alien pathogen and parasite introductions in Europe and Central Asia and their dramatic effects on aquatic wildlife and biodiversity, with several having a direct impact on fish biodiversity and ecosystem services (Peeler *et al.*, 2011). For example, *Anguillicola crassus*, a parasitic nematode, directly impacted wild populations of the European eel, *Anguilla anguilla*. The most severe of all, identified in the last decade as a major threat to European fish diversity (Gozlan *et al.*, 2005), is the rosette agent, a generalist fungal-like pathogen introduced along with the Asian gudgeon (*Pseudorasbora parva*) and responsible for the rapid decline of endemic fish species across Europe and Central Asia. This pathogen and its host have caused the decline and extinction of native population across Europe - some of them endemic or not yet even described. Most of these introductions across the region occured via the aquaculture trade, fisheries or ornamental purposes (Boll *et al.*, 2016; Gozlan, 2016).

3.4.7 Terrestrial Invertebrates

Status and trends

The diversity of terrestrial invertebrates in Europe and Central Asia is unevenly explored, with a substantial lack of knowledge for most taxa, especially for below-ground (soil) fauna. Above-ground terrestrial invertebrates are generally better known, with described insect species numbering in the order of 100,000 in Europe[9], about 80,000 for Kazakhstan (The Fifth National Report on Progress in

9. The countries included in this checklist are listed here http://insectoid.info/checklist/insecta/europe/

Implementation of the Convention on Biological Diversity 2014), and about 30,000 for the Russian Far East (Lelej & Storozhenko, 2010). Scientific knowledge of certain groups is rapidly increasing. For example, the number of described fly (Diptera) species in the Palearctic was 29,579 according to a catalogue published in 1992 (Soós *et al.*, 1992) and increased to 44,894 in 2009 (Pape *et al.*, 2009), an increase of about 15,000 species new to science or to the region. Heteroptera species numbered 9,365 in 2006, an almost 10% increase compared to 1995 (Aukema *et al.*, 2013). Bumblebee species numbers increased from 23 to 33 in the 170,500 km^2 large Tuva Republic (Russia) based on a survey in 2013 (Kupianskaya *et al.*, 2014). For several speciose taxa, there is no information even on species presence, even though some of these include taxa with extreme importance for ecosystem functions, like Hymenoptera (with many parasitoid species), or most soil organisms, contributing to biological control and pollination, or soil fertility, respectively. Despite their extremely high species richness, and importance for ecosystems services, only a very small proportion of species is assessed by the IUCN Red List **(Table 3.10)**.

Trends are known for certain groups, such as butterflies. Major declines of butterfly populations occurred in the 1950s-1970s due to agricultural intensification in Western Europe but one third of species are still declining (van Swaay *et al.*, 2010). Bees (honeybees and wild bees including bumblebees) have been recently evaluated as pollinators by IPBES (2016b). Many wild bee species have been declining in Western Europe. For example, 50% of bee species are threatened in some European countries, while data for other regions are currently insufficient to draw conclusions (IPBES, 2016b). Better taxonomic coverage extists for terrestrial invertebrates of community interest according to the Habitats Directive and monitored throughout the European Union. One quarter of these species (arthropods, molluscs and others) have deteriorating conservation status (EEA, 2015d). A recent meta-analyses found a 77% decline in flying insect biomass across 63 protected sites in Germany from 1987 to 2016, likely due to agricultural intensification in the surrounding fields, with protected sites therefore acting as ecological traps (Hallmann *et al.*, 2017). This analysis suggests that the extent of insect decline in Europe has been greatly underestimated.

In Europe alone, the update of the database of invasive species[10] (Roques *et al.*, 2009), lists 1,590 terrestrial arthropod species of non-European origin established in Europe, including 1,390 insects, 47 spiders, 102 mites, 34 myriapods and 17 crustaceans (Kenis & Branco, 2010).

10. Delivering Alien Invasive Species Inventories for Europe http://www.europe-aliens.org/

Table 3 10 **Number and trends of red listed species, and the major drivers of change for five groups with diverse ecology. The area covered is Western Europe, Central Europe, and part of Eastern Europe (continent of Europe).**

	Number of species	Increasing (%)	Stable (%)	Decreasing (%)	Unknown (%)	Major drivers
Terrestrial molluscs (Cuttelod *et al.*, 2011)	246	0.6	39.8	6.3	53	Urbanization, agriculture, recreation and other human activities, change in fire regime, roads and shipping lanes
Bees (Nieto *et al.*, 2014)	1,942	0.7	12.6	7.7	79	Agricultural expansion and intensification, livestock farming and ranching, pollution (agricultural and forestry effluents), residential and commercial development (urban sprawl), fire and fire suppression, climate change
Butterflies (Swaay *et al.*, 2010)	482	4	55	31	10	Agricultural intensification, abandonment, climate change (including droughts), change of woodland management, tourism and recreation
Saproxylic beetles (Nieto & Alexander, 2010)	436	2.3	26.8	13.8	57.1	Logging and wood harvesting
Grasshoppers, Crickets, Bush-crickets (Hochkirch *et al.*, 2016)	1,082	2.2	7.6	30.2	59	Livestock grazing, arable farming, increasing wild fire frequency, urbanization and infrastructure, touristic development

Local ecological knowledge on invertebrates is scarce, including their status and trends over the last decades. Some culturally salient invertebrate species have, however, functioned as important keystone species in the lives of certain communities (Marian, 1903; Ulicsni *et al.*, 2016). Indigenous and local knowledge can be a valuable information source in understudied regions for those species that migrate northwards as a consequence of climate change. Some of these species (e.g. mosquitos and ticks) may have (or already have) a strong but yet undocumented impact on local wild and domestic livestock.

Drivers of change

Environmental changes may rapidly disrupt biotic interactions (insect-insect, plant-insect, invertebrate-nutritional source). Species involved in species-specific interactions (e.g. pollination, foraging) are particularly sensitive to environmental changes. The extinction of a butterfly species may be locally explained by the extinction of its host plant. A parallel decline in pollinators and insect-pollinated plants in Western Europe favoured wind-pollinated plants, and contributes to global homogenization (Biesmeijer *et al.*, 2006, Carvalheiro *et al.*, 2013). Beyond independent taxon-based extinctions, the possible cascading effects of species loss are often neglected, which are considered likely to greatly contribute to general homogenization and species loss (Kearns *et al.*, 1998; Koh, 2004).

Honeybees suffer from colony collapse disorder, which also affects the production of colonies (Breeze *et al.*, 2014; Kovács-Hostyánszki *et al.*, 2016). Many of the environmental threats to bee diversity are associated with intensified agriculture (shifting agricultural practice linked to pollution, pesticides and the increasing intensification of farming), as well as change in land use and climate (Nieto *et al.*, 2014; Goulson *et al.*, 2008). Similar trends (sensitivity to agricultural intensification, change in land use and climate) were also observed in other kinds of insects acting as pollinators (IPBES, 2016b). Many wild bees and butterflies have been declining in abundance, occurrence and diversity at local and regional scales, as it has been recorded in Western Europe (IPBES, 2016b).

3.4.8 Freshwater invertebrates

Status and trends

No assessment has been performed on freshwater invertebrates for the whole of Europe and Central Asia except molluscs and dragonflies. In the interest of highlighting the magnitude of threat facing freshwater invertebrates, the next paragraph reports some global statistics. Note that the trends for the world and Europe and Central Asia are not necessarily similar, as exemplified by comparig the global trends with European ones in the next two paragraphs.

The great majority of freshwater animals are invertebrates, mostly insects (60%) and crustaceans (10%) with molluscs being the most diverse but also threatened group of animals, with at least 43.7% of the species (373 species) considered as threatened (Cuttelod *et al.*, 2011). In the Red List assessment, IUCN experts have included 7,482 species divided in odonates, molluscs, crabs and crayfish as these taxonomic groups have received extensive attention. Therefore, these groups represent the best available dataset to quantify the extinction risk among freshwater invertebrates. It includes assessments of 1,280 species of freshwater crabs, 590 species of crayfish, 1,500 species of freshwater molluscs (30% of all known species) and 1,500 species of dragonflies and damselflies (26% of all known species). However, the precise level of threat is unknown as there is a high number of species (2,504), which have a data deficient status. Therefore, the level of threat is between 23% and 56% depending on whether we assume that no species or all data deficient species are threatened. Currently, 131 species are classified as extinct with an additional four as extinct in the wild. The most threatened groups are gastropods (from 33%-68%, respectively assuming no data deficient species are threatened or all of them are), bivalves (26%-49%), crayfish (24%-47%) (Richman *et al.*, 2015), crabs (16%-65%) and dragonflies (9%-44%) (Cumberlidge *et al.*, 2009). Due to a high proportion of range-restricted species living in highly specialized habitats subject to pollution (including sedimentation) or habitat destruction, freshwater gastropods have the highest percentage of threatened species (51%). This results in 3% of gastropods and 5% of bivalves being classified as extinct with the greatest number of extinctions reported for molluscs with more than that reported for birds, mammals and amphibians.

Concerning Europe (Europe as defined by IUCN incluing Western and Central Europe, and Eastern Europe up to the Urals and the Caucasus region), the most threatened group among those that are well monitored is gastropods (45-70% of species threatened depending on whether or not data deficient species are considered threatened) (Cuttelod *et al.*, 2011), followed by bivalves (20–26%) (Cuttelod *et al.*, 2011), and dragonflies (15-19%) (Kalkman *et al.*, 2010). Distribution and population of many widespread species of molluscs have been declining since the 1880s, with the greatest losses between 1920 and 1960 due to habitat change and degradation (Cuttelod *et al.*, 2011). Many species of European dragonflies have shown a dramatic decline in distribution and abundance since the second half of the 20th century (Kalkman *et al.*, 2010; Sahlén *et al.*, 2004), particularly in the south of Europe due to the dessication of their habitats. Overall, 24% of assessed populations are declining (only 12% of species have not been assessed). At least in parts of Europe, some of the species of dragonflies considered threatened have recovered since the 1990s as result of improved water management (Kalkman *et al.*, 2010). The number of Plecoptera species decreased due to water quality degradation and physical alteration of streams and rivers, particularly those inhabiting lowland rivers of industrialized Central European countries (Fochetti & Tierno De Figueroa, 2008). *Taeniopteryx araneoides* (Klapálek) and *Oemopteryx loewi* (Albarda), once common in large Central European rivers, are now extinct (Zwick, 2004). These are among the very few documented cases of extinction in insects. Although some invertebrate species have been lost in British rivers since 1800 (four out of 30 stoneflies, three out of 37 dragonflies, three out of 193 cais, and six out of 386 water beetles), the diversity of invertebrate communities has overall increased in recent decades largely due to improvements in wastewater treatment (Moss, 2015). Family level richness increased on average by nearly 20% from 1991 to 2008, particularly in urban catchments, with a widespread shift towards taxa of well-oxygenated and less polluted waters.

Drivers of change

Water pollution, including nitrates and phosphates from agricultural sources, are the main threat to freshwater invertebrates (e.g. Cuttelod *et al.*, 2011). Habitat modifications linked to change of flow patterns as a result of dam construction and, specifically in Europe, as a result of water abstraction for domestic supplies and crop irrigation, threaten about 26% of freshwater invertebrate species. In addition, habitat modifications due to change in land use, including decline of riparian macrophytes as a result of floodplain drainage, for example for housing development projects, are responsible for 19% of threatened freshwater species. A review by Stendera and co-authors (2012) showed an overall decreasing trend in abundance, richness and diversity of invertebrates due to all these stressors, predominantly land use, eutrophication, and habitat destruction.

Alien species introduced as a result of human activities were also found to have a role in causing a decrease and change in invertebrate community structure. For example, invasions of amphipod species from Ponto-Caspian rivers were enabled by the creation of canal networks interconnecting the major Eastern and Western European river systems since the late 1700s and later enhanced by intentional transfers of potential fish food organisms to hydropower reservoirs. The rate and range of the invasions have dramatically increased since the late 1980s and in the 2000s across these three subregions and many river communities are undergoing major change with the aggressive expansion of *Dikerogammarus villosus* (Väinölä *et al.*, 2008). Another example is the North American euryhaline *Gammarus tigrinus*, which was introduced to Britain and then intentionally to Germany in 1957 to replace locally extinct native species and has since then broadly occupied river, lake, and estuarine habitats in Europe (Väinölä *et al.*, 2008). Some *Mysids* autochthonous in the Ponto-Caspian region are also currently invading some aquatic ecosystems of Northern Europe (Leppäkoski *et al.*, 2002). The impact of these species on native lacustrine and riverine ecosystems can be severe, including a reduction in zooplankton abundance, with concomitant negative effects on higher consumers (Ketelaars *et al.*, 1999). However, at least for molluscs, though invasive species are now widely present and have had an impact on some species, their presence impacts less than 5% of the threatened species (Cuttelod *et al.*, 2011). In addition, the introduction of diseases along with the introductions of alien crayfish species has also been a major issue with *Aphanomyces astaci*, the crayfish plague, responsible for the severe decline of the native European crayfish, *Astacus astacus.*

The effects of climate change on macroinvertebrates vary depending on the region and the taxon group (Domisch *et al.*, 2011; Jähnig *et al.*, 2012) and some studies at national scale have confirmed that, in England, for example, improved water quality through positive management better explained assemblages than increased winter temperatures (Durance & Ormerod, 2009). At a local scale Brown and co-authors (2007) found that a lower contribution of meltwater (from snow and glaciers) to streams significantly increased macroinvertebrate diversity, although some cold adapted taxa decreased in abundance. Some groups such as Trichoptera are potentially more at risk than others by changes in climate across Europe (Hering *et al.*, 2009). Recently it has become evident that many dragonflies of temperate regions are responding, both in distribution and phenology, to global climate change (Kalkman *et al.*, 2008). The ranges of common and widespread southern species are expanding in Europe but there is as yet no strong evidence that northern species are decreasing as a result of the rising temperatures, as might be expected. There is evidence that ranges are changing for Odonata (Moss, 2015), bugs (Hickling *e al.*, 2006), Plecoptera, and aquatic beetles (Heino, 2002), and Diptera (Burgmer *et al.*, 2007).

Lake zooplankton has provided good examples of climate change effects on invertebrates. There is evidence of direct and indirect (through changes in hydrology) effects on seasonality, community composition, parasitism, grazing and production. For example, in the lake Muggelsee, in Berlin, zooplankton species with high thermal tolerances or rotifers that grow quickly at high temperatures have become more common (Wagner & Adrian, 2011). The trend towards warm springs and summers has also affected the population dynamics of several cyclopoid copepods whose growth phase was prolonged both in spring and autumn (Gerten & Adrian, 2002). Predatory Cladocera as well as filter feeders have also been affected by warming. In Lake Maggiore, Italy, there was a more than 10-fold increase in the mean annual population density of *Bythotrephes longimanus* between 1987 and 1993, due to warmer winter and spring temperatures (Manca & DeMott, 2009). *Bythotrephes* remained abundant and increased even more during the following ten years, as water temperature continued to increase. *Daphnia hyalina galeata*, the dominant grazer, and a prey of *Bythotrephes*, decreased sharply as *Bythotrephes* increased. Temperature increase in a series of Russian lakes was also associated with a shift from copepods to cladocerans, resulting in the highly unsaturated fatty acid content of the community falling and thus providing food of reduced quality for fish (Gladyshev *et al.*, 2011) irrespective of timing.

Acidification of surface waters was a severe environmental problem, particularly in northern Europe, during the second half of the last century causing freshwater biodiversity loss. International action plans have led to chemical recovery of some surface waters due to decreased acid deposition, but acidification problems persist in some lakes and rivers. Long-term studies (1988-2007) have shown an overall weak recovery of invertebrate species as a response to chemical recovery in boreal lakes (Angeler & Johnson, 2012). In the Vosges mountains (France), Guerold and co-authors (2000) found a high reduction in diversity for many aquatic species, and among them Molluscs, Crustaceans and Ephemeroptera disappeared totally from strongly acidified streams. In addition, there is evidence that acidification has simplified some invertebrate communities in UK streams and probably made them more vulnerable to climate effects, which conversely might offset biological recovery from acidification (Moss, 2015).

3.4.9 Vascular plants

Status and trends

Of the estimated 32,000 vascular plant species occurring in Europe and Central Asia, IUCN evaluated 2,483 (approx. 8%) in the Red List of Threatened Species. Of these, 810 (32.6%) are threatened (270 critically endangered, 287 endangered and 253 vulnerable). Another 166 are listed as near threatened. Four species are extinct and four species extinct in the wild (likely strongly underestimated). There is a remarkably high percentage of species with unknown population trend (approx. 46%). About one fifth of the evaluated plants (19.6%) show a declining population trend, whereas about one third (31.6%) is stable. Only a very small proportion (2.5%) has increasing population sizes. However, these percentages might be biased, as it is likely that more threatened than un-threatened species have been evaluated by IUCN. Especially the total percentage of species with increasing population sizes is likely larger, as many generalists tend to expand their range sizes (Bilz *et al.*, 2011; IUCN, 2017b).

At the national level, all occurring species have often been evaluated in Red Lists and the average proportions of extinct and endangered species are often quite high (e.g. in densely populated regions), reflecting the local decline of species richness and of population sizes (Lozano, 2000; Bornand *et al.*, 2016; Broggi & Waldburger, 1984; Cheffings & Farrell, 2005; Conti *et al.*, 1992; Curtis *et al.*, 1988; Icelandic Natural History Institute, 1996; Lilleleht, 1998; Ludwig & Schnittler, 1996; Marhold & Hindák, 1999; Millaku *et al.*, 2013; Niklfeld, 1999; Olivier *et al.*, 1995; Oltean *et al.*, 1994; Parfenov *et al.*, 1987; Phitos *et al.*, 1995; Procházka, 2000; Rakonczay, 1989; Rassi *et al.*, 2010; Latvian Academy of Science, 1997; Shelyak-Sosonka, 1996; Silic, 1996; Sugar, 1994; Vangjeli *et al.*, 1995; Vangjeli *et l.*, 1997; Velchev, 1984; Weeda *et al.*, 1990; Westling, 2015; Wind & Pihl, 2004; Wraber *et al.*, 1989; Zarzycki & Kaźmierczakowa, 2001).

Europe as defined by IUCN (West and Central Europe, Eastern Europe up to the Ural and Caucasus region) harbors more than 20,000 vascular plant species (Euro+Med, 2017). Of these, 1,826 species have been evaluated for the European Red List of Vascular Plants, comprising species listed as priority for conservation in multilateral environmental agreements (Habitats Directive, Bern Convention, CITES, EU Wildlife Trade Regulation), crop wild relatives and aquatic plants. About one third (467 species; 26%) is threatened with extinction. 45% and 10% of the MEA-listed species are listed as threatened or near threatened, respectively, 12% and 5% of the crop wild relatives, and 7% and 7% of the aquatic species. The percentage of species with an unknown population trend is notable, as this has been determined for only half of the crop wild relative species (48%), approx. one third of the policy species (37%) and about one fifth (19%) of the aquatic plants. Of the evaluated plants, 38% of the policy species, 16% of the aquatic plants and 11% of the crop wild relative species are declining, while the populations of 22% of the species listed in multilateral environmental agreements, 39% of the crop wild relatives species, and 64% of the aquatic plants are stable. However, population trend analyses are often based on survey data from only a small part of the species range or on subjective assessments based on known threats or habitat decline. Moreover, these percentages might be biased as probably more threatened than unthreatened species have been evaluated (Bilz *et al.*, 2011). Sixty-four species are known to have gone extinct (Silva *et al.*, 2008). Currently 6,190 endemic taxa (164 species groups, 5,191 species, 835 subspecies) are listed for Europe and about 50% of them are in danger of extinction. About 3,000 taxa are considered as local endemics, only occurring in one country or one archipelago. Particularly high numbers of endemic taxa are found in the Mediterranean and the Macaronesian Islands (Blondel *et al.*, 2010; Bruchmann, 2011; Cañadas *et al.*, 2014).

Eastern Europe, and more particularly Russia, harbors about 11,400 vascular plant species (Chandra & Idrisova, 2011), 676 of them are considered threatened (Govenment of the Russian Federation, 2015). Only 53 species are evaluated in the IUCN Red List (IUCN, 2017b).

Central Asian countries harbor at least 7,000 vascular plant species. Endemism is particularly high, ranging from <1% to 15% depending on the country (Chemonics International, 2001a, 2001b, 2001c, 2001d, 2001e, 2001f; Nowak *et al.*, 2011) and especially high in the mountains of the Caucasus region. IUCN lists only 38 species as threatened (IUCN, 2017b), which very likely is strongly underestimated.

Drivers of change

Major threats to the diversity of vascular plants in the region are related to habitat destruction and degradation. Habitat loss is the primary cause of risk for 83% of endangered plant species (Silva *et al.*, 2008). Particularly vulnerable are species with small distribution ranges (e.g. endemic species), specialized habitat and/or microhabitat requirements, narrow environmental tolerances and poor dispersal and competitive ability (Bilz *et al.*, 2011; IUCN, 2017b; Pauli *et al.*, 2012). The intensification of agriculture is suggested to have the most severe impacts **(Table 3.11)** (Allan *et al.*, 2014; Bilz *et al.*, 2011; Government of the Russian Federation, 2015; Werger & van Staalduinen, 2012). Land-use intensification promotes generalist species while specialists are decreasing, leading to large-scale homogenization and loss of ecosystem functions (Gossner *et al.*, 2016; Soliveres, Manning, *et al.*, 2016; Soliveres, van der Plas, *et al.*, 2016; van der Plas *et al.*, 2016b).

While the abandonment of intensive land-use regimes can lead to a recovery of grassland ecosystems (Brinkert *et al.*, 2016; Kämpf *et al.*, 2016), the abandonment of traditional non-intensive land-use regimes, can also lead to the disappearance of plant species with the growth of shrubland or forest, especially in mountain or steppe regions (MacDonald *et al.*, 2000; Mathar *et al.*, 2015; Orlandi *et al.*, 2016; Stöcklin *et al.*, 2007).

Recreational human activities, invasive alien species, pollution (e.g. fertilizer, pesticides), habitat fragmentation, habitat loss and overexploitation are also major threats (Bilz *et al.*, 2011; IUCN, 2017b; Government of the Russian Federation, 2015; Sekercioglu *et al.*, 2011; Silva *et al.*, 2008). Islands with high proportions of endemic species are particularly vulnerable to invasive alien species, especially the Macaronesian and the Mediterranean islands (Bruchmann, 2011; Celesti-Grapow *et al.*, 2016; IUCN, 2017b; Silva *et al.*, 2008). However, studies of the impact of invasive alien species on the diversity of native species are largely missing across Europe and Central Asia and statements on negative impacts often anecdotal (Künzi *et al.*, 2015).

Numerous vascular plant species are used for medicinal, ornamental and cultural purposes as well as in traditional agriculture (IPBES, 2016b), in some cases causing overexploitation, i.e. East-Mediterranean orchids used for salep production (Ghorbani *et al.*, 2014).

3.4.10 Bryophytes

Status and trends

Bryophytes are photosynthetic non-vascular plants that reproduce by spores. Despite the wide range of substrates colonized by bryophytes as a group, many species are restricted to narrow ecological niches with specific requirements concerning substrates and habitat persistence. Bryophytes constitute an important component of vegetation, biodiversity and biomass in various ecosystems (e.g. forest, wetland, mountain, tundra) and thereby make essential contributions to ecosystem functions (e.g., soil stabilization, water retention, carbon sinks in peatlands).

Across Europe and Central Asia, only 14 bryophyte species have been evaluated in the IUCN Red List of Threatened Species (IUCN, 2017b). In Europe, nearly 2,000 bryophyte species occur (1,342 mosses, 494 liverworts and hornworts), representing around 10% of the worlds' bryophyte diversity. Fifty-one per cent of these are endangered (693 moss and 242 liverwort and hornwort taxa; Hodgetts, 2015). A checklist for Eastern Europe and northern Asia (including Central Asia) includes 1,302 moss species and complements the European checklist (Ignatov *et al.*, 2006). Although globally and across Europe and Central Asia, only very few bryophyte species have become extinct (Hallingbäck & Hodgetts, 2001), locally or on the country scale many species are endangered or have even become extinct. However, data on population trends are largely missing. Existing trend analyses are often based on survey data from only small parts of the species range or on subjective assessments. This calls for further investigation, especially in less surveyed countries.

Drivers of change

As bryophytes are sensitive to changes, habitat destruction or degradation can eradicate local bryophyte populations leading to decreasing range sizes (Hallingbäck & Hodgetts, 2001; Hodgetts, 2015; Akatov *et al.*, 2012; Natcheva *et al.*, 2006; Sabovljevit *et al.*, 2001). For example, deforestation and the replacement of natural forests in combination with short forestry rotation cycles causes a general lack of over-mature trees and deadwood. This can reduce species richness and change community composition. In particular, habitat specialists, such as old-growth forest species, are then replaced by habitat generalists (Bardat & Aubert, 2007; Hallingbäck & Hodgetts, 2001; Hofmeister *et al.*, 2015; Paillet *et al.*, 2010; Sabovljevit *et al.*, 2001; Vanderpoorten *et al.*, 2004).

In non-forested ecosystems, bryophytes profit from non-intensive management regimes, habitat heterogeneity and low competition (Bergamini *et al.*, 2001; Hejcman *et al.*, 2010; Möls *et al.*, 2013; Müller *et al.*, 2012; Takala *et al.*, 2014; Zechmeister & Moser, 2001). Large-scale habitat conversion, peatland drainage, peat extraction and land-use intensification over recent decades has led to habitat degradation and homogenization at the landscape level. This has greatly reduced the extent of high-quality bryophyte habitats in line with a drastic decline of bryophyte diversity and a persistent loss of bryophyte species, even after applying different regeneration methods (Bergamini *et al.*, 2009; Hallingbäck & Hodgetts, 2001; Hedberg *et al.*, 2012; Hodgetts, 1992; Sabovljevit *et al.*, 2001; Shustov, 2015).

In particular the application of fertilizer promotes competitive vascular plant and bryophyte species that suppress species adapted to poor soil conditions (Alatalo *et al.*, 2015b; Aude & Ejrnæs, 2005; Bergamini & Pauli, 2001; Hallingbäck & Hodgetts, 2001; Heino *et al.*, 2005; Hejcman *et al.*, 2010; Müller *et al.*, 2012; Van Der Wal *et al.*, 2005; Virtanen *et al.*, 2000).

While the abandonment of intensive land-use regimes can lead to the recovery of grassland ecosystems (Brinkert *et al.*, 2016; Kämpf *et al.*, 2016), the abandonment of traditional non-intensive land-use regimes in grasslands, can also lead to the development of shrubland or forest ecosystems. This can result in the loss of bryophyte diversity (Takala *et al.*, 2012).

Environmental pollution can have severe effects on bryophyte diversity, population sizes, regional species pools and bryophyte performance, for example, SO_2 deposition (Bates & Farmer, 1992; Hallingbäck & Hodgetts, 2001; Akatov *et al.*, 2012; Sabovljevit *et al.*, 2001; Zotz & Bader, 2009; Zvereva & Kozlov, 2011), high nitrogen deposition in large parts of Western and Central Europe (Armitage *et al.*, 2014; Bobbink *et al.*, 2010; Field *et al.*, 2014; Kumpula *et al.*, 2012; Phoenix *et al.*, 2012), and various other pollutants (Sabovljevit *et al.*, 2001; Zvereva & Kozlov, 2011).

Climate warming might lead to expanding distribution ranges of warmth-loving bryophyte species northwards and to higher altitudes, but might also consistently negatively affect the abundance and diversity of bryophytes with a particular future threat for oceanic bryophytes across Western and Central Europe (Bergamini *et al.*, 2009; Delgado & Ederra, 2013; Hodd *et al.*, 2014; Zotz & Bader, 2009). Warming experiments further suggest a future productivity increase and shrub encroachment in tundra regions with consistently negative effects on abundance and diversity of bryophytes (well established; Alatalo *et al.*, 2015b; Cornelissen *et al.*, 2001; Elmendorf *et al.*, 2012; Lang *et al.*, 2012; Pajunen *et al.*, 2011; Virtanen *et al.*, 2013; Walker *et al.*, 2006).

Data on the impact of invasive species on bryophyte diversity is largely missing (but see Hallingbäck & Hodgetts, 2001). The rapid colonization of sand dunes and heathlands in 21 European countries by the invasive moss *Campylopus introflexus* suppresses other species (Essl & Lambdon, 2009; Essl *et al.*, 2013).

A relatively minor threat is overexploitation (e.g. use bryophytes for commercial, scientific or private purposes). However, collecting by bryologists has led to the extinction of one Portuguese species (Hallingbäck & Hodgetts, 2001).

3.4.11 Lichens

Status and trends

Lichens are symbiotic associations between mycobiontic (fungi) and photobiontic (algae) partners. They are an important component of vegetation and biodiversity in various ecosystems and contribute to ecosystem functions (e.g. biogeochemical cycling, carbon storage, food-webs; Cornelissen *et al.*, 2007; Curtis *et al.*, 2005; Edwards *et al.*, 1960; Gerson & Seaward, 1977; Pettersson *et al.*, 1995; Seaward, 2008). Despite the wide range of substrates colonized by lichens as a group, many lichen species are restricted to narrow ecological niches with specific requirements concerning substrate or habitat variables (Nash, 2008a).

Global estimates for lichen species numbers range from 13,500 (Hawksworth *et al.*, 1996) to 25,000 (Wirth & Hauck, 2013). In Europe (all 3 subregions, but excluding Russia) around 7,000 species occur (Feuerer, 2013), Russia harbors 3,388 species (Urbanavichus, 2010). Across Europe and Central Asia, only five lichen species have been evaluated in the IUCN Red List of Threatened Species (IUCN, 2017b). National red lists across the region often comprise only parts of the occurring lichen flora and a comprehensive supra-national red list, applying the IUCN criteria, is completely missing. However, the proportion of nationally endangered or extinct species is generally high (Aptroot *et al.*, 1998; Cieslinski *et al.*, 2003; Liška *et al.*, 2012; Nascimbene *et al.*, 2013a; Randlane *et al.*, 2008; Scheidegger & Clerc, 2002; Serusiaux, 1989; Timdal, 2015; Türk & Hafellner, 1999; Westling, 2015; Wirth *et al.*, 2011; Woods & Coppins, 2012; Zamin *et al.*, 2010). Lichens were not considered in the Natura 2000 programme and the Global Strategy for Plant Conservation of the Convention on Biological Diversity (Nascimbene *et al.*, 2013b). This indicates the general need to fill this gap in line with the 2020 Aichi Biodiversity Targets.

Knowledge on endemic lichen species is scarce. An attempt was made by the Arctic Council, listing 133 lichen species which were never found outside Panarctic countries. Of these, 61 lichen species only occur in Europe and Central Asia (Kristinsson *et al.*, 2010). Moreover, 34 lichen species were so far recorded only from the British Isles (Woods & Coppins, 2012) and 12 from the Madeira archipelago (Carvalho *et al.*, 2008). In addition, data on bryophyte population trends are largely missing. Existing trend analyses are often based on survey data from only small parts of the species range or on subjective assessments. This calls for the need of further investigation, especially in less surveyed countries.

Drivers of change

Lichens are very sensitive to changes in their environment. Therefore, pollution, environmental, land-use and climatic changes, and habitat destruction can eradicate local lichen populations leading to a decline in range size. For example, deforestation and the replacement of natural forests with plantations, in combination with short forestry rotation cycles, cause a general lack of over-mature trees and deadwood, and lack of forest structure. This can lead to homogenous lichen communities and the isolation of dispersal or establishment-limited species, reducing the species richness and the genetic diversity of lichens (Cornelissen *et al.*, 2001; Ellis, 2012, 2015; Hauck *et al.*, 2013; Hofmeister *et al.*, 2015; Nascimbene *et al.*, 2013a; Paillet *et al.*, 2010; Scheidegger & Werth, 2009; Wolseley, 1995). In non-forested ecosystems, lichens profit from non-intensive management regimes, habitat heterogeneity and low competition. Large-scale conversion and land-use intensification over recent decades has led to habitat degradation and homogenization at the landscape level in line with a drastic decline of lichen diversity (Boch *et al.*, 2016; Dengler *et al.*, 2014; Gossner *et al.*, 2016; Hölzel *et al.*, 2002; Kamp *et al.*, 2011; Korotchenko & Peregrym, 2012; Mathar *et al.*, 2015; Akatov *et al.*, 2012; Shustov, 2015; Stofer *et al.*, 2006; The Russian Academy of Sciences, 2014; Werger & van Staalduinen, 2012; Wirth *et al.*, 2011; Wolseley, 1995). The abandonment of traditional non-intensive land-use regimes in grasslands is leading to the loss of soil-dwelling lichens (Hauck, 2009; Leppik *et al.*, 2013).

Environmental pollution can have severe effects on lichen diversity, population sizes, regional species pools and lichen performance. For example, sulphate deposition eradicated the lichen diversity in large parts of Europe (Bates & Farmer, 1992; Gilbert, 1992; Hauck, 2009; Hauck *et al.*, 2013; Insarov & Insarova, 2013; Kirschbaum *et al.*, 2006; Akatov *et al.*, 2012; Nash, 2008b; Purvis, 2015; Purvis *et al.*, 2010; Sedelnikova, 1988; Zotz & Bader, 2009). In addition, the high nitrogen deposition in large parts of Europe promotes nitrophytic species to the detriment of acidophytic ones (Hauck, 2010; Insarov *et al.*, 2010; Russian Academy of Sciences, 2008; Liška *et al.*, 2012; Lisowska, 2011; van Herk, 2001); increases the growth of competing species such as vascular plants; and suppresses soil-dwelling lichens (Armitage *et al.*, 2014; Britton & Fisher, 2010; Field *et al.*, 2014; Phoenix *et al.*, 2012).

Climate-warming might lead to expanding distribution ranges of warmth-loving lichen species northwards, but also might consistently negatively affect the abundance and diversity of lichens (Aptroot & van Herk, 2007; Davydov *et al.*, 2013; Insarov & Schroeter, 2002; Zotz & Bader, 2009), for example by productivity increase and shrub encroachment in tundra regions (Alatalo *et al.*, 2015a; Cornelissen *et al.*, 2001; Elmendorf *et al.*, 2012; Lang *et al.*, 2012; Pajunen *et al.*, 2011; Virtanen *et al.*, 2013; Walker *et al.*, 2006) or the replacement of lichen-rich forests (Andreev *et al.*, 2014).

Data on the impact of invasive species on lichen diversity is largely missing. However, the invasive moss *Campylopus introflexus* is causing a decline of lichen abundance and diversity in sand dunes and heathlands of 21 European countries (Biermann & Daniels, 1997; Essl & Lambdon, 2009; Hassel & Soderstrom, 2005; Ketner-Oostra & Sýkora, 2004; Sparrius & Kooijman, 2011). Moreover, the replacement of native forests by stands of non-native tree species negatively affects lichen diversity, for example *Robinia pseudoacacia* stands (Nascimbene *et al.*, 2015). The invasive box tree moth (*Cydalima perspectalis*) is depleting natural European box (*Buxus sempervirens*) forests in the Caucasus region (Russian Forest Protection Centre, n.d.). As many rare epiphyllous lichen species are growing on the evergreen leaves of the European box (Vězda, 1983), this severely threatens their populations. In addition, epidemic tree pests, such as the current large-scale European ash borer, a species of jewel beetle (*Agrilus planipennis*) across Europe threatens many lichen species, as ash is the host tree of a large number of specialized and threatened epiphytic lichens (Ellis *et al.*, 2014; Ellis *et al.*, 2012; Jönsson & Thor, 2012; Lõhmus & Runnel, 2014; Marmor *et al.*, 2017; Rigling *et al.*, 2016).

3.4.12 Fungi

Fungi contribute a large share of terrestrial species richness and are key players in ecosystem processes (Peay *et al.*, 2016). Estimates of the global number of fungal species range between 2.2 to 3.8 million, of which 120,000

Table 3 11 **Summary of past and current trends in the biodiversity of different taxa in Europe and Central Asia and of the attribution of these trends to direct drivers of change (3.4.2-3.4.12).**

🔴 HIGH IMPACT 🟡 MODERATE IMPACT

🟢 NO OR MARGINAL IMPACT

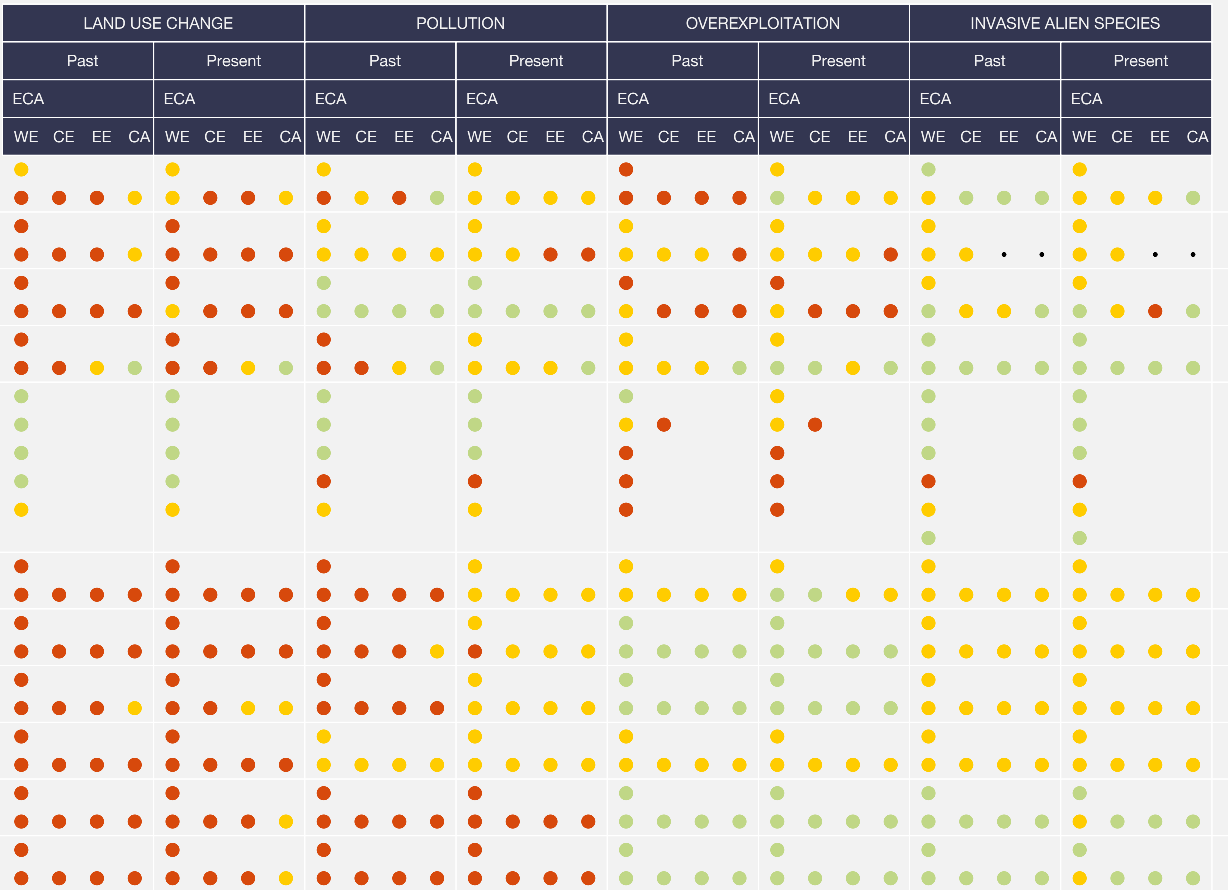
		GENERAL TREND								CLIMATE CHANGE							
		Past				Present				Past				Present			
		ECA				ECA				ECA				ECA			
TAXON		WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
Mammals										🟢				🟡			
		↘	↘	↘	↘	↘	↓	↓	↘	🟢	🟢	🟢	🟢	🟡	🟡	🟡	🟡
Birds		↘				↘				🟢				🟡			
		↘	↘	↓	↘	↘	↘	↓	↘	🟢	🟢	🟢	🟢	🟡	🟡	🟡	🟡
Reptiles		↑				↑				🟡				🟡			
		↗	↗	↗	↗	↔	↗	↗	↔	🟢	🟢	🟡	🔴	🟡	🟡	🟡	🔴
Amphibians		↓				↘				🟢				🟢			
		↓	↓	↕	↔	↘	↕	↕	↔	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Marine fishes	Arctic Ocean	↔				↔				🟢				🟢			
	North East Atlantic pelag./demer.	↔	↓			↔	↕			🟢				🟡			
	Mediteranean	↘				↘				🟢				🟢			
	Black Sea	↘				↔				🟢				🟢			
	Caspian Sea	↘				↕				🟢				🟢			
	North West Pacific pelag./demer.	↘				↗											
Freshwater fishes										🟢				🟢			
										🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Terrestrial invertebrates		↘				↓				🟡				🟡			
		↓	↘	↕	↕	↓	↓	↘	↕	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🔴
Freshwater invertebrates		↓				↘				🟢				🟡			
		↓	↓	↓	↓	↘	↕	↓	↓	🟢	🟢	🟢	🟢	🟡	🟡	🟡	🟡
Vascular plants		↘				↘				🟢				🟡			
		↘	↘	↘	↘	↘	↘	↘	↘	🟢	🟢	🟢	🟢	🟡	🟡	🟡	🟡
Bryophytes		↘								🟢				🟢			
		↘	↘	↘	↘					🟢	🟢	🟢	🟢	🟡	🟢	🟡	🟢
Lichens		↘				↘				🟢				🟢			
		↘	↘	↘	↘	↘	↘	↘	↘	🟢	🟢	🟢	🟢	🟡	🟢	🟡	🟢

currently are described and accepted species. Fungi are, for practical reasons, often divided into macro- and microfungi. The overwhelming number are microfungi, i.e. species without sporocarps like molds and yeast or sporocarps smaller than 1 mm. These are not dealt with here, similar to microorganisms, due to insufficient knowledge of their distribution and ecology and lack of IUCN Red List assessments. Macrofungi (phyla Basidiomycota and Ascomycota), have visible sporocarps (> 1 mm), constitute about 30% of known fungi, and are undergoing extinction risk assessments according to the categories and criteria of IUCN (Dahlberg & Mueller, 2011). Due to their largely hidden mycelial nature and frequently sporadic and short-lived sporocarps, fungi are more poorly understood and appreciated than plants and animals. Hence, fungi have largely been invisible to the conservation community and policymakers and often overlooked in national and international nature conservation actions. During the last decades, however, the knowledge has significantly increased of the status and trends for fungi, how human activities affect fungal diversity and how to counteract threats (Dahlberg & Mueller, 2011; Heilmann-Clausen *et al.*, 2015).

Status and trends

Macrofungal checklists exist for most European countries and for most Russian regions, but have varying degrees of completeness (Senn-irlet *et al.*, 2007). However, there is no combined checklist for Europa or Central Asia. Species richness of macrofungi in Europe has been estimated to be at least 15,000 (Dahlberg *et al.*, 2010) and 8,000 in Russia (Kovalenko *et al.*, 2005, Svetasheva, pers. com). The total species richness of fungi in Europe (Western and Central Europe including Turkey but excluding Isarel), is considered to exceed 75,000 – 100,000 (Senn-irlet *et al.*, 2007). In 2005, the number of known fungi in Russia was 11,000 and the total number of fungi exceeded 25,000 (Kovalenko *et al.*, 2005). Only twenty-five macrofungal species have been globally assessed for extinction risk according to the IUCN Red List categories and criteria (IUCN, 2017c), but the list is growing thanks to a dedicated Red List Initiative

ECA=Europe and Central Asia, WE=Western Europe, CE=Central Europe, EE= Eastern Europe, CA=Central Asia. ↑/↓ denote strong and consistent increase/decrease in the indicator; ↗/↘ denote moderate and consistent increase/decrease in the indicator; ↔ stable indicator; ⇕ variable trend in the indicator.



for fungi[11]. Of these, 13 species are distributed in Europe and Central Asia, of which 10 are distributed in geographic Europe (including geographically European Russia west of the Ural mountains, but not Turkey and Israel) and three in the whole region. Ten of the 13 species are threatened (one EN and nine VU). At least 33 national fungal Red Lists exist in Western and Central Europe, which are widely used for management and conservation actions across Europe (Dahlberg *et al.*, 2010). Similarly, Russia has a national Red Data Book (2008) with 24 listed species of fungi and in addition, 82 of the 85 regions in Russia have regional Red Data Books, which in total include 700 macrofungal species (Svetasheva, 2017). In total, 5,500 macrofungal species are red-listed in at least one European country, of which at least 1,664 species are considered to qualify as red-listed also at the European level (Dahlberg *et al.*, 2010). In European countries with comprehensive fungal red-list assessment, about 20% of known species are red-listed and 10% categorized as threatened (e.g. in Finland, Germany, the Netherlands, Norway and Sweden; Tingstad *et al.*, 2017). These figures imply that about 5% of the European and Central Asian macrofungi would be threatened with extinction (categories vulnerable, endangered and critically endangered) if such a red-list assessment would take place.

The lack of fungi in global and European Red Lists have hindered the inclusion of fungi in international conservation agreements such as in the Annex II, IV and V of the European Union Habitats Directive. Forest ecosystems are by far the most species-rich habitats for macrofungi. Natural and extensively used European and Asian forests provided different conditions and dynamics to fungal diversity than the managed forests of today (Nordén *et al.*, 2014). Accordingly, about 75% of the nationally and globally threatened macrofungi are dependent on woodlands, mainly as associates with coarse dead wood or as ectomycorrhizal fungi with particular habitat requirements, and restricted to old-growth forests conditions. The persistence of threatened woodland fungi is determined by a combination of stand level factors together with factors related to the

11. http://iucn.ekoo.se/en/iucn/welcome

surrounding landscape matrix such as proximity and extent of intensively managed forests and old growth forest habitats (Jönsson *et al.* 2017). Other habitats of large importance for fungal conservation are semi-natural grassland and natural steppe, containing some of the most threatened species, and totalling about 10-20% of national and globally threatened species. These habitats have dramatically declined throughout Europe and Asia due to conversion to arable crops, tree plantations and scrublands (Emanuelsson, 2010). Many grassland fungal species have evolved in nutrient poor and stable conditions, and disappear when artificial fertilizers are applied and decline due to atmospheric deposition of nitrogen (Arnolds, 2001). Furthermore, some types of wetland, e.g. mires and alkaline fens, are important habitats for about 5% of nationally threatened fungi in Europe. These species are sensitive to any change of hydrological regime and eutrophication (Fraiture & Otto, 2015; Svetasheva, 2015). Alcaline fens are of high conservation priority due to extensive past drainage (Šefferová Stanová *et al.*, 2008).

There is strong evidence of a decline of ectomycorrhizal fungi due to eutrophication and linked to the level of nitrogen deposition in Europe (e.g. Arnolds, 2010; Dahlberg *et al.*, 2010).

Drivers of change

The major threats to threatened macrofungi in the region are (i) habitat decline and degradation due to intensified land use of forests, semi-natural grasslands and steppe, (ii) land-use change of forests, semi-natural grasslands and steppe, followed by (iii) eutrophication and (iv) effects of invasive pathogens on native tree species (Senn-Erlet *et al.* 2007; Dahlberg *et al*., 2010). Climate change is an emergent threat likely to directly and indirectly affect fungal diversity (Heilmann-Clausen *et al.*, 2015).

The invasion of the alien fungal pathogens Dutch elm disease and ash decline have been devastating for the distribution of elm and ash in Europe and caused declines in fungal diversity associated with these trees (Brasier & Buck, 2001; Landolt *et al.*, 2016). Ecological impacts of alien invasive pathogens are projected to continue to increase in the future due to trade and climate (Santini *et al.*, 2013).

Long-term Pan-European studies imply climate to drive community changes and range expansion, so far manifested by increased fungal fruiting periods (e.g. Kauserud *et al.*, 2012). Forest management has a potential to compensate negative effects of climate change by increasing set-aside forests to prevent the decline of old-forest species under climate change (Mair *et al.*, 2017). Climate is also affecting the distribution of invasive tree pathogens native to Europe that may become negative for native tree species, e.g. the northerly range expansion of the pathogen *Diplodia* to Scots pine (Oliva *et al.*, 2013). Furthermore, climatic change increasingly fosters alien tree species, e.g. *Acer negundo* and *Robinia pseudacacia* to invade forests and grasslands, thereby changing fungal communities and driving threatened species out of these habitats (Kleinbauer *et al.*, 2010).

3.4.13 Progress towards Multilateral Environmental Agreements for species conservation

European Union Biodiversity Strategy

Target 1 of the European Union Biodiversity Strategy calls for halting the “deterioration in the status of all species and habitats covered by European Union nature legislation (Habitats and Birds Directives), and achieving a significant and measurable improvement in their status so that, by 2020, compared with current assessments:

(a) 100% more habitat assessments and 50% more species assessments under the Habitats Directive show [a favourable or] an improved conservation status [with respect to the last reporting period at the time of adoption of the European Union Biodiversity Strategy to 2020: that is the 2001-2006 reporting period];

(b) 50% more species assessments under the Birds Directive [with respect to 2001-2006 as with the Habitats Directive] show a secure or improved status”.

For the Birds Directive, the baseline was 52% of the 447 species naturally occurring in the European Union having a secure status. In the last reporting period (2007-2012), this figure was unchanged, and 8.5% were assessed as threatened but improving. Therefore, there is still a 17.5% shortfall in the percentage of species that should be secure or improving with respect to 2001, for the European Union target to be met (EEA, 2015a).

An additional 17% of the bird species naturally occurring in the European Union were assessed as threatened, and 15% were assessed as near-threatened or declining or having depleted populations. The remaining 16% of the species had unknown population status. There are no discernible geographic patterns in these status and trends, but there are ecosystem-level and taxonomic differences: grassland, heathland and coastal species, petrels, shearwaters and galliforms have a higher proportion of threatened, near-threatened and declining species than other groups (EEA, 2015a) (Section 3.4.2). Moreover, short-term declining trends are more prevalent among bird species in all marine ecosystems than species in other ecosystems (EEA, 2015a).

For the Habitats Directive, the baseline in 2001 initially assessed 15% of species as being favourable but, when further data became available, a retrospective analysis corrected this baseline to 23%. This means that, for the European Union biodiversity target 1 to be met, 35% of species assessments should be favourable or improving by 2020 (150% of 23%). Overall, 118 monitored species of plants and animals in the European Union have unfavourable conservation status but improving trends, 572 have unfavourable conservation status and deteriorating trends and 905 have unfavourable status and stable trends (EEA, 2015a).

Overall, in the 2007-2012 reporting period, 23% of the assessment were still favourable, 60% were unfavourable and 17% had unknown conservation status. Looking at trends of unfavourable species, 4% of the species assessments were unfavourable but improving 20% were unfavourable stable, 21% unfavourable and deteriorating and 14% unfavourable with unknown trends. There is therefore a 8% shortfall in species assessments that should be favourable or improving with respect to 2001 for the European Union target to be met (EEA, 2015a).

The terrestrial and freshwater species faring worst in terms of status and trends are slightly more prevalent in the Pannonian and Steppic biogeographic regions of Central Europe (Hungary, part of Slovakia and Czech Republic, part of Romania) and the Continental, Atlantic and Mediterranean biogeographic regions (all of Western and Central Europe part of European Union , except Hungary, Scandinavia, and the Baltic Countries) (EEA, 2015a). The Macaronesian islands stand out by having the highest number of unfavourable but improving population assessments (12.1%) followed by Boreal and Atlantic regions (9% and 6.8% of assessment, respectively).

Assessing progress towards the European Union Biodiversity Strategy for marine species is marred by uncertainty in status and trends (Section 3.4.6), over half of the assessments having unknown trends. The exception is the Baltic Marine Bioregion, for which all trends are considered known and 60% are improving.

The main drivers of recent past population declines across all realms are agriculture (use of biocides and chemicals affected 73% of assessed populations, intensification 42%, modification of cultivation practices 36%); reduction of habitat connectivity (55%); pollution of surface waters (56%); invasive alien species (46%); human induced changes in hydraulic conditions (43%); and forestry (removal of dead trees (39%), clearance (38%), logging of natural and plantation forests (38%) (EEA, 2015a).

Across all species and realms, 99% of the favourable assessments for species in the 2007–2012 period were already favourable in the 2001–2006 period; this means that only 0.4% (11 assessments) truly changed from unfavourable to favourable (EEA, 2015a). At this rate, European Union Biodiversity target 1 will not be met for species.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Strategic Vision for 2020 includes Goal 3 "Contribute to significantly reducing the rate of biodiversity loss and to achieving relevant globally agreed goals and targets by ensuring that CITES and other multilateral instruments and processes are coherent and mutually supportive". CITES is legally binding and regulates trade in live plants and animals, their parts and products derived from them. Species subject to regulations are listed in three Appendices[12]. 529 species in Appendices of CITES occur in Europe and Central Asia. Of the 334 species with known population trends, 74% are declining **(Table 3.12)**. Importantly, 206 of these species continue to be threatened by direct large-scale overexploitation and 23 of these are endemic of Europe and Central Asia. It was not possible to track the trade flows of these species, however 17 of these are endemic, and therefore their unsustainable harvest occurs within the region. These are nearly 50% of the 40 endemic species listed in CITES annexes. This suggest that countries in Europe and Central Asia are moving away from achieving the CITES vision for 2020[13].

Aichi Biodiversity Targets

Here we report on progress towards Aichi Biodiversity Targets 12 and 13, the only ones exclusively focusing on species. Aichi Biodiversity Target 12 calls for halting species extinctions and improving the conservation status of threatened species by 2020. The indicators identified to monitor progress towards this target are the Red List Index and the Living Planet Index, although any credible measure of population trends or conservation status can be used to assess progress at national or regional scale. The Red List Index for Europe and Central Asia is declining and the Living Planet Index, only available for selected terrestrial vertebrates, is slightly declining since 2004 **(Figure 3.54)**. Our independent review of the conservation status of all reported taxa in Europe and

12. Those in Annex I are particularly threatened and their commercial trade is banned; those in Annex II are those for which permits are needed for their international trade; those in Annex III are species included at the request of a Party that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation; these species also require permits. Some species, including the gray wolf, are in Annex I in some countries and in Annex II in other.

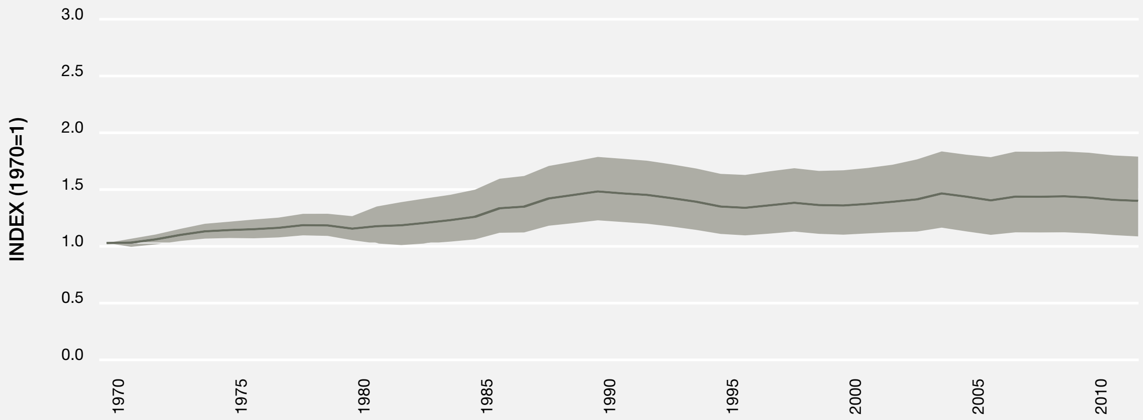
13. Number obtained by intersecting IUCN data on direct threats to species with population trends from the IUCN Red List Database version 2017.1 (IUCN, 2017c) on the subset of species listed in the CITES Annexes and whose range overlap with the Europe and Central Asia region. The list of threats considered where: Hunting & collecting terrestrial animals (threat code 5.1.1: target species, threat code 5.1.4: motivation unknown or unrecorded), Gathering terrestrial plants (threat code 5.2.1: target species, threat code 5.2.4: motivation unknown or unrecorded), Logging and wood harvesting (threat code 5.3.2: target species, large scale harvest, threat code 5.3.5: motivation unknown or unrecorded), Fishing & harvesting aquatic resources (threat code 5.4.2: target species, large scale harvest; threat code 5.46: motivation unknown or unrecorded).

Table 3 12 **Trends in CITES-listed species in Europe and Central Asia. Data obtained from analysing IUCN assessment data retrieved in September 2017 (IUCN, 2017c). Species lists for CITES were obtained by querying https://www.speciesplus.net.**

	Increasing	Stable	Declining	Unknown
Appendix I	11	6	23	7
Appendix II	15	50	216	183
Appendix I and II	0	3	0	1
Appendix III	1	1	8	4

Figure 3 54 **Trends of the Living Planet Index for Europe and Central Asia for terrestrial vertebrates.**

The Living Planet Index is the geometric mean of the rate of change in population abundance of vertebrate species populations since 1970. Source: LPI (2016). The Living Planet Index is based on the population abundance of 2,707 populations of 392 species monitored within Europe and Central Asia between 1970 and 2012. The black line shows the index values and the shaded areas represent the 95 per cent confidence limits surrounding the trend. The trend indicates a 10% increase (range: -17 to +45 per cent) between 1970 and 2012 and a steady decline since 2004.



Central Asia **(Table 3.11)** confirms the trends reported by these two indicators, which, unlike our review, are taxonomically biased towards vertebrates and selected plant groups. There are notable exceptions to these general trends. For instance, the conservation status of large mammalian carnivores and bird species that have benefited from conservation attention has improved in the last two decades (Sections 3.4.2, 3.4.3). Nevertheless, 44.4% of the species extant in Europe and Central Asia with known population trends in the IUCN Red List are declining (over a total of 5,244 species extant in the region and with known trends of July 2017), 50.2% are stable and only 5.3% are increasing.

For marine species these figures are 436 decreasing, 410 stable, and 59 increasing, respectively, i.e. 48.2%, 45.3% and 6.5%; for terrestrial species 42%, 51.7%, and 6.3%; and for freshwater species 50.2%, 7.3% and 42.5%. Note, however, that population trends are assessed throughout a species range which could extend outside the region[14]. These results combined suggest that, despite decelerating trends in extinction risk, countries in Europe and Central Asia are not on track to meet Aichi Biodiversity Target 12.

Aichi Biodiversity Target 13 calls for the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives to be maintained by 2020. The indicator chosen for animals is the trend in conservation status of domestic breeds. In 2005, 2,228 domesticated breeds of mammals and 976 domesticated breeds of

14. Data obtained by analyzing population trends and geographic range from IUCN (2017b)

birds were recorded for Europe and the Caucasus by the Food and Agriculture Organization of the United Nations. Of these, a minimum of 50.7% and a maximum of 74.6% were either extinct or at risk of extinction, depending on how many species with unknown trends were assumed to be at risk. In 2015 a further 540 mammal breeds and 426 avian breeds were listed in Europe and Central Asia. The minimum number of breeds extinct or at risk had decreased to 45.3% but the maximum number increased to 80.4% or, put in a different way, the number of certainly safe breeds decreased by 5.8% in 10 years (FAO, 2007, 2015a).

For plant species, the indicators are more complex. A common proxy is the number of crop varieties grown in a country or region. However, this is not always correlated with genetic diversity. While genetic erosion was reported in several countries in Europe and Central Asia, a recent meta-analysis found that, overall, there appears to have been no substantial reduction in genetic diversity as a result of crop breeding in the twentieth century (van de Wouw *et al.*, 2010). In addition, the threat of hybridization of ornamental species with domestic congeners seems not to be high (Klonner *et al.*, 2017). On the other hand, several local crop varieties were lost due to replacement by higher-yielding crops, for instance all local maize and wheat varieties in Albania (FAO, 2010). As the latest FAO report on genetic diversity of cultivated plants and wild relatives puts it, "convincing evidence may be lacking for genetic erosion in farmer varieties on the one hand and released varieties on the other hand, far greater consensus exists on the occurrence of genetic erosion as a result of the total shift from traditional production systems depending on farmer varieties to modern production systems depending on released varieties" (FAO, 2010). Based on these conclusions and those of the FAO reports on domestic animal breeds it appears that, despite efforts to protect rare domestic breeds and germoplasms of cultivated plant varieties, Aichi Biodiversity Target 13 is not on track to be met for Europe and Central Asia.

Convention on Migratory Species

The Convention on Conservation of Migratory Species of Wild Animals is more commonly known as the Convention on Migratory Species (CMS). Its Strategic Plan for Migratory Species (2015-2023), mirrors the Strategic Plan for Biodiversity 2011-2020. Its target 8 is, "[by 2023] the conservation status of all migratory species, especially threatened species, has considerably improved throughout their range".

To report on progress towards this target for Europe and Central Asia, we intersected information from the IUCN Red List database, reporting global population trends for over 12,000 species in Europe and Central Asia, with the list of species in Appendices I[15] and II[16] of the CMS.

There are 371 migratory bird species listed in the annexes of the Convention occurring in Europe and Central Asia. 150 of them have declining trends, 111 are stable, 67 increasing and 43 have unknown trends. Among the long-distance migrants, most engage in various Afro-Palearctic flyways. The majority of these species have long-term population declines, especially over the period 1970-1990, in particular those that winter in open savannas and breed on agricultural land (Vickery *et al.*, 2014). More recently, Sahelian-wintering birds have shown some sign of recovery, whereas birds wintering in less arid parts of sub-Saharan Africa have shown a continued decline (Vickery *et al.*, 2014).

Migrating ungulates have not fared better. Six out of eight have declining trends, including the saiga antelope which has twice suffered population collapses since the early 1990s, due to hunting and infectious diseases (Section 3.4.3). Of the 42 migratory bat species in Europe and Central Asia, 15 are declining, nine are stable, one is improving and 17 have unknown trends.

Among marine species listed in the appendices of the Convention on Migratory Species, all three sea-turtles in Europe and Central Asia - loggerhead, green and leatherback - have declining population trends. Twenty-three out of 27 cetaceans have unknown trends. Of the remaining four, three are increasing (blue, humpback and bowhead whale) and one, the Indo-Pacific humpback dolphin, is declining.

Twelve of 13 migratory sharks and rays have overall population declines, while the great white shark has unknown trends in Europe and Central Asia.

The only bony fishes listed in the Convention appendices from Europe and Central Asia are 14 sturgeon fishes, of which 13 are declining, while the Syr darya shovelnose sturgeon has unknown trends. A 15th species of the same family occurring in Europe and Central Asia, the Siberian

15. Appendix I comprises migratory species that have been assessed as being in danger of extinction throughout all or a significant portion of their range. Source: http://www.cms.int/en/page/appendix-i-ii-cms Parties that are a Range State to a migratory species listed in Appendix I shall endeavour to strictly protect them by: prohibiting the taking of such species, with very restricted scope for exceptions; conserving and where appropriate restoring their habitats; preventing, removing or mitigating obstacles to their migration and controlling other factors that might endanger them.

16. Appendix II covers migratory species that have an unfavourable conservation status and that require international agreements for their conservation and management, as well as those that have a conservation status which would significantly benefit from the international cooperation that could be achieved by an international agreement. The Convention encourages the Range States to species listed on Appendix II to conclude global or regional Agreements for the conservation and management of individual species or groups of related species. Source: http://www.cms.int/en/page/appendix-i-ii-cms

sturgeon *Acipenser baerii*, is not listed by the Convention despite being migratory, and is also declining. There are no migratory invertebrates listed in the Convention appendices.

Overall, these results show that Europe and Central Asia countries are moving away from achieving Convention on Migratory Species targets **(Table 3.13)**.

3.5 FUTURE DYNAMICS OF BIODIVERSITY AND ECOSYSTEMS

3.5.1 Terrestrial systems

3.5.1.1 Species distribution and conservation status

Short term projections of the impact of climate change on plants, mammals and birds to 2020 indicate widespread contractions in suitable climatic ranges spanning from 10% to 55% depending on climate scenario and taxonomic group considered (Casazza *et al.*, 2014; Thuiller *et al.*, 2011). Extrapolations of trends in farmland bird abundance to 2020 assuming business-as-usual socio-economic trends and full implementation of the Common Agricultural Policy in the European Union also show overall declines across the region, as well as national declines for 15 out of 26 countries considered (Scholefield *et al.*, 2011).

Few studies investigated projections for a period relevant to the lifespan of the Sustainable Development Goals (2030). Disaggregated results of species richness intactness (ratio of species native to a pristine community extant in a given location) of plant and animals for the region from Newbold *et al.* (2015), report an 8% decline by 2035 under two alternative scenarios of land use, compatible with relative concentration pathways scenarios IMAGE 2.6 (w/m^2 of radiating forcing), and AIM 6.0 (w/m^2). For 2030, Verboom *et al.* (2007) found a 4% decline in relative richness under the 4 Special Report on Emissions Scenarios (SRES).

Combined effects of land-use and climate change under business-as-usual scenarios for the second part of the 21st century, are projected to cause widespread range shift and contraction and local population declines across animal and plant species. On average, ranges of mammalian carnivore and ungulate species in Europe (excluding the Russian Federation) are expected to contract by 8% assuming that all species can adapt locally to climate change (therefore declining exclusively due to habitat loss); by 15% if they are allowed to track suitable climatic conditions by dispersing at their maximum physiological dispersal; or by 24% if it is assumed that they cannot disperse (Rondinini and Visconti, 2015). Under these conditions, range shifts and contractions are predicted by 2050 for two-thirds of European breeding birds (Barbet-Massin *et al.*, 2012), for tree species in France (Cheaib *et al.*, 2012) and for alpine plants in Europe with about 50% average reduction in range size by 2100 (Dullinger *et al.*, 2012; Engler *et al.*, 2011).

On average, across all plant and animal groups, local richness and mean species abundance are projected to continue to decline throughout the region, under business-as-usual socio-economic scenarios **(Figure 3.55, Figure 3.56)**. Declines are widespread throughout Europe and Central Asia with the exception of the arid parts of Central Asia and the Russian Federation which are less suitable to agricultural expansions and therefore are not projected to incur further habitat loss **(Figure 3.55)**.

Extinction risk prognoses assessed through IUCN Red List criteria, are projected to deteriorate for one to eight species of large mammals in Western and Central Europe (out of 27 investigated), depending on the assumption made with regards to ability to track climate change (Rondinini & Visconti, 2015; Visconti *et al.*, 2016).

Overall, these results provide evidence that, under business-as-usual socio-economic trends and in absence of new policies for conservation of biodiversity and ecosystem

Table 3 13 **Trends in species listed in appendices of the Convention on Migratory Species in Europe and Central Asia. Data obtained from analysing IUCN assessment data retrieved in September 2017 (IUCN, 2017c). Species lists for the Convention were obtained by querying https://www.speciesplus.net.**

	Increasing	Stable	Declining	Unknown
Appendix I	5	0	13	4
Appendix II	64	118	158	76
Appendix I and II	5	4	30	7

Figure 3 55 **Bivariate map showing spatial pattern in species richness (shades of blue) and local mean percentage changes in extent of suitable habitat between 2010 and 2050 (shades of red, d-ESH in the caption) for all mammalian terrestrial carnivore and ungulate species under a business-as-usual scenario, with land use and climate change and assuming that species cannot disperse to track climate change A and species can disperse one mean dispersal distance per generation B. Source: Visconti *et al.* (2016).**

A B

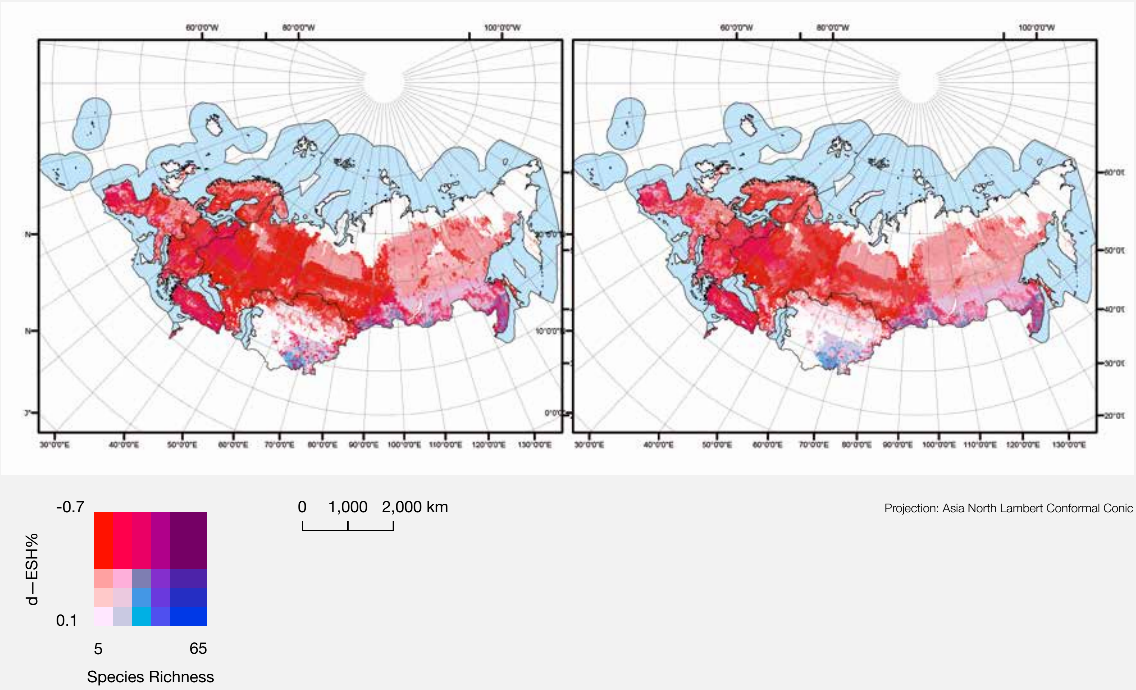
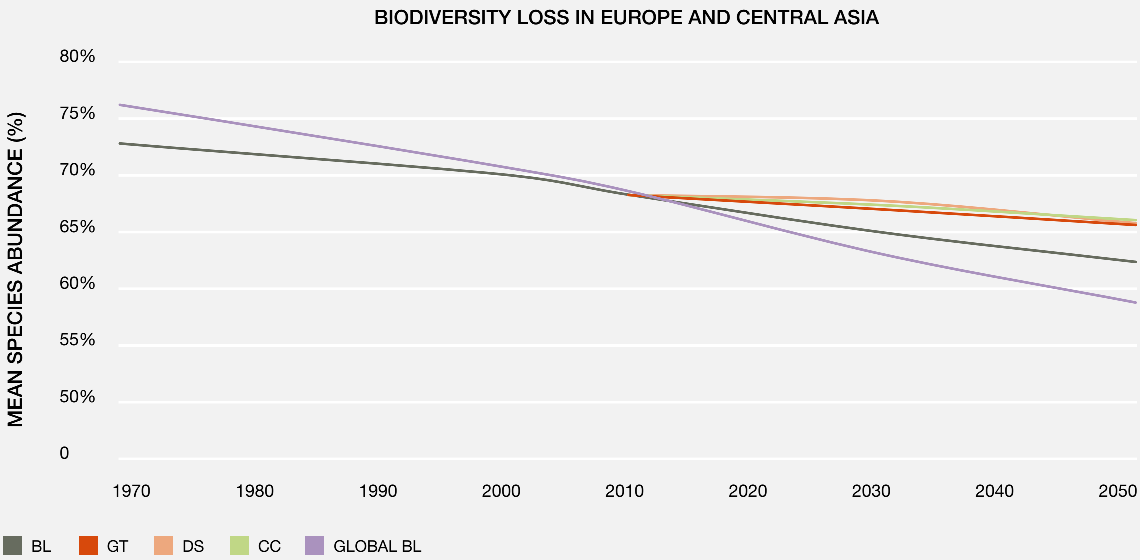


Figure 3 56 **Trends in mean species abundance across animal and plant groups for four future scenarios for Europe and Central Asia and the world.**

BL: baseline; GT: global technology, DS: decentralized solutions, CC: consumption change. Storylines for each scenarios are in Chapter 5. Source: PBL (2014).



services, the Convention on Biological Diversity vision to halt the loss of biodiversity, will not be met by 2050 and beyond for Europe and Central Asia. Normative scenarios that aim to meet these targets have been produced (PBL, 2010, 2012, 2014). These studies showed that policies to mitigate climate change that involve replacing intensive forestry with reduced-impact logging, and increasing yields to spare land from cultivation, can together stem biodiversity losses expected under baseline patterns of consumption and production (see also Chapter 5 on normative scenarios designed to meet biodiversity goals).

3.5.1.2 Community composition

Local taxonomic richness of native species (alpha diversity) across plants, fungi and animal taxa in the terrestrial environment is expected to decline across all of Europe and Central Asia under business-as-usual scenarios of habitat loss (ignoring other drivers of change), except for boreal forests in Fennoscandia and Russia and for the arid regions of central Asia which are not projected to incur agricultural expansion (Newbold *et al.*, 2015). Similar richness patterns are found in freshwater environments (below).

Species range shift, ecological filtering through loss of native vegetation, and the introduction of new species are projected to result in increased temporal turnover of species across most terrestrial ecosystems (Barbet-Massin & Jetz, 2014; Newbold *et al.*, 2015; Verboom *et al.*, 2007). Similarly, local functional diversity is also expected to increase, at least for birds across all subregions of Europe and Central Asia, as a result of climate-driven range shifts (Barbet-Massin & Jetz, 2014). Climate-driven range shifts, and species introductions are likely to lead to declines in beta (i.e. between-site) diversity across the region, with resulting spatial biotic homogenization. For instance, beta taxonomic diversity of plant species in the French Alps is expected to decline by 10-23% by 2050, depending on the climatic model applied (Thuiller *et al.*, 2014a). Beta phylogenetic diversity in Europe for birds and mammals is expected to decrease by 32% and 30% by 2080 under BAU socio-economic scenarios, as a consequence of climate-induced range shifts, expansions and contractions (Thuiller *et al.*, 2011).

3.5.1.3 Ecosystem extent, function and structure

Within Europe and Central Asia, the extent of coniferous forests is expected to be maintained or even increase. Meanwhile, tundra, other Alpine ecosystems, Mediterranean ecosystems, and broad-leaved and mixed forests are expected to substantially contract, because of climate and land-use change (Benito Garzon *et al.*, 2008; Lehsten *et al.*, 2015; Verboom *et al.*, 2007). Increasing water deficit (aridification) may lead to range contractions of some tree species, especially those with limited migration ability, such as European beech (Saltré *et al.*, 2015). A rapid upward shift of mountain vegetation belts by ca. 500 m and treeline positions of ca. 2,500 m a. s. l. by the end of this century is also predicted (Schwörer *et al.*, 2014).

Alpine, Scandinavian, and Icelandic glaciers are projected to retreat. The range of losses depends of climate modelling scenario and varies from 20% to 90% from the 2006 ice volume (IPCC, 2014b).The extent of tundra in the region is limited northward by the ocean and by a small area of Arctic desert. Shrinking of the tundra belt due to loss of permafrost, most active in Siberia and in the southern Arctic (IPCC, 2014a), with subsequent replacement by coniferous forests is expected by the end of the 21st century (Lindner *et al.*, 2010, Kharuk *et al.*, 2006).

It is likely that aridification will reduce the geographical ranges of broadleaved forests, and that Euro-Siberian conifers at medium and high elevations will be displaced by Mediterranean sclerophyll species. Mediterranean mountains might lose their key role as refugia for cold-adapted species and this may have a disproportionate impact on phylogenetic diversity (Barbet-Massin *et al.*, 2012; Benito Garzon *et al.*, 2008; Ruiz-Labourdette *et al.*, 2012; Thuiller *et al.*, 2011, 2014a).

Mediterranean-type ecosystems will suffer from rising temperature, rainfall change (declining in most cases), increased drought, and increased fire frequency (IPCC, 2014b).

Increased seasonal thawing of permafrost due to climate warming may alter the hydrological and thermal regime of polygon and palsa peatlands, as well as their spatial structure (Minayeva & Sirin, 2009, 2010; Minayeva *et al.*, 2017b). However, many forecasts of the effect of climate change are ambiguous. Climate change may lead to permafrost degradation in the southern parts of the Asian territory of Russia, whereas forest is likely to expand into in the forest tundra. Fires on peatlands and other paludified habitats have already become more frequent from the tundra to the steppe (Minayeva *et al.*, 2013).

The carbon stored in natural vegetation is likely to increase under business-as-usual scenarios of climate change (Friend *et al.*, 2014). However, changes in plant respiration and release in soil carbon will be such that there will be a net release of soil carbon in forest and grassland ecosystems (Wolf *et al.*, 2012). The potential standing stock of plant biomass in Russia is predicted to increase in response to elevated precipitation (Shuman & Shugart, 2009).

3.5.1.4 Emerging drivers of change

Russian tundra is expected to be further fragmented, polluted and degraded by projected transport systems, settlements and industrial sites (Government of the Russian Federation, 2013). A warmer climate and longer period of open sea water will make territories of Polar Islands more available for tourism which can become a negative factor of disturbance for animals and birds (Bagin *et al.*, 2011).

3.5.2 Freshwater systems

3.5.2.1 Species distribution and conservation status

Freshwater molluscs, most aquatic insects, headwater fishes and crustaceans are expected to contract their ranges due to climate change with greater than 2˚C warming by 2070 (IPCC Assessment Report 4, scenarios A1B and A2), while aquatic macrophytes, dragonflies and downstream fishes have the potential to expand their range, assuming they are able to disperse and that no other threats will impede their expansion (Alahuhta *et al.*, 2011; Capinha *et al.*, 2013; Cordellier *et al.*, 2012; Domisch *et al.*, 2011). Stenothermal species (with narrow thermal ranges, such as Arctic charr, *Salvelinus alpinus*) will probably shift range or become locally extinct, whereas eurythermal species (with a wide thermal tolerance, such as common carp, *Cyprinus carpio*) will likely be able to adapt to new thermal regimes. At high latitudes, cold-adapted species, such as salmonids, and amongst them notably the northernmost freshwater fish species, Arctic charr, will likely experience major population reductions, a continuation of current trends (Brucet *et al.*, 2010; Moss, 2015).

In a large analysis of projected bioclimatic envelopes for 323 freshwater plants, 470 fishes, 659 molluscs, 133 odonates, 54 amphibians, five crayfish and four turtles across 18,783 European catchments Markovic *et al.* (2014) found that in Europe under the climate change scenario A1B for 2050, 6% of common and 77% of rare species are predicted to lose more than 90% of their current range and 59% of all freshwater species are predicted to lose habitat suitability across more than 50% of their current range. They forecasted that nine molluscs and eight fish species should experience 100% range loss. As the most species-rich group, molluscs are particularly vulnerable due to the high proportion of rare species and their relatively limited ability to disperse. Furthermore, around 50% of molluscs and fish species will have no protected area coverage given their projected distributions. Dragonflies might be able to shift or even expand their ranges, assuming they are able to disperse to track suitable climate.

Caddiesflies (order Trichoptera) are among the most sensitive taxa to climate change. About 20% of the Trichoptera species in most southern European ecoregions and about 10% in high mountain range possess characteristics that make them vulnerable to climate change (Hering *et al.*, 2009).

Macroinvertebrate communities are central to ecological assessments of river and stream ecological quality under the Water Framework Directive. Systems by which these assessments are made could be upset by effects of climate change (Hassall *et al.*, 2010). For example, range shifts in Odonata could change scores derived from the Biological Monitoring Working Party (BMWP) system that is used and have effects consequently on conservation monitoring and assessments (Moss 2015). The Plecoptera are particularly crucial, since they have been allocated some of the highest BMWP scores and have been shown to be “cold-adapted” and to decline in species richness with increasing temperature (Heino *et al.*, 2009).

Many southern countries in Europe, such as Portugal, Spain, Italy, Greece and Turkey are home to high numbers of endemic and threatened species. The consumption of freshwater is expected to increase in the coming years, both as a result of increasing demand and climate change, posing a threat to freshwater habitats and species (Freyhof & Brooks, 2011). This is also true for the Crimean Peninsula where a highly endemic fish fauna is restricted to a few small streams, from which water is already extracted in large and unsustainable amounts.

3.5.2.2 Community composition

Under scenarios of strong climatic impacts (e.g. SRES A1B and A2), freshwater ecosystems are projected to undergo large changes in community structures and therefore loss of ecological integrity. Local species richness in freshwater systems is projected to decline for most taxa due to climate change, but this is expected to be partially compensated by colonisation of new species; species turnover for instance is projected to increase for freshwater stream fishes in France by about 60% by 2080 (Buisson *et al.*, 2008), and aquatic plants and dragonflies local richness is expected to increase in Western Europe assuming unlimited dispersal (Markovic *et al.* 2014). Floating invasive alien plant species are projected to become more prevalent in the region (Meerhoff *et al.*, 2012; Moss, 2015).

Global warming and associated changes in water level and salinity will likely seriously affect community composition in lakes and ponds (Brucet *et al.*, 2009, 2012; Jeppesen *et al.*, 2012, 2015) with some effects already being observed. For example, complex changes in fish community structure

Box 3 2 **21st century scenarios for mountain ecosystems.**

Trends in future climate, land use and invasion projections for mountain systems

Similar to other regions of the world, mountain systems in Europe and Central Asia are projected to warm at a higher rate than other areas (Rangwala *et al.*, 2013). Climate models predict an average temperature change for mountain ranges worldwide of 2-3°C by 2070 and 3-5°C by the end of the century (Nogués-Bravo *et al.*, 2007), with greater increases for mountains in northern latitudes than in temperate and Mediterranean climates, with severe impacts expected on biodiversity. Additional threats on biodiversity are represented by invasive species, predicted to increasingly invade mountains under climate change (e.g. Pauchard *et al.*, 2009; Petitpierre *et al.*, 2015) and by land-use change and pollution (Yoccoz *et al.*, 2010). Biological responses to ongoing global changes were already evidenced, and these trends are expected to intensify in the future (Pereira *et al.*, 2010), with complex biophysical dynamics in mountain systems (Bugmann *et al.*, 2007).

Vegetation

Both mechanistic and correlative modelling approaches predict an advance of the treeline, and a consequent reduction of the alpine and nival areas (Körner, 2012; Pellissier *et al.*, 2013). Currently, however, the main driver of upward treeline shifts is land abandonment (Gehrig-Fasel *et al.*, 2007), which shows the importance of considering land-use changes in combination with climate change. Most models project strong changes in composition and structure of temperate and Mediterranean mountain forests, affecting biodiversity and ecosystem services, such as protection against rockfalls and avalanches (Elkin *et al.*, 2013). 21st century climate change scenarios predict a massive reduction of high-elevation grassland plant diversity and high community turnover, possibly changing the structures of current natural ecosystems (Engler *et al.*, 2011), but first extinctions may only be observed in several decades (e.g. 40 years at high elevation in the Swiss Alps; Engler *et al.* 2009). For the whole European Alps, Dullinger *et al.* (2012) predicted a range reduction around 44-50% for 150 high-mountain species, including several endemics, with possible delays in extinctions (extinction debt). Species that already occur near mountain tops with no possible escape upward have a greater risk of extinction, as predicted for Europe (e.g. Dirnböck *et al.*, 2011; Dullinger *et al.*, 2012; Engler *et al.*, 2011; Randin *et al.*, 2009; Thuiller *et al.*, 2005), Spain (Felicísimo *et al.*, 2011), or Norway (Wehn *et al.*, 2014). On the other hand, mountain systems that have pronounced microclimatic variations may allow species to persist locally (Randin *et al.*, 2009; Scherrer & Körner, 2011; Trivedi *et al.*, 2008). The melting of permanent snow and ice may also provide new potential habitats at higher elevations than currently found, although the formation of soils may take several hundred years (Engler *et al.*, 2011; Guisan & Theurillat, 2001). In the lower alpine areas, losses of grasslands are to be expected by upward shift of treelines (Dirnböck *et al.*, 2003; Körner, 2012; Pellissier *et al.*, 2013), with a 2.2 degree warming leading to an upward shift of the treeline of about 400 m, to a reduction of the lower alpine zone of more than 20% and of the upper alpine and nival zones of more than 50% (Körner, 2012; see Theurillat & Guisan, 2001 for 3.3 degree warming). Counteracting these trends in alpine habitat losses would require the maintenance of large summer farms (Dirnböck *et al.*, 2003). Model simulations show that pasture-woodland systems on lower elevation mountains (e.g. Jura mountain in Western Europe), in particular, may suffer from increased drought, resulting in progressive shifts from Norway spruce to beech under moderate warming, or to Scots pine under extreme warming.This may require changes in silvopastoral practices, such as intensifying pasturing and moving to mixed herds (e.g. cattle, horses, sheep, and goats) to prevent forest encroachment and the loss of species-rich open grasslands and forest-grassland ecotones (Peringer *et al.*, 2013). Also using simulations combining land-use and climate change scenarios for the Larch in the French Alps, Albert *et al.* (2008) conclude that ongoing and future agri-environmental policies have to be quickly adapted to protect biodiversity and ecosystem services provided by subalpine grasslands.

Much fewer modelling studies exist that examine the effects of pollution on plant species and vegetation in mountains of Europe and Central Asi. In the Jizera Mts of Northern Bohemia, ongoing nitrogen deposition results in an unbalanced nutrition of Norway spruce, causing crown defoliation that may ultimately decrease the upper optimal limit for the young spruce stands (Lomský *et al.*, 2012), but positive effects of nitrogen deposition combined with climate warming were also observed in other mountains (Hauck *et al.*, 2012), making prediction of pollution effects on vegetation still uncertain.

More studies exist on invasions by exotic plants in mountain areas. Although mountains areas were long considered as more preserved than lowlands from biological invasions (Pauchard *et al.*, 2009), recent modelling studies predict increasing threats by invasive alien species in mountains of the region under climate change, sometimes combined with land-use change (Cervenkova & Münzbergová, 2009; Hof, 2015; Kašák *et al.*, 2015; Petitpierre *et al.*, 2015; Simpson & Prots, 2013).

may be expected owing to the direct and indirect effects of temperature, and indirect effects of eutrophication, water-level changes and salinisation on fish metabolism, biotic interaction and geographical distribution (Jeppesen *et al.*, 2010). Local extinctions and changes in community composition are likely in the coldest and the most arid regions, after the expansion of the warm adapted species. Fish species richness will likely increase in many continental lakes owing to a poleward expansion of warm-tolerant species.

Enhanced salinization may also promote changes in fish assemblages leading to a greater importance of small-bodied or planktivorous species, and therefore, a strengthening of eutrophication effects (Brucet *et al.*, 2010; Jeppesen *et al.*, 2010).

Several studies have reported projected impacts on community composition of invasive alien species, in isolation or in combination with climate change. For example the Louisiana red swamp crayfish *Procambarus clarkia*, a highly invasive species, is projected to expand its range throughout Europe in the coming decades (Ellis *et al.*, 2012), the African clawed frog *Xenopus laevis* is expected to become invasive in Europe (Ihlow *et al.* 2016), as is the Asian gudgeon *Pseudorasbora parva*, which has been predicted to expand its invasive range throughout Europe and Central Asia with significant ecological implications for its fish diversity (Fletcher *et al.*, 2016). In some instances, the extent of overlap between native species and their invasive alien competitors is projected to increase, this is the case of the native depressed river mussel (*Pseudanodonta complanata*) and its invasive competitor *Dreissenia polimorpha*. In other cases, climate change can partially reduce the overlaps between invasive and native species. This is the case for the invasive *Pacifastacus leniusculus*, which is projected to lose suitable habitat due to climate more than the native white-clawed crayfish *Austropotamobius pallipes* (Gallardo & Aldridge, 2013). Most of these patterns also emerge with lower emission scenarios (e.g. SRES B1 and B2 climate scenarios) but with less dramatic change (Capinha *et al.*, 2013; Cordellier *et al.*, 2012; Sauer *et al.*, 2011).

An increase in species richness at warmer temperature is predicted for phytoplankton and periphyton in shallow lakes, while the opposite is true for macroinvertebrates and zooplankton (Brucet *et al.*, 2012; Jeppesen *et al.*, 2012; Meerhoff *et al.*, 2012). Another study (Shurin *et al.*, 2010) suggested that potential impacts of global change on lake zooplankton biodiversity will depend on the relative magnitudes and interactions between shifts in chemistry and temperature. The study shows that temporal fluctuations in the chemical environment tend to exclude zooplankton species whereas temperature variability tends to promote greater richness. Thus, increasing frequency of extreme events and greater ranges of variability may be as or more important than changes in average conditions as drivers of zooplankton community diversity.

3.5.2.3 Ecosystem functioning

In inland waters, total biomass stock of planktonic autotrophs has been projected to either remain stable or increase under business-as-usual climate projections for the 21st century (Elliot *et al.*, 2005; Markensten *et al.* 2010, Arheimer *et al.*, 2005). Mooij *et al.* (2007) predict that cyanobacteria blooms will increase productivity despite related declines in diatoms and green algae. Cyanobacteria being a poor food source for zooplankton, these and higher trophic levels are likely to decline as a result of climate change. Moreover, due to reduced critical nutrient loading and eutrophication, temperate lakes (with temperature varying between 2 and 22 degrees) are likely to switch from the clear to the turbid state in a 3 degree-warming scenario.

Changes in important functional traits are expected in the future due to global warming. For example, the body size of fish and zooplankton is expected to decrease under higher temperature with negative consequences for the functioning of the food web and the biodiversity of aquatic ecosystems (Daufresne *et al.*, 2009; Emmrich *et al.*, 2014; Meerhoff *et al.*, 2012). Global warming is also expected to affect other fish life-history traits (e.g. shorter life span, earlier and less synchronized reproduction), as well as the feeding mode (i.e. increased omnivory and herbivory); behaviour (i.e. stronger association with littoral areas and a greater proportion of benthivores); and winter survival (Jeppesen *et al.*, 2010). The increased dominance of smaller fish and omnivory will lead to stronger predation by fish on zooplankton and weaker grazing pressure of zooplankton on phytoplankton in warmer lakes (Jeppesen *et al.*, 2014). This will have negative consequences for the ecological status of shallow lakes. Importantly, changes in fish communities that occur with global warming partly resemble those triggered by eutrophication. This implies a need for lower nutrient thresholds to obtain clear-water conditions and good ecological status in the future (Jeppesen *et al.*, 2010; Meerhoff *et al.*, 2012).

Increased salinity due to global warming, water abstraction and pollution may also have negative consequences for the ecosystem structure, function, biodiversity and ecological state of lakes, temporary and permanent ponds, wetlands and reservoirs (Brucet *et al.*, 2009; Cañedo-Argüelles *et al.*, 2016; Jeppesen *et al.*, 2015).

3.5.2.4 Emerging drivers of change

Aquaculture is growing worldwide, already providing more than 50% of the fish and other aquatic organisms on the market. Development of aquaculture, which is now mainly focused on intensive technologies, including integrated agriculture-aquaculture multi-trophic farming, pond culture, cage-culture, recirculating aquaculture systems (RAS) technologies (Karimov, 2011; Thorpe *et al.*, 2011) might have contrasting effects on biodiversity. On one hand aquaculture might substitute the demand for natural fish and other aquatic species and will promote the conservation of biodiversity. On the other hand, aquaculture has historically been the source of invasions in some parts of the region, specifically in Eastern Europe and Central Asia. Lack of adequate management, development of aquaculture and use of genetically modified organisms can further increase invasions of alien species and threaten biodiversity and/or endemic species.

The Brönmark & Hansson (2002) review on environmental threats to lakes and ponds predicted that biodiversity in fresh waters will, in most parts of the world, have decreased considerably by the year 2025. Changes in biodiversity may in turn affect freshwater ecosystem processes such as primary productivity, detritus processing and nutrient transport at the water-sediment interface. In addition, loss of species at higher trophic levels may have strong repercussions down the food chain (Brönmark & Hansson, 2002). Furthermore, these authors suggested that "old" problems such as eutrophication, acidification and contamination, may become less of a problem in the future, whereas "new" threats such as global warming, UV radiation, invasive alien species and endocrine disruptors most likely will increase in importance.

3.5.3 Marine systems

3.5.3.1 Species distribution and conservation status

Direct and indirect impacts of climate change on species distribution and abundance have been predicted for all marine systems and virtually all taxonomic groups investigated.

Climate change effects on Arctic and sub-Arctic marine mammal and bird species will vary by life history, distribution, and habitat specificity with some major negative effects on ice-obligate species (such as hooded seal, narwhal and ivory gull; Moore & Huntington, 2008); some species coming to the region seasonally may benefit from ice loss (killer whale, grey whale) (Larsen *et al.*, 2014). It is projected that polar bear number will decrease dramatically with approximately two-thirds of the world's polar bears extirpated by the middle of the 21st century under A1B scenario (Amstrup *et al.*, 2008; Larsen *et al.*, 2014). There is a risk that Arctic shelf species might become locally extinct due to shortage of climatically suitable shelf habitat (Fossheim *et al.*, 2015a).

In the North East Atlantic, pelagic ecosystems and taxa are projected to display higher modifications than demersal communities, a pattern explained in some regions by the influence of regional topography (e.g. North Sea; Weinert *et al.* 2016). This does not mean that demersal species are not affected by the projected changes, only that rates are variable. For instance, marine fish in the North Sea have projected poleward shifts which can be up to two times higher than the observed current rate of shift (Cheung *et al.*, 2016). Benthic communities of the North Sea were also shown to be strongly impacted under the IPCC AR4 scenario A1B, with latitudinal northward shift projected in 2099 for 64% of the 75 species examined by Weinert *et al.* (2016). Seabirds, which are often faithful to breeding colonies, are also expected to show important changes in their distribution in the North East Atlantic. For example, the ranges of 65% or 70% of 23 seabirds from the British Isles are expected to shrink by 2100 under two emission scenarios (IPCC AR4 climate change scenario A1B and A2 respectively) and under the hypothesis of unlimited dispersal; this value increases to 100% (and all of them lose at least 25% of their range) with no dispersal (Russell *et al.*, 2015).

Less information is available on projected impacts of fisheries in the region. For the Atlantic cod and the European seabass, under a scenario of an increase in demand of 5.6% per year, a decline of the spawning stock sizes of the North Sea cod by 97% is predicted toward by 2050, compared with a scenario with a stable demand (Quaas *et al.*, 2016). Cascading effects are also projected along the trophic network: by 2040, climate change, in particular summer warming, is projected to lower the abundance of the copepod *Calanus finmarchicus* which is used as a prey by cod in the North East Atlantic (Kamenos, 2010).

Some catch species will also have reduced survival and fertility due to direct and indirect impact of climate change. For instance, Baltic Sea cod eggs require certain environmental conditions regarding oxygen (>2 ml/l oxygen) and salinity (> than 11 g/kg). Physical and chemical changes in the Baltic will reduce cod reproductive potential by 75% by 2100 (Neumann, 2010).

3.5.3.2 Community composition

Species turnover is projected across all marine systems in the region and across a large range of marine habitats and taxa. Reductions in sea ice in the central Arctic are likely to enhance invasion of benthic taxa from the Pacific to the Atlantic due to more freely flowing currents (Hunt *et al.*, 2016, Renaud *et al.*, 2015). The Chukchi and the Barents Seas along with the western part of the Kara Sea are the most likely locations for the expansion of some boreal benthic species and communities (Renaud *et al.*, 2015).

The advection of zooplankton to the Arctic Basin along the Eurasian shelf is projected to cease during the 21st century, as revealed by models based on climate scenario A1B, with increased participation of the species of temperate origin in the communities of the Eurasian Arctic Seas (Wassmann *et al.*, 2015). In particular, for the Barents Sea by 2059, zooplankton of Atlantic origin will increase and zooplankton of Arctic origin will decrease under moderate climate change (SRES B2 scenario, Ellingsen *et al.*, 2008).

Boreal fish species replacing Arctic species are known to be opportunistic generalists, and their expansion is known to alter the structure of Arctic food webs and is predicted to increase the connectivity between benthic and pelagic habitats. As a result, more densely connected and less modular Arctic marine food-webs are expected to emerge (Kortsch *et al.*, 2015).

Models of fish invasions have shown that the rate of spread of non-native species in the Barents Sea are five times higher than the global average, with the central Barents Sea fish community spreading northwards and Arctic community retreating. This shift appears to be taking place at a speed at >159 km per decade.

For some marine alien species already introduced in the North East Atlantic, like the American clam, *Ensis directus* (Raybaud *et al.*, 2014), and the Pacific oyster, *Crassostrea gigas* (Jones *et al.*, 2013), expansion of their current range is projected with high level of confidence by the end of the 21st century, under medium to severe climate change scenarios.

In the North East Atlantic, 21st century scenarios of moderate (e.g. IPCC RCP 4.5, 550 ppm B1) to severe climatic change (e.g. IPCC RCP 6.0 or RCP 8.5, 720 ppm A1B), are projected to generate important changes in marine community structure, population abundance, and species range and richness (Beaugrand *et al.*, 2015; Blois *et al.*, 2013; Cheung *et al.*, 2009; Garciá Molinos *et al.*, 2016; Jones & Cheung, 2015). These scenarios establish with high confidence that communities are modified because of the joint effect of loss of species and colonization by new species (i.e. species turnover). In addition, the projections highlight that expansion of species ranges are prevailing over species loss or range contraction, thus leading to a transient net local increase in richness, particularly around the 40-30°N line of latitude **(Figure 3.57)**.

3.5.3.3 Ecosystem extent and function

Across all marine systems and habitats, 21st century climate change and ocean acidification are projected to induce changes in extent and functioning of ecosystems. Most of the Eurasian Arctic Seas lie within today's seasonal ice zone. The general trend of "borealization" of the region is expected to continue (Fossheim *et al.*, 2015), inducing habitat gains and losses and a large species turnover; changes in phenology and production; substantial food web reorganizations; and changes in ecosystem functioning (Kortsch *et al.*, 2015; Larsen *et al.*, 2014).

In the Baltic Seas, maximum sea-ice cover is expected to decline by 75% under high climate change (SRES A1B) and by half under the most optimistic scenarios of climate change (B1) by the end of the 21st century. Melting sea ice will decrease water salinity and the resulting warming and changes in water density are projected to promote instability in water stratification thereby reducing the areas of suboxic water (with < 2 ml/L of oxygen) (Neumann, 2010).

Kelp forest ecosystems (*Laminaria hyperborea*) are expected to expand to northern territories under all plausible climate change scenarios. This, coupled with significant loss of suitable habitats, is projected at low latitude range margins, including in areas where long-term persistence was inferred (e.g. north-western Iberia) (Assis *et al.*, 2016b), might have important consequences on the genetic diversity, and adaptive potential, of these habitat-structuring species (Assis *et al.*, 2018). A significant loss of maerl beds, dominated by coralline algae, is also predicted to occur by 2100 in the North East Atlantic, due to elevated pCO_2 (Brodie *et al.*, 2014).

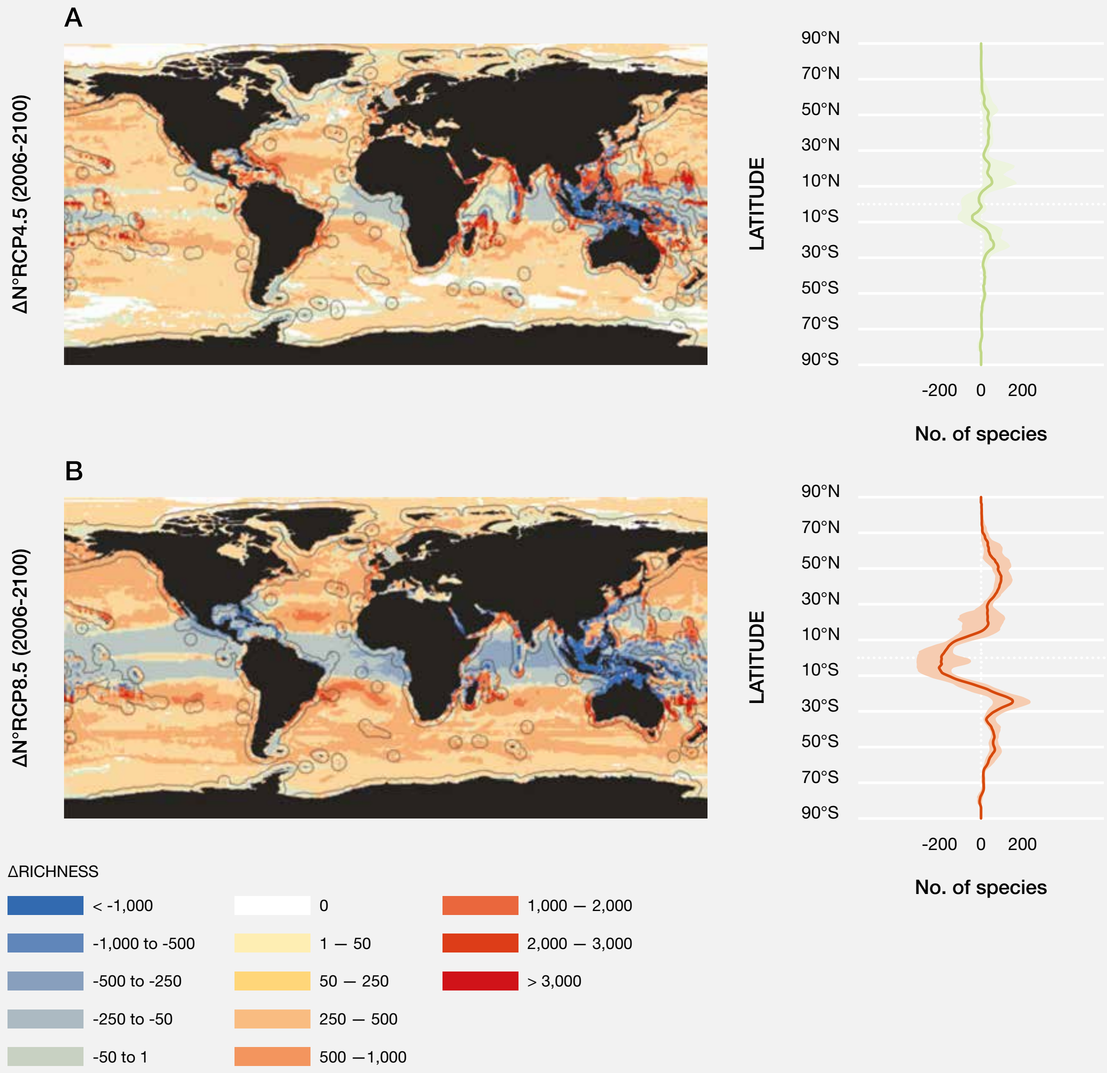
Species range changes, phenological reactions, and variations in production, is expected to cause the Eurasian Arctic Seas ecosystem structure and functions to change (Larsen *et al.*, 2014).

Though primary production on ocean shelves is expected to increase (Hunt *et al.*, 2016), so far no unidirectional changes in the primary production in the individual Eurasian Arctic Seas have been observed. Reliable trends in its variation (increasing) were ascertained for the Barents, and Kara seas (Vetrov & Romankevich, 2011). There are two peaks in primary production in the Arctic Seas: spring ice algal peak and consecutive phytoplankton bloom. The role of the first one is expected to diminish; the timing of maximum phytoplankton production is expected to change and to influence the variability in time-lags between ice algal and phytoplankton peak production (from 45 to 90 days; Ji *et al.*, 2013, Kędra *et al.*, 2015). The frequency of mismatch between peak in demand from marine grazers and supply of their food, will increase. This will alter trophic flows throughout the food chain (Ji *et al.*, 2013). The spatio-temporal mismatch between the breeding season and the peak in food availability will potentially have a negative impact on seabird populations (Grémillet & Boulinier, 2009).

Phenological changes due to climate change and chemical changes have been already observed and further projected in the future. For instance, the decrease of anadromy prevalence of Arctic char (over 50% to the end of 21st century with high-levels of global warming, under the IPCC AR4, A2 emission scenario) because of the increase of lake and terrestrial catchments productivity (Finstad & Hein, 2012). Seasonal Cyanobacteria blooms in the Baltic are projected to to start earlier and last a month longer by the end of the 21st century (Neumann, 2010). Invasive species like the Pacific oyster, *Crassotrea gigas*, have also shown phenological changes. Specifically, reproductive effort and spawning periods are changing as a response to increased seawater and phytoplankton concentration (Thomas *et al.*, 2016).

Figure 3 57 **Differences between current (2006) and projected (2100) species richness (ΔRichness) based on models of 12,796 marine species from 23 phyla for IPCC RCP 4.5 A and RCP 8.5 B climate change scenarios.**

Source: García Molinos *et al.* (2016). Reprinted by permission from Macmillan Publishers Ltd: Nature Climate Change, copyright (2016).



In the North East Atlantic and the North Sea, the projected general trends point to accelerating changes in ecosystem functioning, notably due to the effect of climate change on nutrient availability, and changes in timing of phytoplankton production, phytoplankton and zooplankton biomass, with cascading effects on the trophic network (Friocourt *et al.*, 2012 and examples in Soto, 2001). For instance, larval cod survival probability is declining by 22-44% in the North Atlantic, notably because of starvation effect due to food limitations (Kristiansen *et al.*, 2014). And the growth and weight of adult cod is also projected to be declining under IPCC Assessment Report scenario RCP 8.5 (highest green-house emission scenario for this assessment), because of physiological constraints (Butzin & Pörtner, 2016). Physiological processes as well as metabolic pathways will thus be modified as a response to climate change and ocean acidification. Responses may, however, be very different across taxa: for instance, autotrophs like seagrasses and many macroalgae are expected to display higher growth and photosynthetic rates under elevated pCO_2 (Koch *et al.*, 2013), whereas calcareous algae like maerl are likely to suffer from ocean acidification (Brodie *et al.*, 2014). Particularly well documented are changes in breeding phenology and success and the timing of migration of seabirds of the North East Atlantic (e.g. effect on breeding phenology; Frederiksen *et al.*, 2004). Among other documented changes are migration patterns. For instance, migration patterns of the North East Atlantic mackerel are projected to change under moderate and high climate change scenarios (RCP 4.5 and 8.5, respectively). The outcome of these scenarios is that this living natural resource could expand in the near future.

3.5.3.4 Emerging drivers of change

Discovery of gas and oil fields across Europe and Central Asia, especially in the Arctic circle and the far north-east of the region (Sakhalin shelf and Kamchatka) pose a threat to terrestrial and marine biodiversity (Kontorovich *et al.*, 2013).

Enormous amounts of manganese, copper, nickel and cobalt are found on or beneath the seafloor (World Ocean Review, 2014). Demand for these resources are set to increase since they are needed for developing clean technologies, such as making wind turbines or hybrid cars. Deep-sea mining has not yet begun, mostly for technical reasons, but there has been an increase in the number of applications for mining contracts and it is estimated that by the end of 2017 there will be about 27 projects worldwide (Wedding *et al.*, 2015). Research to determine the impacts of deep sea mining has shown that deep-sea mining cannot be done without directly destroying habitats and species, resulting in biodiversity loss (Vanreusel *et al.*, 2016) and indirectly degrading large volumes of the water and seabed area with the polluted sediment plume it generates (Van Dover *et al.*, 2017). This mining requires enormous areas: a single 30-year operation license to mine metal-rich nodules will involve an area about the size of Austria. Most mining-induced loss of biodiversity in the deep sea will not recover for decades or centuries, given the very slow rates of recovery of many deep-sea species and ecosystems (Vanreusel, *et al.* 2016).

Shipping is expected to double by 2050, emphasizing the need for alternative shipping routes. Alternative routes are essential to minimalize impacts caused by the increased threats from shipping accidents and oil spills (Kotta *et al.*, 2016).

With projected sea-ice declines, large swaths of Arctic Ocean will be opened up to shipping and fisheries (Jørgensen *et al.*, 2016a; Mullon *et al.*, 2016). This will cause additional pressure on the biodiversity of the region, speeding introductions of boreal fauna (Renaud *et al.*, 2015), and possibly reducing bottom complexity. Changes in advection are projected to accelerate the transboundary pollution effects increasing the number of contaminants in the food web (Jørgensen *et al.*, 2016a).

The continuing enlargement of the Suez Canal will allow greater cohorts of deeper living biota to enter the Mediterranean Sea, enhancing the risk of establishment and spread (Galil *et al.*, 2017). Increase in commercial shipping and recreational boating will enhance the introduction and secondary spread of non-native biota.

3.6 KNOWLEDGE GAPS

Knowledge gaps concern a) the full geographic (and temporal) coverage of past, current, and future trends of some ecosystem types and some taxa across Europe and Central Asia, b) patterns and underlying mechanisms of the biodiversity – ecosystem service relationship, and c) consideration of indigenous and local knowledge for all ecosystem types and taxa.

Geographic gaps

Overall, we found large gaps in knowledge on habitat extent and intactness, and species conservation status and trends for Eastern Europe and Central Asia. For instance, there is no systematic monitoring of plant and animal species across the range of these subregions. This is of particular concern given the size of these subregions and the diversity of habitat and species there. Outside the European Union long-term monitoring data is available almost exclusively for protected areas, which poses the risk of underestimating overall biodiversity trends in these regions.

Role of drivers

Information on future trends in biodiversity was predominantly focused on the impact of climate change, especially on plants and vertebrate species. There were very few studies investigating the impact of land-use change and even fewer investigating future projected impacts of pollution, invasive species, fishing and other drivers of change.

It was often impossible to quantify the relative role of drivers of change in determining trends in species and ecosystems. This was due to lack of synthetic studies on this subject and the limited ability to meta-analyze the literature to provide this evidence. Therefore, the attribution of drivers to trends was based on the qualitative expert assessment of the authors rather than on quantitative empirical evidence from experimental or quasi-experimental studies.

Marine systems

Most marine systems are hidden to human eye and therefore lack of visibility, knowledge gaps, and lack of concerted actions are regularly pointed out for marine systems (e.g. Allison & Bassett, 2015; Mccauley *et al.*, 2016).

Nevertheless, the rate of description of new marine species has been increasing, since 1955, at a higher rate than for terrestrial species (Appeltans *et al.*, 2012). Still, it is estimated that between one-third and two-thirds of marine species are still to be described, with estimates of the total number falling in the range of 0.7 to 1 million (as compared to the 226,000 species currently described). Under-estimation of marine diversity is not restricted to remote and under-studied locations. It also holds in Europe and Central Asia, with the increasing discovery of cryptic species (i.e. species that are not, or are hardly, distinguished according to morphological criteria). This underestimation of marine diversity implies that the trends are incomplete for most marine taxa.

An important gap in knowledge regarding current as well as future changes is genetic responses to environmental changes. Only few taxa, among them fishes and algae, have been studied so far (e.g. Araújo *et al.*, 2016; Assis *et al.*, 2016a; Hutchinson *et al.*, 2003; Nicastro *et al.*, 2013), but these studies indicate changes in genetic diversity and genetic structure of marine species. Integration of a genetic component is of paramount importance for conservation of genetic resources as well as for modelling of future trends in marine biodiversity (Arrieta *et al.*, 2010; Gotelli & Stanton-Geddes, 2015).

Until recently, scant attention was paid to marine ecosystems and most marine taxa in conservation policies (e.g. see Habitats Directive and species lists in the European Union). Only a small number of species and few habitat types are included in Annex I of the Habitats Directive (EEA, 2015a). The gap in knowledge is exemplified by the large percentage of species in the "unknown" category in the first assessment of "good environmental status" in light of the newer Marine Strategy Framework Directive (2008) in the European Union **(Figure 3.58)**.

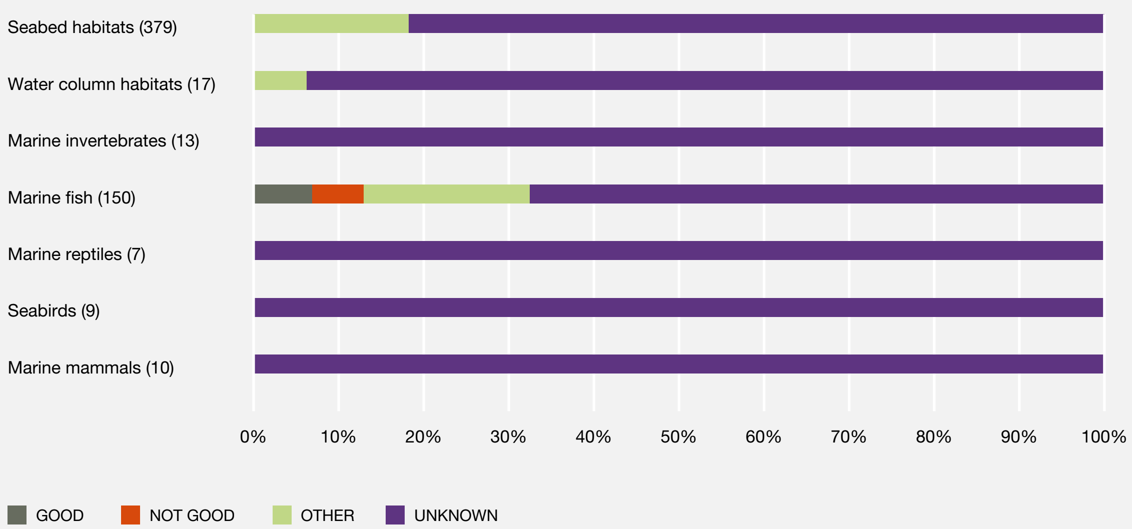
Most long-term marine datasets (since the 1950s) concern pelagic ecosystems (e.g. Beaugrand *et al.* 2002), intertidal rocky shores (e.g. Mieszkowska *et al.*, 2006), or specific taxa or taxonomic groups (in particular fishes, marine mammals or seabirds). Almost no data are available to document changes in subtidal rocky areas although they are rich in biodiversity and support key engineer species, for instance in subtidal kelp forests (Smale *et al.*, 2013).

Open ocean plankton communities are also poorly known. It is estimated that, in each litre of seawater, there are on average 10 billion organisms, including viruses, prokaryotes, unicellular eukaryotes, and metazoans.

The most notable knowledge gap in marine biodiversity for Europe and Central Asia is the lack of data on status and trends of biodiversity in deep-sea areas (>200 m) despite canyons, seamounts and other important deep-sea habitats and ecosystems being present in Europe and Central Asia Seas and Oceans. Less than 1% of the deep-sea floor (UNEP, 2007; Rogers *et al.*, 2015) and 0.4-4% of known seamounts (Kvile *et al.*, 2014) have been sampled. Those that are known are mainly areas with sandy bottoms that can be trawled. This highlights significant gaps in basic knowledge, including lack of baseline data on biodiversity, abundance and biomass and its spatial and temporal variations. New habitat types and species are still being discovered on almost every deep-sea scientific cruise.

Some progress in addressing these knowledge gaps is signified by recent marine assessments. For instance, an assessment of data available and surveys needed was recently reviewed for kelp in the North East Atlantic (Araújo

Figure 3 58 **Knowledge and categorization of "good environmental status" in marine ecosystems of the European Union. Source: ETC/ICM (2014).**



et al., 2016). The results from Tara Oceans and Malespina cruises and Ocean Sampling Day program, which collected genetic, morphological, and physico-chemical samples from stations around the world (about 35,000 biological samples and about 13,000 contextual measure taken a three different depths just for Tara Oceans) is now being analysed by a large international team of scientists. Metagenomes and meta-barcodes from stations are being built as well as quantitative and high-resolution image databases, and the first global studies are being published (e.g TARA Ocean (https://www.embl.de/tara-oceans/start/). IUCN recently coordinated an assessment dedicated to the Anthozoans of the Mediterranean Sea, which include, for instance, iconic species like the red coral (Otero *et al.*, 2017).

Freshwater systems

The chemical status of 40% of Europe's surface waters remains unknown (EEA, 2015d), considering that good chemical status was only achieved for all surface bodies in five of the 27 European Union member States, it is likely that the environmental conditions of some of these water bodies are poor.

Agricultural areas

Overall information on biodiversity trends in agricultural areas decreases from west to east. In particular, studies on biodiversity and agriculture for Eastern Europe and Central Asia often focus on drivers of biodiversity in agricultural areas rather than biodiversity trends (Smelansky, 2003), while biodiversity is surveyed for semi-natural ecosystems rather than more productive agroecosystems in these countries. Capacity building for monitoring biodiversity in agricultural areas in the eastern part of the region is thus needed.

The level of knowledge on biodiversity trends in agricultural areas and main direct drivers has increased substantially during the last decade. However, most studies have used species richness or abundance (and genetic diversity for animal breeds and plant varieties) as indicators of biodiversity. Promoting a stronger focus on functional diversity in future studies and monitoring schemes may be the best way to complement previous approaches. To better understand and predict biodiversity trends in agricultural areas in Europe and Central Asia, it will be necessary: (i) to reinforce the knowledge basis on the demography and population dynamics of species (including the role of behaviour, density-dependent effects, and extinction debt); (ii) to account for small-scale spatio-temporal effects and scale up biodiversity changes and trends from local to national and regional levels; and (iii) to detail the effects of changes in agricultural practices (characteristics of the varieties grown, harvesting techniques, types of pesticides used, etc.) to a greater extent (Kleijn *et al.*, 2011).

Urban areas

The data available for urban areas are mostly for the larger and more easily observed taxa, such as vascular plants, birds and mammals. There is good data for bats, and reasonably good data on amphibians, reptiles and some insect taxa, including butterflies. The small amount of data available on taxa more difficult to observe and distinguish, such as Syrphids and other Diptera, suggest high levels of diversity and numerous rare and threatened species (Kelcey, 2015). Thus, more surveying of such taxa would generate valuable new knowledge on urban biodiversity.

Taxonomic gaps

While birds are arguably the most studied and best known group in Europe and Central Asia, there is still one species, the large-billed reed-warbler, *Acrocephalus orinus* listed as being data deficient by the IUCN and therefore having unknown extinction risk, and there are also 79 species with unknown population trends in the European Union (EEA, 2015a). Long-term trends are rarely available. Low capacity or difficult access means that regions such as Caucasus, the Arctic part of Europe, Romania, Croatia, the Faroe Islands and the Azores are underrepresented in bird conservation status assessments (BirdLife International, 2015).

More substantial knowledge gaps exist for other terrestrial vertebrate groups. There are, respectively, 55 mammals, 11 reptiles and three amphibians that are classified as data deficient by the IUCN. In addition, population trends are unknown for 100 of 1,026 bird species extant in the region and assessed by IUCN as well as 263 of 537 mammals, 7 of 129 amphibians and 56 of the 268 species of reptiles (IUCN, 2017c).

There are at least 100,000 species of insects known in Europe, and an unknown number of earthworms, arachnids, snails and other invertebrate species. However, it is plausible that several hundreds of thousands of species of invertebrates occur in Europe and Central Asia. Despite this extremely high diversity, and importance for ecosystem services, only a very small proportion is listed in the IUCN Red List. More specifically, there are only 2,132 species of terrestrial invertebrates in the IUCN Red List that are extant in the Europe and Central Asia region. The majority of these are European bees, which include 1,965 species (Nieto *et al.*, 2014). Moreover, almost nothing is known about species, trends and threats for this taxonomic group from Central Asia.

There are no meaningful trends in geographic extent or population size of freshwater species available for Europe and Central Asia. Therefore, a table of trends and importance of drivers was impossible to produce. Of particular concern is the lack of data for freshwater invertebrates, for which even current status is available only for a minority of species (EEA, 2010). For example, several freshwater crab species have data deficient status according to the IUCN Red List, which highlights the need to increase monitoring efforts globally but also in Europe and Central Asia.

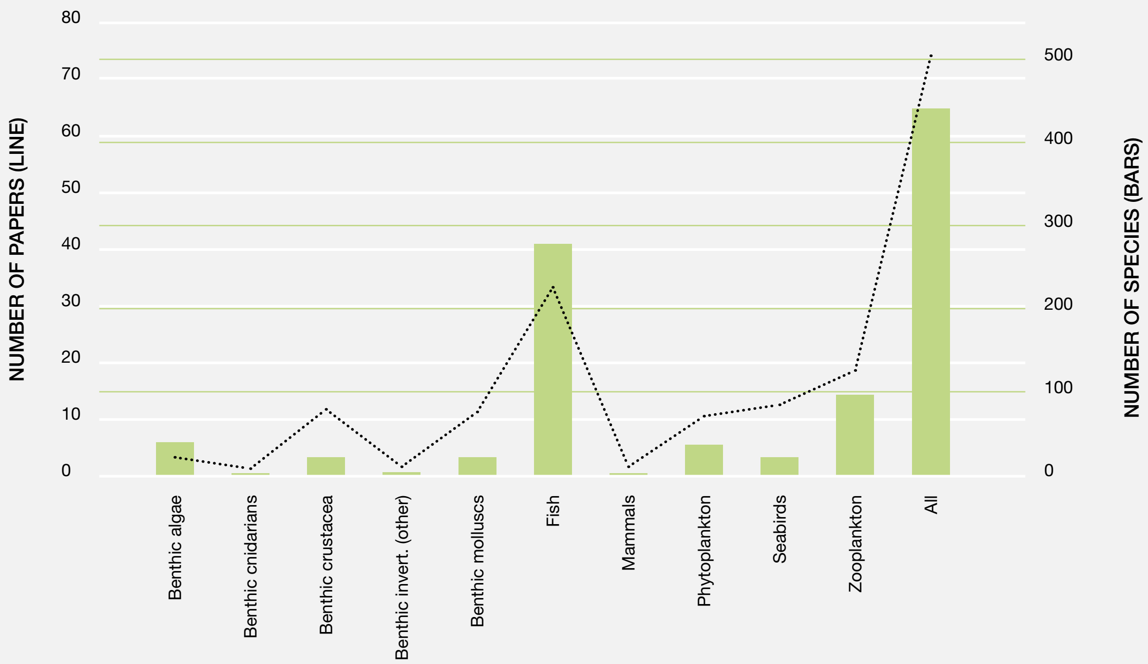
Similarly, almost a quarter of all European freshwater molluscs are data deficient and many might prove to be threatened once enough data become available to evaluate their extinction risk. However, the number of data-deficient species may well increase, since 76% of freshwater fishes and 83% of freshwater molluscs have unknown population trends (Cuttelod *et al.*, 2011). Data are also deficient for many other freshwater invertebrate groups (Balian *et al.*, 2008). This is owing to several reasons such as lack of taxonomic information, knowledge gaps in geographical coverage of data and lack of long-term data. These gaps need to be assessed urgently, by fostering taxonomic research and monitoring and by making proprietary databases and databases under pay-wall freely and openly available.

Biases across taxonomic groups in marine systems are also largely documented (McCauley *et al.*, 2015; Poloczanska *et al.*, 2013) **(Figure 3.59)**. For instance, no extinction of marine animal species has been documented in the past five decades (IUCN, 2017b), but only a small fraction of described marine mammals has been evaluated and 17 that were assessed were determined to be data deficient (IUCN, 2017c; McCauley *et al.*, 2015). This is exemplified by the extensive work carried out by Brooks *et al.* (2016) in which marine taxa are not included, except for decapods. This is not surprising, since trend data are not available even for 69% of the best-known group of marine organisms, the European marine fish species.

Availability of regional information on marine plankton and invertebrates is varied across Europe and Central Asia, with certain systems having more information on biodiversity status available (e.g. the North East Atlantic (OSPAR, 2017); the Mediterranean (Coll *et al.*, 2010a); and the Baltic (Ojaveer *et al.*, 2010). Most often, information remains descriptive: existence, abundance, geographical distributions of species for instance, but little meta-information is available yet to discern conservation status. OSPAR (2008) lists five marine invertebrate species as threatened or declining in the North Atlantic and North Sea since 2003, as well as a series of habitats formed by marine invertebrates (e.g. mussel beds, deep sea sponge aggregations). In the Mediterranean, while much information is available, marine invertebrate knowledge is often considered to be limited, with new species still being described. There is also a high proportion of endemic

Figure 3 59 **Number of papers examining past and current trends in marine communities and ecosystems (total 73) in the Atlantic.**

The total number of species examined (total 440) in these papers (per taxonomic group) is indicated by the bars. Source: Data extracted from raw data compiled by Poloczanska *et al.* (2013).



species in the Mediterranean, especially sponges and mysids (Coll *et al.*, 2010a). Mediterranean anthozoans have been reviewed in detail by IUCN, showing that 13% of them are threatened while almost half lack sufficient data for assessing risk of extinction (Otero *et al.*, 2017).

Marine microbes may represent more than 90% of the ocean's biomass, are the major drivers of its biogeochemical cycles (Danovaro *et al.*, 2017), and can be found in the whole water column up to 2,000 metres below the seafloor. Although there has been an exponential increase in research on marine archaea, bacteria and viruses, and evidence that archaea and viruses may increase in importance with depth (Danovaro *et al.*, 2015) their biodiversity and functioning is still largely unknown.

At least 7,000 species of lichens are known to occur in Europe (excluding Russia), while across the whole of Europe and Central Asia only five lichen species have been assessed in the IUCN Red List and have known conservation status (IUCN, 2017b).

Less than 10% of all species of vascular plants known to occur in the region have been assessed by the IUCN Red List (2,483 species for an estimated >30,000 for the region) (IUCN, 2017c). Among those assessed, 46.2% have unknown population trends. These also include species of conservation concern, such as 20% of the species included in the European Red List of Vascular Plants; (Bilz *et al.*, 2011). These knowledge gaps are caused by lack of field data, difficulties in accessing data for some countries, and uncertain taxonomy. Processes threatening vascular plants are also unknown for several species.

The number of fungus species in Europe exceeds 75,000, 15,000 of which are macrofungi (Senn-irlet *et al.*, 2007). Currently there are no regional or continental data on status and trends of fungi.

We were unable to assess status and trends in diversity, biomass and community composition of soil and freshwater micro-organisms: Protozoa, Bacteria, Rotifera, Nematoda, Tardigrada, despite the key role of these organisms in soil formation, nutrient and carbon cycling, and water retention (Orgiazzi *et al.*, 2016).

Relationship between biodiversity and ecosystem function and services

For some ecosystem services, there is insufficient data to evaluate the relationship between biodiversity and ecosystem service provision. For example, the effects of fish diversity on fisheries yield and the effects of biodiversity on flood regulation are inconclusive (Cardinale *et al.*, 2012). Additionally, ecosystem services provided by taxa other than plants are only beginning to be studied. Finally, the majority of studies reviewed focused on taxonomic diversity at the community level (i.e. species richness or diversity), rather than on intraspecific, functional phylogenetic diversity.

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CHAPTER 4

DIRECT AND INDIRECT DRIVERS OF CHANGE IN BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE

Coordinating Lead Authors:

Marine Elbakidze (Ukraine/Sweden), Thomas Hahn (Sweden), Niklaus E. Zimmermann (Switzerland)

Lead Authors:

Pavel Cudlín (Czech Republic), Nikolai Friberg (Norway), Piero Genovesi (Italy), Riccardo Guarino (Italy), Aveliina Helm (Estonia), Bengt-Gunnar Jonsson (Sweden), Szabolcs Lengyel (Hungary), Boris Leroy (France), Tommaso Luzzati (Italy), Ann Milbau (Belgium), Ángel Pérez-Ruzafa (Spain), Philip Roche (France), Helen Roy (United Kingdom of Great Britain and Northern Ireland), Adam Vanbergen (United Kingdom of Great Britain and Northern Ireland), Vigdis Vandvik (Norway)

Fellow:

Rahat Sabyrbekov (Kyrgyzstan)

Contributing Authors:

Lucas Dawson (Australia/Sweden), Jesper H. Andersen (Denmark), Alexei Andreev (Republic of Moldova), Per Angelstam (Sweden), Sakina-Dorothée Ayata (France), Clémentine Azam (France), Grégory Beaugrand (France), Fjoralba Begeja (Albania), Céline Bellard (France), Elisabeth Conrad (Malta), Cédric Cotté (France), Nicolas Dubos (France), Victoria Elias (Russian Federation), Amy Elizabeth Eycott (United Kingdom of Great Britain and Northern Ireland/Norway), Martin Forsius (Finland), Lucy Frances (Ireland), Bella Galil (Israel), Mariana García Criado (Spain), Marine Herrmann (France), R. Justin Irvine (United Kingdom of Great Britain and Northern Ireland), Steffen Kallbekken (Norway), Konstantin Kobyakov (Russian Federation), Zheenbek Kulenbekov (Kyrgyzstan), Edward Lewis (United Kingdom of Great Britain and Northern Ireland), Anne Lyche Solheim (Norway), Mikael Malmaeus (Sweden), Concepción Marcos (Spain), Dan Minchin (Ireland), Zsolt Molnár (Hungary), Jan Mulder (Norway), Olga Murashko (Russian Federation), Ana Nieto (Spain), Geert Jan van Oldenborgh (The Netherlands), Alexander Prishchepov (Russian Federation/Denmark), Bohdan Prots (Ukraine), Gilles Reverdin (France), Aibek Samakov (Kyrgyzstan), Hanno Seebens (Germany), Nikolay Shmatkov (Russian Federation), Ilya Smelansky (Russian Federation), Isabel Sousa Pinto (Portugal), Yuliia Spinova (Ukraine), Kanat Sultanaliev (Kyrgyzstan), Anne Sverdrup-Thygeson (Norway), Oleksiy Vasyliuk (Ukraine), Piero Visconti (Italy/United Kingdom of Great Britain and Northern Ireland), Marten Winter (Germany), Rafael Wüest (Switzerland), Taras Yamelynets (Ukraine), Alexey Zimenko (Russian Federation)

Review Editors:

Heli Saarikoski (Finland), Theo van der Sluis (The Netherlands)

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CHAPTER **4**

DIRECT AND INDIRECT DRIVERS OF CHANGE IN BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE

EXECUTIVE SUMMARY

The major direct anthropogenic drivers – natural resource extraction, land-use change, pollution, climate change and invasive alien species – all strongly impact on biodiversity and nature's contributions to people in Europe and Central Asia, posing substantial risks for nature and human well-being (*well established*) (4.2.1). Direct drivers act independently and in combination, amplifying and altering their context-specific individual and combined effects on biodiversity and nature's contributions to people (*well established*) (4.2.3, 4.9.1). For example, the impacts of climate change are considerably exacerbated by adverse land-use changes. Direct drivers also impact each other through different feedback systems and alter driver trends (*established but incomplete*) (4.9.1). Indirect drivers – institutional, economic, demographic, cultural & religious and scientific & technological – interactively determine the trends and impacts of direct drivers (*well established*) (4.2.3).

The belief that further GDP growth will facilitate sustainable development is a deeply rooted cultural driver, especially evident in Western and Central Europe, calling for smart, inclusive and sustainable growth. However, this requires an absolute decoupling between GDP growth and degradation of biodiversity and nature's contributions to people which has not generally been observed (*established but incomplete*). Such decoupling is theoretically possible but would require a radical change in policies and tax reforms at the global and national levels (4.3.1, 4.3.2, 4.3.4). Domestic material consumption has increased in almost all European Union countries since the year 2000 (except for the economic contraction following the financial crisis in 2008), supported by growth-oriented policies (4.4.4.2). There is some evidence that human well-being does not increase further once a certain income threshold has been reached. Indeed, the sustainability challenge is to decouple quality of life (well-being) from environmental degradation and pay less attention to GDP (*unresolved*) (4.3.2, 4.3.4). Such decoupling would require new indicators on well-being, equity, environmental quality, biodiversity conservation and nature's ability to contribute to people. Policies for resource efficiency have been implemented, but the tax system continues to impede recirculation and resource efficiency and hence transitions towards a "green economy". For example, the total revenue from environmental taxes in the EU-28 in 2014 was only 2.5% of GDP, or 6.3% of the total revenues derived from all taxes and social contributions. These proportions have decreased since 2002, from 2.6% and 6.8%, respectively (*well established*) (4.3.2).

Demography as an indirect driver varies significantly between the subregions, with a dramatic population decrease projected for Central Europe (*established but incomplete*). Urban development will continue to affect natural and semi-natural rural land in large parts of Europe and Central Asia. The population of Europe and Central Asia, 910 million, is stable, but a dramatic population decrease in Central Europe (excluding Turkey) is projected until 2050, from 123 to 104 million, due to currently low fertility rates and high emigration rates (4.3.3). On-going rapid urbanization as people move from rural areas into cities in Central and Eastern Europe and in Central Asia is fuelled by the deterioration of livelihoods in rural areas (4.3.3 and 4.5.6). The consequent urban development results in both urban sprawl and rural land abandonment. In Western Europe, urbanization occurs increasingly as people move from inland areas to coastal cities, which puts further pressure on estuaries and other coastal ecosystems (*well established*). There is a high potential for migration from Turkey and Central Asia to Eastern and Central Europe in the coming decades. Armed conflicts have profound effects on migration; for example, Turkey recently received (by March 2016) over 3 million refugees from Syria, Iraq and Afghanistan. These large migrations may have important effects on other drivers of biodiversity change (*established but incomplete*) (4.3.3).

Conventional intensification of agriculture and forestry has resulted in habitat loss, fragmentation, and degradation and has negative impacts on biodiversity and nature's contributions to people (*well established*)

(4.5.1, 4.5.2, 4.5.3). Intensification of agriculture has resulted in conversion of natural and semi-natural habitats on fertile landscapes, with severe negative impacts on biodiversity (*well established*) (4.5.1, 4.5.2, 4.5.3). In marginal lands, the side-effect of agricultural intensification has been the degradation and abandonment of traditionally managed semi-natural habitats and cultural landscapes that support high biodiversity and provide the magnitude of nature's contributions to people (*well established*) (4.5.1, 4.5.2, 4.5.5). Despite agri-environmental schemes and other mitigation measures, conventional intensive agriculture is jeopardizing sustainable land management, biodiversity, and food production (*established but incomplete*) (4.5.1, 4.5.2). Measures including ecological restoration, sustainable approaches to agriculture, e.g. ecological infrastruture that harness nature's contributions to people and inclusion of indigenous and local knowledge, have mitigated some of the adverse effects of intensive agriculture and represent opportunities to simultaneously secure diverse nature's contributions to people and conservation of biodiversity (*established but incomplete*) (4.5.1, 4.5.2).

Production of forest biomass for energy purposes and intensification of forest management have negative impacts on biodiversity and soil quality, as well as an array of material and non-material contributions from nature. The trade-offs between increasing intensity of forestry and delivery of diverse nature's contributions to people are recognized as a major challenge for forestry in Europe and Central Asia. Additionally, there is continuous logging in intact forest landscapes across the region (*established but incomplete*) (4.5.3). Environmental NGOs have played a key role in the adoption of forest certification schemes, which have reduced "wood mining" of remaining intact forests and have led to the inclusion of biodiversity conservation criteria and indicators in intensive forest management systems (*well established*) (4.5.2, 4.5.3).

Abandonment of intensively managed agricultural land has been widespread across Europe and Central Asia (*well established*). However, a comprehensive assessment of the effects of this process on biodiversity and nature's contributions to people is limited by knowledge gaps. In the European Union, cropland area has decreased by almost 1.2 million hectares in recent decades and largely been replaced by forested and urban areas (4.5.2, 4.5.4). Enlargement of the European Union to Central Europe and implementation of the European Union Common Agricultural Policy in new member States have resulted in the reconversion of some of this abandoned farmland to intensive agriculture – a trend that is likely to continue. Eastern Europe and Central Asia are and will remain hotspots of agricultural land abandonment (*well established*) (4.5.2). This has resulted in substantial reduction in livestock, and decline in crop production in these subregions. With the economic recovery and increasing domestic and foreign investments in agriculture after the year 2000, re-cultivation of some abandoned croplands began, particularly in the agriculturally favourable black soil regions in the south of European Russia, Ukraine and northern Kazakhstan (4.5.2, 4.5.3).

Abandonment of extensively managed traditional land-use systems, and loss of associated indigenous and local knowledge and practices, has been widespread in Europe and Central Asia (*well established*) (4.5.5). Cessation of traditional land use has led to loss of semi-natural habitats which support biodiversity of high conservation value (*well established*) (4.5.1). Loss of traditionally managed semi-natural habitats, especially grasslands, has resulted in decline and loss of associated biodiversity and ecosystem functions. Demographic trends, including urbanization, continue to diminish indigenous and local populations, with concomitant negative impacts on traditional land-use knowledge, culture and identities (*established but incomplete*) (4.5.5). In Europe and Central Asia, production-based subsidies driving growth in agricultural, forestry and natural resource extraction sectors tend to exacerbate conflicting land-use issues, often impinging on available territory for traditional users (*established but incomplete*) (4.5.5). In some areas, traditional practices are maintained to a certain extent, and traditional ecological knowledge is adapting to new ecological and socioeconomic conditions. Maintenance of traditional land use and lifestyles in Europe and Central Asia is strongly related to institutional adequacy and economic viability. Traditional land uses and knowledge are becoming increasingly recognized for their value in solving problems related to biodiversity conservation and the sustainable use of natural resources and ecosystems (*established but incomplete*) (4.5.5). The growth of green tourism and demand for products derived from traditional practices and the availability of subsidies for traditional land uses are important factors in ensuring the economic viability of indigenous peoples and local communities (*well established*) (4.5.5).

Protected areas have enormous importance for biodiversity conservation, and the area under protection has been constantly expanding during recent decades across the region (*well established*) (4.5.4). In Europe and Central Asia, the total coverage of areas declared as protected is 10.2%, with 13.5% of the terrestrial area and 5.2% of the marine area being protected. Natura 2000 in the European Union represents a systematic effort to develop new protected areas (4.5.4). Measures to improve environmental status within conservation areas combined with landscape-scale approaches that improve matrix quality for native biodiversity are needed (*established but incomplete*) (4.5.1.7). The prioritization and implementation of adequate legal frameworks for protected area development has largely been driven by the adoption of international agreements, as well as increasing public environmental awareness. The perceived trade-offs with economic development goals, however, have in many cases delayed the development of, or weakened, adequate nature conservation policies. The inadequacy of institutions in navigating local resistance to protected areas and regulating the negative impacts of conflicting land uses outside of protected areas poses important problems for biodiversity conservation. Environmental NGOs have had an important impact in building public awareness of the role of nature protection, leading to shifts in consumer preferences and political priorities. Additionally, Europe and Central Asia is unfortunately the arena for a number of recent and current armed conflicts. Armed conflict has many deleterious effects on protected areas, including multiple direct and indirect environmental impacts, diversion of economic resources from protected area budgets, loss of institutions and human resources, and interruption of long-term monitoring. There is considerable evidence that protected areas alone cannot prevent global biodiversity loss (*well established*) (4.5.4).

Within the present institutional framework, fishing, hunting, and mining pose considerable threats to biodiversity (*well established*). Depletion of local mineral and fish stocks are disguised by global trade, which delays effective responses, and harmful subsidies exacerbating unsustainable extraction levels (*established but incomplete*). Fossil fuels and rare earth minerals are the largest contributors to GDP in Central Asia and the volume of coal mined has doubled in the last decade. The mineral extraction industry in Central Asia has been driven by trade liberalization and increasing world market prices (*well established*) (4.4.4.2). Demand for fish in the European Union continues to exceed the sustainable yield and an increasing proportion of fish is imported. In a closed market economy, the local shortage of material contributions to people due to excessive use would increase prices, drawing attention to the shortage and the reasons for it. However, in a global economy these feedbacks (price signals and awareness) are often masked by substitution. For example, the shortage of cod in Europe has partly been substituted by cod and other white fish from other regions (4.4.1). The more successful globalization and substitution becomes, the longer the delays between declining material contributions to people, e.g. fish stocks, within one region, and policy responses in this region to correct that decline (*established but incomplete*) (4.2.5, 4.4.1). Institutional drivers have changed, e.g. the European Union's Common Fisheries Policy, but economic drivers have not (4.3.1, 4.3.2, 4.4.1.3). Inefficiently low prices of fish are further lowered by harmful subsidies and technological drivers, which result in high harvest levels despite declining stock. Europe, mainly the European Union and Russia, continue to pay about 6 billion USD annually in capacity-enhancing (harmful) fishing subsidies (*well established*) (4.4.1.3).

Despite effective regulations for some forms of pollution, this direct driver still poses major threats to biodiversity, nature's contributions to people and human health *(well established)*. The drivers of pollution are mainly economic, i.e. effects of industrialization and globalization, including conventional intensive agriculture and increases in transportation (*well established*). Pollution is also increased by institutional drivers that foster adverse technological development and the cultural belief that a prosperous life must entail more material consumption (*unresolved*). Pollution is a function of the industrial development model (4.6.6) and in general correlated to GDP (4.3.2) *(established but incomplete)*. However, some pollution problems such as acidification and eutrophication of terrestrial ecosystems have been decreasing in Western and Central Europe since 1990, from 30% and 78%, respectively, of areas exceeding critical pollutant loads of sensitive ecosystems, to 3% and 55%, respectively. This has mainly been accomplished by regulations (*well established*) (4.6.1, 4.6.3). Phosphorous and nitrogen (except ammonia) pollution is decreasing in Europe but, partly due to time lags, many terrestrial systems and a large proportion of lakes and rivers in Western and Central Europe continue to be negatively affected (*well established*) (4.6.1, 4.6.2). Although marine and coastal eutrophication has decreased, the number of marine dead zones due to oxygen depletion resulting from nutrient and organic pollutants has increased markedly (*established but incomplete*) (4.6.1, 4.6.2). Overall, there is evidence that pollution particularly negatively affects freshwater and marine biodiversity and water quality across Europe and Central Asia (*well established*). Global sales by the chemical industry doubled between 2000 and 2009 and continue to increase. Due to synergistic or "cocktail" effects, substances present in concentrations below recognized health threshold values can still be toxic, leading, for example, to human hormone disruption (*well established*) (4.6.4). Two kinds of pollution are increasing rapidly: plastic debris and microplastics affecting a wide array of marine organisms; and artificial light at night affecting terrestrial, aquatic and marine ecosystems (*established but incomplete*) (4.6.5).

There is strong evidence that the climate of Europe and Central Asia is changing towards warmer temperatures and regionally changed precipitation (*well established*) (4.7.2.1, 4.7.2.2), with generally drier summers in the southern and wetter winters in the northern parts of the region and increasing risk and amplitude of extreme climatic events such as droughts and storms (*established but incomplete*) (4.7.2.2, 4.7.2.5). Evidence that climate change impacts biodiversity and nature's contributions to people is emerging rapidly, and climate change is likely to become one of the most important drivers in the future, especially in combination with other drivers (*established but incomplete*)

(4.9.2.2). The temperature will increase in the next decades and most units of analysis (biomes and land cover types) will experience an average warming between 1 and 3°C by 2041-2060 relative to 1986-2005, with larger increases for northernmost biomes such as snow and ice dominated ones and tundras (*well established*) (4.7.1.2). Precipitation patterns are projected to change across Western and Central Europe: drier climates and increased drought risk in their south-west, no change or increased precipitation in their north-west, while trends for Eastern Europe and Central Asia are ambiguous (*established but incomplete*) (4.7.2.2). Effects on biodiversity and nature's contributions to people vary according to the ecosystem itself, in particular depending on whether productivity is precipitation-, radiation- or temperature-limited. Climatic warming and precipitation change are driving shifts in seasonal timing, growth and productivity, species ranges and habitat occupancy with impacts on biodiversity, agriculture, forestry, and fisheries (*well established*) (4.7.1.1). Knowledge of the underlying processes and mechanisms suggests that many species will not be able to respond, migrate or adapt fast enough to keep pace with the projected rates of change in mean climate conditions, threatening ecosystem functioning and livelihoods (*established but incomplete*) (4.7.1.1.2). Across Europe and Central Asia, increased drought results in decreased primary productivity, increased net carbon flux to the atmosphere, nutrient leaching from terrestrial systems and algal blooms, biodiversity loss, and decreased water quality in aquatic systems (*established but incomplete*) (4.7.1.1). The fifth assessment report of the Intergovernmental Panel on Climate Change established that economic growth is the main driver of greenhouse gas emissions and hence climate change in Europe and Central Asia (*well established*) (4.7.3). From 1970–2010, economic growth has been only partially offset by improvements in the energy intensity of the economy and the emissions intensity of energy production, and policies have proved insufficient in influencing infrastructure, technological, or behavioural choices at a scale that curbs the upward greenhouse gas emissions trends (*well established*) (4.7.3). Per capita emissions vary widely, depending on geography, income, lifestyle, and the available energy resources and technologies, leading to differences in climate footprints within Europe and Central Asia (*established but incomplete*) (4.7.3).

Evidence is emerging that indirect climate change effects, such as increased fire and flood risks and loss of permafrost are affecting biodiversity and nature's contributions to people in Europe and Central Asia (*well established*) (4.7.1.3). Increased precipitation, especially in winter, will result in increased flood risk in the northern parts of Western and Central Europe (*established but incomplete*) (4.7.2.1). Floods are a serious hazard to people, and increase erosion, water turbidity and eutrophication, impacting freshwater provisioning (*established but incomplete*) (4.7.1.2). Increased fire risk is projected across large parts of Western and Central Europe (*established but incomplete*), while projected increases in fire danger for Eastern Europe and Central Asia are uncertain. Near-surface permafrost extent at high northern latitudes is projected to decrease by between 37% (RCP2.6) and 81% (RCP8.5) by the end of the 21st century, (*established but incomplete*). In Arctic and alpine regions, permafrost melting may lead to large greenhouse gas emissions, and short-term heat waves negatively impact productivity and may result in reduced food availability for wildlife and livestock (*unresolved*). Climate change further leads to ocean acidification, sea level rise and changes in ocean stratification, generally resulting in biodiversity loss, reduced growth and productivity and hence impaired fisheries and increased release of CO_2 to the atmosphere (*established but incomplete)* (4.7.1.3).

Invasive alien species have increased in number and for all taxonomic groups across all subregions of Europe and Central Asia and this has severe effects on biodiversity and nature's contribution to people (*well established*). For Eastern Europe and Central Asia, the rate of invasion has been less severe than in Western and Central Europe, but is expected to increase at a rate that strongly depends on GDP development (*established but incomplete*) (4.8.1, 4.8.2). Rates of increase in numbers of invasive alien species are strongly correlated with introduction rates. Introduction rates of alien species are strongly related to trade networks and have increased dramatically over the last 200 years in all environments (terrestrial, freshwater and marine), with 37% of first records reported from 1970-2014 (*well established*). Invasive alien species are affected by interactions with other drivers of change such as land-use change and climate change (*established but incomplete*). The invasion process (transportation, introduction, establishment and spread) is influenced by economic factors. Major pathways of introduction in Europe and Central Asia include horticulture and ornamental trade, accidental transportation, creation of commercial paths such as canals, and tourism (*well established*). International, national and sub-national legal instruments targeting invasive and alien species have been developed in Western and Central Europe but are currently lacking in Eastern Europe and Central Asia. In addition, proactive educational outreach programmes as well as transboundary legal instruments targeting major introduction pathways have shown promising potential for improved prevention and earlier detection of invasive alien species (*well established*). However, Aichi Biodiversity Targets 5 and 9 are unlikely to be achieved for Europe and Central Asia because of ongoing habitat conversion and fragmentation (Target 5) and because invasive alien species are not adequately controlled and are still increasing in numbers (Target 9) (*established but incomplete*) (4.5.1, 4.8.2). Invasive alien species generally tend to have negative effects on biodiversity and nature's contributions to people. However, their magnitude and direction vary among types of impact, taxa and environments (*well established*) (4.8.1).

In addition to immediate effects, the individual and combined effects of natural resource extraction, land-use change, climate change, diffuse pollution and invasive alien species can have chronic, prolonged and delayed impacts on biodiversity and the provision of nature's contributions to people, due to considerable time-lags in the response of ecological systems (e.g. extinction debt, colonization time-lags) (*well established*) (4.9.1). For example, species extinctions due to habitat area loss and increasing fragmentation can take decades or centuries due to the slow intrinsic dynamics of populations of many species (*well established*) (4.5.1, 4.9.1). Climate change can have delayed effects on change in species distribution patterns and development of species assemblages under new conditions because of time lags in population response and migrational lags (*established but incomplete*) (4.7.1.1.2, 4.9.1). Nutrient pollution continues to influence terrestrial and aquatic ecosystems for decades after external inputs are reduced (*well established*) (4.6.1). Considerable delays occur between the initial introduction of alien species and their possible spread as invasive alien species (*well established*) (4.8.1). Such time-lags introduce uncertainty and can lead to serious underestimation of the effects of current direct drivers on biodiversity and nature's contributions to people. Decisive and proactive policies would avoid future loss of species and nature´s contributions to people (*established but incomplete*) (4.5.1, 4.6.1, 4.7.1, 4.8.1, 4.9.1).

4.1 INTRODUCTION

4.1.1 Aim of the chapter

The aim of this chapter is to assess evidence of the status and trends of the drivers that affect biodiversity and nature's contributions to people. There are three wider categories of nature's contributions to people: regulating, material and non-material contributions, that are similar to, but not identical to classifications of ecosystem services (see Chapter 1). Ecosystems are dynamic interacting networks of animals, plants, fungi, and microorganisms, above and below ground and water-surfaces. These biodiverse networks of interacting organisms respond to a set of environmental factors such as climate, soil, or water conditions. Social-ecological systems also include human activities (direct drivers) that modify almost all of these ecosystem interactions and environmental factors, and the underlying societal (indirect) drivers of these activities. It is thus important to understand the status and trends of the direct and indirect drivers that affect biodiversity, including ecosystems and, thereby, affect nature's contributions to people.

4.1.2 Scope and organization of the chapter

This chapter focuses on the effects of drivers on biodiversity and nature's contributions to people and thereby only indirectly on quality of life, which is dealt with in greater detail in Chapter 2. Section 4.1 describes the scope of the chapter, the role of drivers in the IPBES conceptual framework, and methodological approaches. Section 4.2 explains which system of "drivers of change" is addressed in this assessment. We compare and specify concepts which have been used in earlier assessments to justify the choice of direct and indirect drivers, including their sub-categories. The section also discusses the importance of the temporal and spatial variability of drivers and interregional flows. Section 4.3 assesses major trends in the five individual indirect drivers in Europe and Central Asia. Indirect drivers are then assessed for each direct driver in the subsequent sections.

Chapters 2 and 3 of the IPBES Regional Assessment for Europe and Central Asia identified strong evidence that biodiversity and nature's contributions to people are declining, and that natural resource extraction, land-use change, pollution, climate change, and invasive alien species are the main direct drivers of these changes. Sections 4.4 to 4.8 assess five direct drivers, one in each section. We first assess the overall effects of the direct drivers on biodiversity and nature's contributions to people in Europe and Central Asia (please note that the specific effects of direct drivers on specific taxa and each unit of analysis (i.e. types of ecosystems, see Chapter 1) are the subject of Chapter 3). After establishing the general effects of the direct drivers, we provide an assessment of the trends in each direct driver and sub-categories of the drivers within the different regions and units of analysis over the recent past (20-40 years) and projected into the future (50-85 years). We use the word "projected" rather than "predicted" because in the medium long run, predictions of the future are not possible. Then we assess the indirect drivers that underpin the direct drivers of changes in biodiversity and nature's contributions to people. As described below, the indirect drivers interact considerably and are often context specific, and therefore they should not be assessed in isolation. We use causal loop diagrams (CLDs) to illustrate some of the complex interactions and causal relationships affecting each driver.

Section 4.9 synthesizes the main findings for the overall trends in, and impacts of, drivers on biodiversity and nature's contributions to people across subregions and biomes (the unit of analysis) in the past and projected into the future. For direct drivers, this synthesis is based on an assessment of all sub-categories of drivers and their compound impacts. For indirect drivers, the synthesis in 4.9.3 is based on the empirical sections.

4.1.3 Driver as a concept

The distinction between "indirect" and "direct" drivers was popularized by the Millennium Ecosystem Assessment (MEA, 2005b) and this classification still dominates the debate on ecosystem change (e.g. Pereira *et al.*, 2010). The older DPSIR terminology (drivers, pressures, states, impacts, responses), popular in Western Europe (Stanners & Bourdeau, 1995), divided drivers into "driving forces" and "pressures", with the former corresponding to indirect drivers and the latter corresponding to direct drivers of the Millennium Ecosystem Assessment (Tzanopoulos *et al.*, 2013).

4.1.4 Natural and anthropogenic drivers

Analytically it is sometimes difficult to distinguish whether an element (process, factor, driver) belongs to the natural or the human system. Biogeophysical processes and factors such as volcanic eruptions, tsunamis, El Niño, solar radiation, or storms, are natural and they influence all elements of life on earth. These "natural drivers" and extreme events are not assessed in this chapter. Our analysis is limited to drivers linked to human activities, and are therefore considered anthropogenic or at least anthropogenically influenced drivers. In this context, direct drivers are the result of human interactions with natural processes that directly act upon biodiversity, including ecosystems, by altering natural processes, while indirect drivers are structures and processes governing the human interactions, thereby influencing direct drivers. So, while we would consider climate and weather, habitats, and species' dispersal and range dynamics to be natural processes, anthropogenic climate change, land-use change and invasion by alien species reflect the human influence on climate, land use and biodiversity dynamics, respectively.

However, to unequivocally disentangle natural variability from anthropogenic drivers is often difficult. Human impacts now affect more than half of the Earth's ice-free terrestrial surface (Ellis *et al.*, 2010) and humans now exert a dominant influence on key Earth system processes and on ecosystem change and biodiversity loss (Newbold *et al.*, 2015, 2016; Steffen *et al.*, 2007). This has led to the coining of a new geological epoche, the "Anthropocene" (see Crutzen, 2002). While there is debate over when, exactly, the transition from the Holocene to the Anthropocene occurred, it is often set to when human impacts took over as a dominating influence on the earth system processes, early in the 20th century (see Steffen *et al.*, 2007). Human influences were also present prior to this transition, and the nature and magnitude of the impacts through time and especially in the more distant past 3,000-8,000 years ago, are still debated (Ruddiman, 2013; Scott *et al.*, 2014). This assessment takes a pragmatic approach to this challenge, focusing on assessing the impacts of major modern (i.e., post-industrial) anthropogenic drivers relative to the more-or-less human affected pre-industrial landscapes (see also Nybø *et al.*, 2017). **Box 4.1** exemplifies the analytical challenges in distinguishing between "natural" or "anthropogenic" factors in the past through the example of forest fires.

4.2 DRIVERS OF CHANGE IN BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE

4.2.1 Direct drivers

The Millennium Ecosystem Assessment (MEA, 2005b) distinguished five major classes of direct drivers of

Box 4 1 Natural or human control over forest fires in northern Europe?

It is sometimes difficult to clearly separate natural (Earth system) and anthropogenic (human activities) drivers and land use often interacts with natural processes. A typical example is the occurrence of forest fires in the northern boreal forests of Europe and Central Asia.

Long term chronologies based on charcoal in sediments, covering 10,000 years after the last glaciation (Holocene), suggest climate has been the main governing factor for fire regimes (Carcaillet *et al.*, 2007). Although humans have been present during most of the Holocene (based on carbon-14 dated archaeological features) on millennial scales, fire history does not show any relationship to human presence in these remote landscapes. Hence, Carcaillet *et al.* (2007) suggest that natural processes have been decisive for the long-term fire pattern. It has also been argued, based on dendrochronological (tree-ring based) reconstructions that years with many large fires may be controlled by the climate (Drobyshev*et al.*, 2015).

However, several dendrochronological reconstructions (with high temporal resolution) show clear links between fire patterns and human presence in the landscape during most of the last millennium (Granström & Niklasson, 2008; Walleniuset *al.*, 2004). Granström and Niklasson (2008) depict several fairly distinct periods of human influence on forest fires. In the earliest stage (during the millennia after the deglaciation), prehistoric moose hunters may have used fire to open the landscape in order provide better grazing conditions.

When the Sami people in the northern parts of Europe and Central Asia began changing from hunting reindeer to reindeer husbandry in the 17th century (Hahn, 2000), they had an incentive to ensure that ground vegetation conditions (lichens) were suitable for reindeer. Since only an estimated 1% of the stands naturally burned every year (Zackrisson, 1977) and the repeated burning was important to create open all-aged tree stands optimal for maintaining lichen cover on the ground (Axelsson & Östlund, 2001; Berg *et al.*, 2008; Östlund *et al.*, 1997), fires were probably an important management practice also for the early forms of reindeer husbandry. When commercial forestry was established from the mid-1800s, it resulted in increasingly effective fire suppression. Dense monoculture forests and lack of fires have reduced the extent of lichen covered areas in Sweden by 70% since 1955 (Sandström *et al.*, 2016).

On the border between current Finland and Russia there is an apparent mismatch between predicted lightning ignition frequency and observed fire history, suggesting that as far back as a millennium ago, a very small human population may have played a role in the fire history of remote boreal forests (Wallenius *et al.*, 2010a). This leads to the conclusion that potentially the boreal forests that developed after the glaciation have to quite some extent been formed by human presence in the landscape.

biodiversity change, namely habitat change, climate change, invasive alien species, over-exploitation and pollution (mostly nitrogen and phosphorous). Here, we largely follow this classification of direct drivers, although we use "natural resource extraction" instead of "over-exploitation, to avoid using value-laden terms **(Table 4.1)**. However, we still use "over-fishing" since this is such an established term in contemporary global fisheries (Worm *et al.*, 2006). Water extraction and fish harvesting are considered here as two sub-categories of natural resource extraction, not as two separate direct drivers as in Pereira *et al.* (2010). Here, we briefly describe the five categories of direct drivers including sub-categories, and explain what is summarized within each of these (see **Table 4.1** for an overview of all classes). None of the sub-categories is uniform in its expected impacts on biodiversity and nature's contributions to people, and we have, therefore, distinguished a number of further elements within sub-categories when analysing the available information for recent and projected future trends.

Natural resources extraction: For biotic resources extraction, we distinguish fishing and hunting. Logging is treated as a sub-category of land-use change and therefore not included here. Gathering of plants for human use (e.g. berries, mushrooms) is identified by IUCN as a threat to biodiversity (Maxwell *et al.*, 2016), but not assessed here. For the extraction of abiotic resources, we distinguish water use & desalination, and mineral & fossil fuel extraction.

Land-use change: Changes in five major land-use categories are assessed, namely: changes in agriculture, forestry, protected areas, traditional land use and urban development.

Pollution: Past assessments focused on pollution from nitrogen and phosphorus (MEA, 2005a, 2005b). In this assessment, we distinguish five main categories of pollutants, namely: nutrient pollution, organic pollution, acidification, xenochemical and heavy metal pollution and "other" pollution (including ground-level ozone, light and plastic pollution).

Climate change: This driver class has been studied prominently in recent IPCC reports, with regards to both its current and projected future trends, and its expected impacts on terrestrial and marine ecosystems (IPCC, 2013b, 2014a, 2014b). Here, we distinguish seven major sub-categories, namely: changes in precipitation, temperature, atmospheric CO_2 concentrations, glacier and permafrost extent, sea-level, extreme events, and marine ocean-atmosphere interchange.

Invasive alien species: An alien species (also known as an exotic or introduced species) is a species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities (CBD, 2011). Invasive alien species (IAS) are alien species whose introduction or spread threaten biological diversity or that have other negative effects on ecosystems, economy or society (CBD, 2011; Roy *et al.*, 2014a). In this report, we distinguish three major categories of invasive alien species, namely: terrestrial, freshwater (including brackish waters), and marine.

Table 4.1 **Categories of direct drivers of change in biodiversity and nature's contributions to people. The five major categories are composed of two to six subcategories. More details for each sub-category are given in the text.**

Natural resources extraction • Fishing • Hunting • Water use & desalination • Mineral & fossil fuel extraction	**Climate change** • Temperature change • Precipitation change • Sea-Level change • Glaciers & permafrost • Extreme events • Marine circulation and deoxygenation • Atmospheric CO_2 concentration
Land-use change • Changes in agriculture • Changes in forestry • Changes in protected areas • Changes in traditional land use • Changes in urban development	**Invasive alien species** • Terrestrial • Freshwater & Brackish • Marine
Pollution • Nutrient pollution • Organic pollution • Acidification • Xenochemical & heavy metal pollution	

4.2.2 Indirect drivers

We identify five categories of indirect drivers, adapted from Hauck *et al.* (2015) building on the MEA (2005b) framework. Some scholars call indirect drivers "underlying drivers" (van Vliet *et al.*, 2015), "underlying causes," "fundamental social processes" (Geist & Lambin, 2002), "categories of origin" or "key driving forces" (Brandt *et al.*, 1999). Hence, there are different attempts to conceptualize indirect drivers **(Table 4.2)**. If indirect drivers are the underlying causes of, for example, land-use change or pollution, then the tangible results of human activities can be seen as direct drivers, or "proximate causes". For example, for deforestation, proximate causes can include agricultural expansion, wood extraction or the extension of road infrastructure (Geist & Lambin, 2002). Indirect drivers do not directly impact biodiversity, but may have a direct impact on nature's contributions to people, according to the IPBES conceptual framework. For example, some legal restrictions may reduce nature's contributions to people to certain groups of people and some non-material contributions of nature are co-produced by people and nature (Díaz *et al.*, 2015).

The literature on indirect drivers often treats land-use change as the dependent variable and gives less attention to its consequences for biodiversity and ecosystem services. Van Vliet *et al.* (2015) include "location factors" as an underlying (indirect) driver, consisting of accessibility, climate, topography, and soil quality ("EU" in **Table 4.2**). Similarly, Brandt *et al.* (1999) include "natural environment" ("UNESCO" in **Table 4.2**) as a key driving force, consisting of geomorphology, soil, climate and hydrology. Geist and Lambin (2002) also include "pre-disposing environmental factors" such as soil, topography and fragmentation mediating the underlying drivers ("IGBP-IHDP" in **Table 4.2**). Furthermore, they address biophysical and social triggers, which ecologists call "fast variables" or "disturbances".

Based on Geist and Lambin (2002), we identify biophysical triggers including fires, droughts, floods and storms, and social triggers including revolution, social disorder, abrupt displacements, economic shocks, and abrupt policy shifts. These triggers emerge from indirect drivers and may have dramatic effects on direct drivers. The breakdown of the Soviet Union (Baumann *et al.*, 2011; Prishchepov *et al.*, 2013) and the nuclear accident of Chernobyl (Hostert *et al.*, 2011) could not be foreseen, but led to widespread farmland abandonment and decreasing land-use intensity. From a policy perspective, it is important to understand both drivers and triggers, to "accept uncertainty, be prepared for change and surprise, and enhance the adaptive capacity to deal with disturbance" (Folke *et al.*, 2005).

Here, we use categories of indirect drivers similar to previous assessments and studies **(Table 4.2)**. However, the sub-categories of indirect drivers have been updated as outlined in **Table 4.3**.

Institutional drivers: Legislation and regulations provide the institutional arrangements (formal institutions, or legal framework) for all natural resource management. We refer to these as "regulations", to distinguish institutional drivers from informal institutions, which are mainly social norms and therefore belong to cultural & religious drivers. Some regulations promote sustainable natural resource management and governance to a greater or lesser extent.

Table 4 2 **Different categorizations of indirect drivers.**

UNESCO[1]	IGBP-IHDP[2]	EU[3]	MA 2005a	IPBES
Socioeconomic	Economic	Economic	Economic	Economic
Policy	Policy/Institutional	Institutional	Socio-political	Institutional
Culture	Cultural	Sociocultural	Cultural & religious	Cultural & religious
–	Demographic	Demographic	Demographic	Demographic
Technology	Technological	Technological	Science & technology	Scientific & technological
Natural environment	(Environmental factors)	Location factors	–	–

[1] Brandt *et al.* (1999); [2] Geist and Lambin (2002); [3] van Vliet *et al.* (2015)

Table 4 3 **Categories of indirect drivers that underpin direct drivers of change in biodiversity and nature's contributions to people. More detailed information about, and motivation for selecting the sub-category under each main category is given in the text.**

Institutional • Regulations • Institutional capacity • Environmental policy integration • Political/armed conflicts	**Economic** • Material intensity of GDP • Globalization • Taxes and subsidies • Environmental fiscal reform
Demographic • Population growth & density • Urbanization • Migration	**Cultural & religious** • Public awareness, knowledge • Values, beliefs, social norms • Lifestyle, consumption • Social capital • Cultural capital
Scientific & technological • New technologies • Innovation	

However, regulations safeguarding biodiversity and nature's contributions to people may not be enforced or, if they are, may not be effective. This depends on the institutional capacity, or the governability of the state, for example to regulate the private/public sectors and to engage civil society (Breukers & Wolsink, 2007; MEA, 2005b). Important institutional drivers are those sector regulations that impact biodiversity and nature's contributions to people, for example, energy, mining, conventional agriculture and forestry, large-scale fisheries, and tourism. Improving or changing these sectoral policies to better account for biodiversity and nature's contributions to people is sometimes called "mainstreaming" or "environmental policy integration" (Nilsson & Persson, 2003), including consistent multilevel governance (Malayang III *et al.*, 2006; Pahl-Wostl, 2009).

The international discussion has lately emphasized the role of policy integration. For example, Strategic Goal A of the Strategic Plan for Biodiversity 2011-2020 addresses "the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society" (CBD, 2010). Hence, assessing changes in institutional drivers can be framed regarding the extent to which countries and regions have succeeded in environmental policy integration (mainstreaming). Institutional drivers are intertwined with other indirect drivers. For example, since markets are influenced by legislation (Bromley, 1991), global trade as an economic driver is largely the result of trade agreements, which are not always consistent with international environmental regulations. Finally, the literature also refers to the role of international collaboration as well as political or armed conflicts.

Economic drivers: Global GDP is expected to increase from about 50 trillion US$ in 2005 to between 155 trillion (UNEP, 2012) and 300 trillion in 2050 (OECD, 2001). These figures diverge considerably and provide no information about how sustainable the growth of GDP is expected to be. Hence, we see material intensity of GDP, not GDP in itself, as a driver. Global trade increases demand for many nature's contributions to people and changes production and consumption patterns, and therefore ecosystem use, at local, national, and global levels. Economic drivers are strongly linked to institutional drivers, which govern production through regulations, taxes and subsidies, thereby influencing relative prices of, for example, fossil fuel versus renewable energy. Internalising external environmental costs may, however, be difficult due to its effects on global competitiveness. Hence, the environmental fiscal reforms called for by the United Nations Environment Programme to make the economy more efficient, must be seen in a global context.

Demographic drivers: This group includes population density and growth, urbanization and migration as well as ageing population (Hossman *et al.*, 2008; Kroll & Kabisch, 2012). Human population growth is one of the most fundamental reasons behind all direct drivers.

Cultural and religious drivers: Public awareness and knowledge about environmental change are fundamental indirect drivers. Filtered by values, beliefs and social norms, public awareness exerts pressure on decision-making about the environment (Nelson *et al.*, 2006). Culture conditions the individual's perceptions of the world, influences what he or she considers important, and suggests courses of action that are appropriate and inappropriate. Although culture is most often thought of as a characteristic of national or ethnic groups, our definition emphasizes the emergence of cultures within professions, organizations and gender, along with the possibility that an individual may be able to draw on or reconcile more than one culture (Nelson *et al.*, 2006). Cultural values are materially manifested in lifestyles and consumption patterns. To enable transitions to sustainability, cultural drivers such as social capital may be mobilized by trust-building (Pretty, 2003).

Scientific and technological drivers: Technology is a major driver of economic growth, accounting for more than one third of the GDP growth in the US 1929-1980 (MEA, 2005b) and similar effects might be expected in Europe and Central Asia. Technology also directly influences direct drivers in very tangible ways, for example in forestry, agriculture and fisheries, resulting in intensification of land uses (MEA, 2005b). Technology can be seen as just a "tool", neither good nor bad. Its effects depend on how it is used and developed. For instance, new information and communication technologies might have the potential for both agricultural intensification and disintensification (Grimes, 2000). At the same time, the direction of technological development is a function of price relations, which in turn are influenced by institutions. For example, the "green" revolution has promoted fossil fuel derived inputs to replace natural inputs in agriculture (Perelman, 1972). With different institutions, technological innovations and development can increase resource efficiency and decoupling, being an integrated part of the transformation to a green economy and an important part of the development of the circular economy (European Commission, 2017b; UNEP, 2011). However, technological development resulting in resource efficiency may lower the price of the natural resource, which in turn may increase the consumption of this resource; this is called Jevons paradox or the rebound effect. Taxes on natural resources (e.g. an environmental fiscal reform) are needed to prevent the rebound effect (Polimeni *et al.*, 2012).

4.2.3 Relationship between indirect and direct drivers

The previous section suggests that indirect drivers are intertwined and in combination influence direct drivers. The interaction among indirect drivers is highly complex, i.e. they are hard to trace back to a single point of origin, and their impacts are often reciprocal and not unidirectional. Jointly, indirect drivers impact on direct drivers, which in turn also interact in the way they drive ecosystem change **(Figure 4.1)**. For example, climate change affects the survival of invasive alien species, and land-use change can have feedback effects on climate. Knowledge about the effects of direct drivers on biodiversity and nature's contributions to people increases public awareness and feedback to the underlying indirect drivers.

4.2.4 Spatial and temporal variability

Even though the major direct drivers are known, their specific effects and overall trends over time are not always easy to identify, quantify and assess. This is primarily due to their high spatial and temporal variability. Some drivers are local in nature (e.g., land-use change and point-source pollution of heavy metals or nutrients), while others are regional (e.g., ozone or atmospheric nitrogen pollution from combustion engines) or global (e.g., atmospheric CO_2 or sea-level rise). Some of these drivers affect all species and ecosystems more-or-less equally (e.g., radioactive pollution), while other drivers affect species and ecosystems very selectively (e.g., nitrogen deposition), and therefore often exert complex effects on biodiversity and nature's contributions to people.

While the effect of some drivers is immediate (e.g. mining), others exhibit significant time lags in their effect on biodiversity and nature's contributions to people. While climate and land-use change and invasions by alien species are steadily increasing, their full effect is often visible only much later, since the biodiversity and ecosystem response is slow. This has given rise to the terms invasion debt (Essl *et al.*, 2011) or extinction debt (Dullinger *et al.*, 2012; Tilman *et al.*, 1994), to express the expected time lags until the full effects of drivers are realized. The many facets of climate change rarely affect species and ecosystems without delay, and the climate itself also lags behind the increase in greenhouse gas concentrations (IPCC, 2014a).

While some effects are steadily shifting (e.g., sea-level rise), others are unstable and show high temporal variability. This is especially the case with climate, which includes changes in mean conditions, time course and extremes (such as heat-waves, drought, fire, floods or winds). The biological response can be linked to the changes in means, time courses and in extremes, and the responses can be gradual or they can be in the form of tipping points between alternative stable states (Barnosky *et al.*, 2012; Hoegh-Guldberg *et al.*, 2007), which can be irreversible.

4.2.5 Interregional flows

Interregional flows include trade in agricultural commodities, fish and wood, which can be measured as human appropriation of net primary productivity (HANPP) (Krausmann *et al.*, 2013). As a result of international and even interregional trade, and with the exception of northern parts of Western Europe, and Eastern Europe, Europe and Central Asia appropriates a larger amount of nature's contributions to people than it produces. Put differently, their ecological footprints exceed their biocapacity (Global Footprint Network, 2017). Interregional trade of nature's contributions to people has consequences for local ecosystems in the exporting country, but also direct global effects. For example, in 2004, the deforestation embodied in final consumption within the EU-27 was 732,000 ha, which was about 10% of the world's annual deforestation (European Commission, 2013) (see also Section 2.2.4 in this Volume).

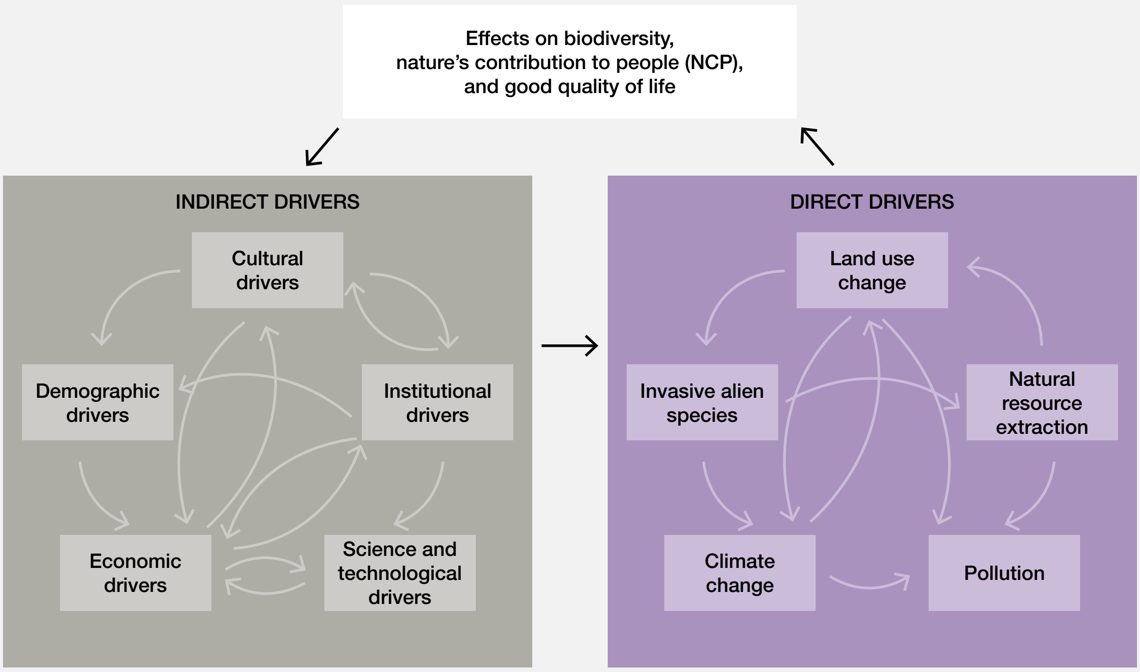
Besides these direct biophysical effects, interregional flows of nature's contributions to people also have profound effects on direct and indirect drivers of ecosystem change. First, the pressures on domestic and regional ecosystems can be reduced when nature's contributions to people are imported, i.e. when natural resource extraction, pollution and land-use change are "exported". Second, interregional flows may have repercussions for other sectors, sometimes referred to as telecoupling. For example, biofuel mandates in the European Union contributed to global food shortages in 2008 and subsequent civil unrest in other world regions (Liu *et al.*, 2015).

Interregional trade is justified in terms of economic efficiency. Differences in the market price of agricultural or forestry commodities, fish, and minerals can be seen as differences in scarcity, which are levelled out by trade, resulting in increased efficiency. However, if the external costs of production and trade are not taken into account, interregional trade may not enhance efficiency. Without interregional trade, a region consuming more than its biocapacity (or extraction of minerals) would experience increased physical scarcity which, in a market economy, would result in increasing prices. This price signal would, in turn, drive producers and consumers to search for substitutes. It would also raise public awareness of the scarcity, which could become a pressure for institutional change. Interregional trade offsets this price signal and thereby inhibits the feedbacks to economic and institutional drivers. This is the purpose of trade, not a side-effect, and it would not be a problem for nature or human quality of life if trade were based on sustainable harvest and extraction levels (Daly & Farley, 2014).

However, if harvest levels or the production methods of these goods are not sustainable, partly because external costs are not included in their price, then inefficient and unsustainable production of material contributions of nature are exacerbated by interregional trade. Policy failures such as inappropriate environmental regulations in producing countries, increase incentives to export these goods. Importing countries subsequently enjoy low prices and offsetting of scarcity. This "organized irresponsibility" (Beck, 2005) has not emerged by accident. On the contrary,

Figure 4 1 **Illustration of multiple interactions among indirect and direct drivers within a specific context that have impact on biodiversity and nature's contributions to people.**

The graph illustrates important links; more are possible. Knowledge and awareness of changes in biodiversity and nature's contributions to people influence indirect drivers and make adaptations possible. Source: Own representation.



export-oriented economic growth has been a common growth strategy for many developing countries, supported by the World Bank and other international organizations. For example, unsustainably produced agricultural commodities such as soy, coffee, and palm oil have flooded the world market, resulting in low and fluctuating prices and thereby increased vulnerability in the producing countries (Adger *et al.*, 2009). In this way, global drivers of market integration become drivers of both local vulnerability and global unsustainability. In a sustainable world, global trade would not be a problem. However, in the contemporary world, unsustainable production methods in the producing countries are reinforced and scaled-up by short-term profits from trade and the lack of environmental regulations in present global and bilateral trade institutions (Daly & Farley, 2014).

Natural resource extraction of minerals and fish are also important interregional flows. Western and Central Europe import most of their mineral resources due to the depletion of their own resources, and high extraction costs partly due to environmental regulations (European Commission, 2014). Without cheap imported minerals, there would be pressure to increase recycling and substitution. However, interregional trade softens and delays these economic and institutional feedbacks. Similarly, the depletion of fish stocks in Europe and Central Asia has partly been met by supply of imported fish, preventing increases in the cultural drivers of prices and awareness, respectively. Both reduce public pressure for institutional responses (see Section 4.4.1.3).

4.2.6 Methodological approach

4.2.6.1 Effects of, and trends in, direct drivers

Each of the main five direct drivers (see Section 4.2.1) was assessed focussing on a set of sub-categories of these main driver categories. The literature was screened for effects of direct drivers on biodiversity and nature's contributions to people, and for trends of the recent past and of the projected future within Europe and Central Asia. Most weight was given to literature published after 2005, since earlier literature was largely covered by the Millennium Ecosystem Assessment. For some drivers (e.g. some aspects of natural resource extraction, land-use change, or biological invasions), there is less available information than for others, or it is only available for recent periods. To assess the trends in climate change drivers, more publications are available than for the other direct drivers, and also large databases of spatial data. While we did not perform primary analyses for this assessment, we assessed climate drivers through observational data and data from the CMIP5 (Coupled Model Intercomparison Project Phase 5) climate change simulations used in the IPCC AR5 WGI reports (IPCC, 2012, 2013a, 2013b) and extracted from the KNMI climate change atlas website (IPCC, 2012; van Oldenborgh, 2016). For historical climate data we used five data sets, namely: 1) GISTEMP (GISTEMP Team, 2015; Hansen *et al.*, 2010); 2) HadCRUT version 4.2.0.0 (Morice *et al.*, 2012); and 3) NCDC MOST (Jones & Moberg, 2003; Peterson & Vose, 1997); 4) CRU TS 3.24 (Harris *et al.*, 2014); and 5) GPCC V7 (Schneider *et al.*, 2011). For future climates, we used data used in IPCCs AR5 (IPCC, 2013a, 2013b), using all four representative concentration pathway (RCP) scenarios, indicating levels of radiative forcing by greenhouse gases in the atmosphere), namely: RCP2.6, RCP4.5, RPC6.0, and RCP8.5. Higher numbers indicate a higher greenhouse gas effect and a higher level of change to the atmosphere and climate.

Status and trends of temperature and precipitation were extracted for the whole region and for its four subregions. Values for time series were averaged over land grid. Average historical trend estimates and projected future anomalies were calculated for each unit of analysis within each subregion. Spatial distributions of the units of analysis were derived from multiple datasets (see Chapters 1 and 3) **(Figure 4.2)**. Average climate values were computed by overlaying units and subregions with climate data, and calculating mean values for summer (JJA) and winter (DJF). Time series were generated for 1950-2060 as anomalies relative to 1986-2005. As an indication of model uncertainty and natural variability, the time series of each individual model and scenario was included over the analyzed period (see **Figure 4.3** and IPCC (2013b) for more information). Future anomalies were estimated as 20-year means for the time period 2041-2060. Maps of projected trends were generated for Europe and Central Asia similarly to the IPCC AR5 WG1 Annex 1 (IPCC, 2013a), using the KNMI climate change atlas. Two representative concentration pathway scenarios were used to generate maps: scenario RCP 4.5 and 8.5 (IPCC, 2013b). Spatial averages over complex regions provide general trends, but may not explain the details for particular locations.

4.2.6.2 Indirect drivers

Various methods were employed to assess indirect drivers. We used a combination of key words in English and several native languages in the Europe and Central Asia region (such as French, Italian, Swedish, Albanian, Russian, Ukrainian, Hungarian) to retrieve peer-reviewed articles in Scopus, e-library and Google Scholar. We also made use of the grey literature published in native languages of countries from different subregions of Europe and Central Asia. Indigenous and local knowledge and practices were assessed through analysis of traditional land uses of indigenous peoples and local communities and their drivers of change.

Figure 4 2 **Spatial distribution of units of analysis for Europe and Central Asia A and additionally important land cover elements B for Chapter 4 (see Chapter 1). Source: Own representation.**

A

Deserts

Temperate grasslands

Tropical and subtropical dry and humid forests

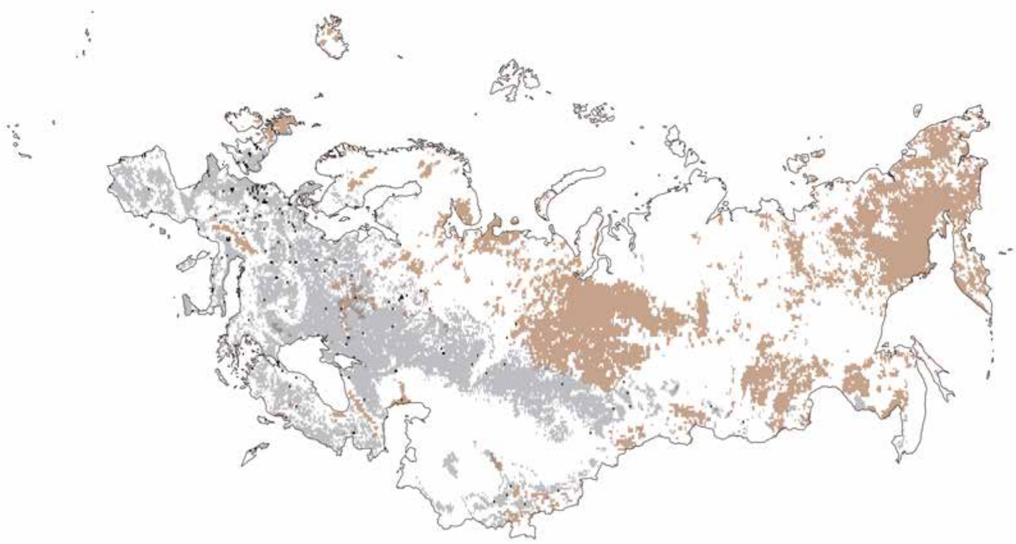
Mediterranean forests, woodland and scrub

Broad-leaved, mixed and coniferous forests

Tundra and mountain grasslands (only high-elevation grasslands)

Snow and ice-dominated systems

B



Urban ecosystems

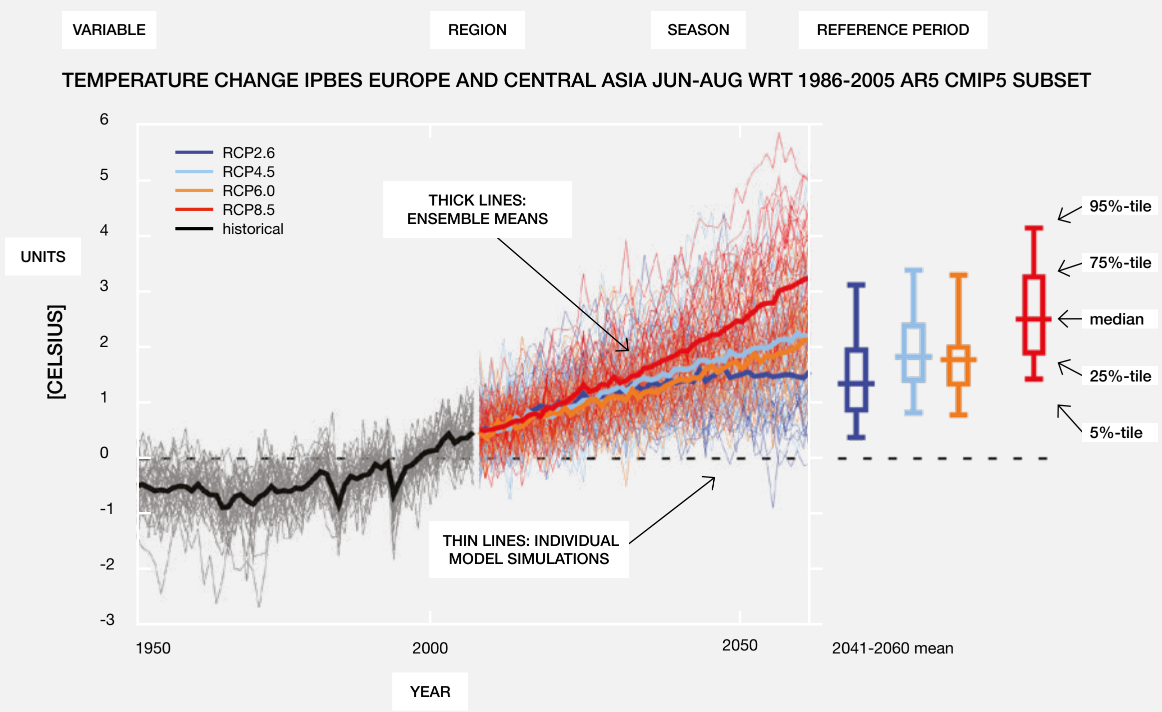
Agroecosystems

Peatlands and mires

We applied qualitative systems modelling methods (e.g., Wolstenholme & Coyle, 1983) using causal loop diagrams to structurally map the dynamic inter-relationships within and between indirect and direct drivers of change in biodiversity and nature's contributions to people. Causal loop diagrams provide a concise format for describing complex interconnected system structures and behavioural directionality. They use arrows to indicate direct causal relationships between independent and dependent variables. These relationships can be either in the same direction, represented by a positive (+) sign, or in the opposing direction, represented by a negative (–) sign. Thus, if independent variable A connects to dependent variable B by an arrow with a plus (+) sign, the underlying logic of the causal loop diagram is that an increase (decrease) in A's behaviour will lead to an increase (decrease) in B's behaviour. If the arrow connecting A to B is accompanied by a negative (–) sign then the diagram indicates that an increase (decrease) in A will lead to a decrease (increase) in B. In some cases, variable concepts have been amalgamated or broadly aggregated, or otherwise relationships between independent and dependent variables have been strongly simplified, in such a manner as to impair the clear directionality of a relationship. In these cases, arrows are not represented by a sign. For example, several arrows in overview causal loop diagrams do not carry directional signs, as these arrows are aggregates of multiple, variously signed, relationships.

The causal loop diagrams (CLDs) provided in this chapter are intended to convey the major dynamic relationships identified via the literature review process. Each variable and link is thus based on explicit evidence from one, or several, references. Although expert opinion was gathered during a series of workshops to guide an iterative modelling process, no dynamics have been included in the finalized CLDs without substantiation in published materials. No representation of a fully interconnected model of all identified dynamics is provided. Such a model would be too complex, and would defeat the purpose of using CLDs as communicative devices. Rather, we present a set of nested models throughout the chapter, each providing a level of detail regarding identified trends and major driver dynamics. As such, the CLDs unpack the indirect and direct driver boxes of the IPBES conceptual framework into an overview model of indirect and direct driver categories (see **Figure 4.1**). This overview model is then further unpacked at a variety of levels of detail to examine the major dynamics influencing the indirect and direct driver interactions. Indirect and direct driver categories are colour-coded in each of the CLDs according to the legend. Boxes around variables are used either to

Figure 4 3 **Explanation of a typical time series figure used to present projected temperature and precipitation changes for Europe and Central Asia. Source: Modified from IPCC (2013b).**



signify stocks or to contain a variety of identified sub-variables within an overarching variable. Variables in bold text are used to help guide readers in linking the CLDs with the central themes discussed in respective texts. Grey diamond-shaped boxes around variables are used similarly to aid readers in locating the major trends in land-use change within the diagrams.

4.3 GENERAL TRENDS IN INDIRECT DRIVERS IN EUROPE AND CENTRAL ASIA

As described in Section 4.1.2, a more specific assessment of indirect drivers in relation to each direct driver is conducted in Sections 4.4-4.8. General trends are assessed in this section.

4.3.1 Institutional drivers

Regulations, including legislation and detailed institutional arrangements, shape all direct drivers and also to some extent all the other indirect drivers. Regulations are the result of purposeful collective political action and reflect the power balance between conflicting interests. Therefore, political and economic conflicts (cultural and economic drivers), influence institutional drivers. Knowledge about the effects of direct drivers on biodiversity and nature's contributions to people increases public awareness and the prices of material contributions from nature and thereby acts as a feedback to institutional drivers **(Figure 4.1)**.

In general, the institutional capacity to make and enforce regulations is strong in Western and Central Europe (see Chapter 6). For example, the European Union's Common Fisheries Policy (CFP) illustrates institutional capacity in that regulations have been passed to restore and maintain fish stocks above biomass levels capable of producing maximum sustainable yield, although half of the fish stocks exploited by the fishing fleet of European Union countries are still overexploited (Guillen *et al.*, 2016), see Section 4.4.1.2.

On the other hand, for the European Union's Common Agricultural Policy (CAP) the new environmental prescriptions – including maintaining existing permanent grasslands, crop diversity, and establishing ecological focus areas – maybe "so diluted that they are unlikely to benefit biodiversity"(Pe'er *et al.*, 2014) (Section 4.5.2.2). The most significant recent change in environmental institutional drivers in Europe and Central Asia is arguably the transformation of the energy sector in the European Union. Here, political leadership, new policies and economic incentives have catalysed technological advancements resulting in lower prices for solar and wind power. These lower prices have subsequently become economic drivers for decreased pollution and greenhouse gas emissions (Bürer & Wüstenhagen, 2009).

For example, the German Renewable Energy Act (EEG) from 2000 has become a major driver for transforming the energy sector, increasing generation of renewable energy from 29 TWh in 1999 to 161 TWh in 2014 (Lauber & Jacobsson, 2016). However, substantial trade-offs may result from a lack of mainstreaming. In a scenario for energy crops, (Gutzler *et al.*, 2015) project substantial reduction in biodiversity and landscape scenery, and increased soil erosion and need for water protection. These three examples from the fishing, agriculture and energy sectors suggest that strong institutional capacity is not sufficient to safeguard biodiversity and nature's contributions to people.

4.3.2 Economic drivers

We have identified the material intensity of GDP, rather than GDP itself, as a main economic driver. The relationship between GDP and resource use has long been debated. The contributions of many scholars – for instance Carson (1962), Boulding (1966), Georgescu-Roegen (1993) – highlighted that serious problems arise from both the quality of the waste (ecotoxicity) and the scale of human activities. The amount and the rate at which matter passes through society (the material throughput) and becomes waste is a major indirect driver of biodiversity loss. This is also called the industrial and socioeconomic metabolism (González de Molina & Toledo, 2014). Despite some evidence that prosperity or human well-being does not increase further once an average income threshold has been reached (Kubiszewski *et al.*, 2013 suggest a threshold as low as 7,000 USD/year and person), Governments in countries with much higher per capita GDP strive hard to increase it further. A growing body of literature suggests that the challenge is to decouple quality of life (well-being or prosperity) from environmental degradation and pay less attention to GDP (Jackson, 2009; Raworth, 2017; Røpke, 2016; van den Bergh, 2010, 2011; Victor, 2008).

Fundamentally, economic growth is largely explained by investments in real capital and there is a near-linear relationship between GDP growth and physical capital accumulation in most countries (Malmaeus, 2016). There are, in turn, clear correlations between investments in physical capital, and resource use including metals (Chen & Graedel, 2015; Kondo *et al.*, 2012), gravel and sand (UNEP, 2014), and biomass.

Growth-oriented policies aim to enhance production and consumption and, except for the economic contraction following the financial crisis in 2008, domestic material consumption (DMC) has not recently decreased in general in most countries in Western and Central Europe (4.4.4.2) (Eurostat, 2017b). Target 8.4 of Sustainable Development Goal 8 ("decent work and economic growth") requires governments to "endeavour to decouple economic growth from environmental degradation". However, GDP growth will have a negative effect on ecosystems unless countries succeed in absolute decoupling, sufficiently large to achieve the environmentally-oriented Sustainable Development Goals. Relative decoupling, where resource use increases, but at a slower pace compared to GDP, is no longer an option except for low-income countries (Raworth, 2017).

Decoupling of GDP growth from resource use and environmental impacts is a requirement for sustainable growth (Bithas & Kalimeris, 2013; OECD, 2011; van den Bergh, 2010). This can be achieved theoretically, but has proved difficult to accomplish empirically. For example, global modelling suggests that absolute decoupling, in terms of 50% reductions of CO_2 emissions and resource use, would require very strong abatement and resource efficiency policies. Because of economic adaptations and technological development this would have negligible effects on economic growth and employment until 2050 (Schandl *et al.*, 2016). The lack of absolute decoupling has been observed empirically (UNEP, 2011). It is often explained by the so-called rebound effect, stating that less demand for natural resources arising from increased productivity results in lower prices and therefore higher demand for natural resources (Sorrell, 2007).

The most well documented case of economic growth as a driver of environmental impact is between GDP growth and CO_2 emissions (e.g. Raftery *et al.*, 2017). Lægreid (2017) found a very robust connection between economic growth and larger greenhouse gas emissions, hence no absolute decoupling. However, in a study of 131 countries, Szigeti *et al.* (2017) found absolute decoupling between GDP and ecological footprint for 40 countries and relative decoupling for 77 countries. Although the evidence is inconclusive, there are signs of relative decoupling occurring in Europe and Central Asia, and sometimes also absolute decoupling, but this is rarely sufficient to achieve climate goals.

The European Union has recently adopted several policies to promote resource efficiency (EEA, 2014e) and sustainable growth (European Commission, 2017b). Economic drivers have been altered, for example by new legislation and the emission trading system for carbon. However, the challenges of decoupling and the rebound effect require more profound changes in economic drivers, especially taxes (Font Vivanco *et al.*, 2016; Polimeni *et al.*, 2012). The tax system is of fundamental importance as an institutional and economic driver since it modifies all market prices and therefore changes incentives for producers and consumers. Despite proposals for environmental fiscal reform (EFR) by UNEP's "Green Economy" (2011) and the United Nations' Strategic Plan for Biodiversity 2011-2020, little progress is evident in Europe and Central Asia. For example, the total revenue from environmental taxes in the EU-28 in 2014 was 2.5% of GDP, or 6.3% of the total revenues derived from all taxes and social contributions. These proportions have *decreased* since 2002, from 2.6% and 6.8% respectively (Eurostat, 2017b).

Decoupling is an important issue only if growth in GDP is assumed. This is the case for the European Union and its growth strategy Europe 2020, in which economic growth and job creation are top priority goals expressed as smart, sustainable and inclusive GDP growth (European Commission, 2017b). However, if a more "agnostic" approach to GDP growth is taken, resource efficiency and meeting the Sustainable Development Goals can be targeted directly without too much attention to whether GDP increases or decreases a few per cent (Raworth, 2017; van den Bergh, 2011). The literature on "degrowth" aims at decoupling human well-being and quality of life from GDP growth: the prefix smart, sustainable and inclusive are kept, but "growth" is replaced by "development" (Martinez-Alier, 2016).

While sustainability transformations would result in growth in sustainable technologies, it would also shrink non-sustainable technologies (van den Bergh, 2010, 2011). Targets for GDP growth (or de-growth) obfuscate the idea of transformation. For example, sustainable consumption in high-income countries is more about reducing the unsustainable aspects of consumption than increasing the more sustainable aspects of consumption. Focusing on such transformations or transitions represents different policy goals compared to pleas for green or sustainable growth (Geels *et al.*, 2015; Lorek & Spangenberg, 2014; Spangenberg, 2014).

Global trade exposes ecosystems as being part of global supply and demand. This impacts interregional flows (see 4.2.5) and prevents price signals from responding to local scarcity of natural resources (see 4.4.1.3). A third aspect of global trade is the institutional competition it entails. National Governments are reluctant to internalize external costs from natural resource extraction and pollution because that may impede the international competitiveness of taxed corporations (Ayres *et al.*, 2013). Globalized financial markets, including commodity derivative markets and algorithmic trade, have increasing impacts on the world's ecosystems (Galaz *et al.*, 2015).

4.3.3 Demographic drivers

Europe and Central Asia is home to approximately 910 million people or 14.5% of the total world population (United Nations, 2015), almost half of whom live in Western Europe **(Table 4.4)**. Although the population in the region is projected to be stable until 2050, there are important differences within subregions. For example, the population growth rate of Turkey is 1.69% and, without Turkey, the rate of population decline in Central Europe is much greater (-0.25%) than illustrated in **Table 4.4** (-0.14%). The population decline projected for 2015-2050 in Central and Eastern Europe due to low birth rates, coupled with emigration and moderate mortality due to low life expectancy, is unprecedented in recent history (Lutz, 2010). Because human populations are increasing in Central Asia and Turkey and decreasing in Central and non-Caucasus Eastern Europe, it is likely that a high potential for migration from Turkey and Central Asia to Central and Eastern Europe will develop until 2050 (Lutz, 2010). Armed conflicts have profound effects on migration, for example, Turkey recently received (by March 2016) over 3 million refugees from Syria, Iraq and Afghanistan (UNHCR, 2017).

The age distribution of the population is also changing. With improvements in health care, life expectancy is increasing in each subregion and their populations are aging, meaning a higher proportion of older age groups (Lutz *et al.*, 2008). This has several consequences for biodiversity and nature's contributions to people. First, total consumption may further increase as the consumption of energy, food, medicine and others by elderly people increases even if population size decreases. Ecological footprints may therefore increase even in subregions currently showing human population declines (Hossman *et al.*, 2008). Second, aging in rural areas will lead to a decrease in the number, capacity and effectiveness of the rural workforce, which will ultimately create the socio-economic conditions for intensified use of natural resources (mainly by agriculture, forestry, or fishery) by large corporations rather than by private farmers (Gentile, 2005). Third, age profile also strongly influences where people choose to live, which affects urban growth patterns and subsequent impacts on biodiversity and nature's contributions to people (Fontaine *et al.*, 2014).

Fast population growth in Central Asia, with further expected increase in urbanization, will present risks to the already overpopulated lowland and riparian areas of the subregion and will influence biodiversity and ecosystem services (Osepashvili, 2006). Human population growth will take a heavy toll on water use. This is likely to result in a decline in water-related services, which may trigger water conflicts (e.g. in Fergana valley in Uzbekistan, Tadzjikistan and Kirgizistan) or water-use regulations. In other areas, the collapse of irrigation-based agriculture due to water shortages may cause desertification, such as the complete drying up of the Aral Sea (Gentile, 2005).

4.3.4 Cultural and religious drivers

In democratic societies, public awareness and knowledge of environmental change are the underlying drivers for both institutional change and consumer demand (Nolan & Schultz, 2015). Hence, the feedback to indirect drivers often starts with the cultural driver that we call "public awareness". The cultural belief that further GDP growth will facilitate sustainable development is deeply rooted in Europe and Central Asia, calling for smart, inclusive and sustainable growth (European Commission, 2010). In recent years, many studies have shown that, if biodiversity and nature's contributions to people are to be used sustainably, growing anthropogenic pressures paralleled by environmental

Table 4 4 **Population trends in Europe and Central Asia. Source: United Nations (2015). ECA: Europe and Central Asia, WE: Western Europe, CE: Central Europe, EE: Eastern Europe, CA: Central Asia.**

	ECA	WE	CE	(Turkey)	EE	CA
Population 2015 (million)	910	423	202	(79)	218	67
Fertility rate (children/woman)	-	1.71	1.54	-	1.67	2.83
Net migration (per 1,000 inhab.)	-	2.98	-1.35	-	-1.55	-1.47
Population growth/year (%)	-	0.39	-0.14	(1.69)	0.02	1.65
Population 2050 (million)	913	441	192	(88)	192	88

degradation would require a radical change in our political value system, with a reorientation of fundamental policy goals from GDP growth towards well-being, environmental quality, employment and equity (Hardt & O'Neill, 2017; Jackson, 2009; Kallis *et al.*, 2012; Martínez-Alier *et al.*, 2010; Røpke, 2016; Victor, 2008).

All regional cultures are increasingly becoming part of a global cultural process. With increasing access to media, information and exchange among regions, the cultural changes taking place in Europe and Central Asia form part of the general globalization trend. Although distinct local cultures, with their beliefs and specific relation to nature may well persist, they will do so in parallel to global cultural trends (Harari, 2014). Cultural and religious beliefs are often exploited politically, which has been evident in the region in recent years. However, it is not clear how these changing beliefs and opinions affect biodiversity and nature's contributions to people.

Central to the effect on biodiversity is how cultural identity and religious beliefs influence lifestyles in terms of consumption patterns. Values promoting a vegetarian diet are, for example, likely to reduce the land-use area needed to produce food, and thus the impacts on nature Alexander *et al.* (2016).

Heterogeneous agricultural landscapes provide biodiversity and are therefore supported by agri-environmental schemes in the European Union. An increasing focus on recreation and eco-tourism in Western Europe has become a further justification for, and therefore driver of, political and economic support to heterogeneous landscapes (Hahn *et al.*, 2017; Beilin *et al.*, 2014; Navarro & Pereira, 2012). Beyond eco-tourism, the increasing popularity of spiritual refreshment and other spiritual experiences have considerable potential for the recognition of nature's contribution to people.

4.3.5 Scientific and technological drivers

If population is constant and affluence, measured in GDP per capita, is increasing, the equation I = P*A*T (Impact = population * affluence * technology) suggests very high expectations of technology to ensure sustainable growth. However, technological innovation is not a driver, which in itself ensures lower negative environmental impact. Scientific and technological innovation is a double-edged sword (Westley *et al.*, 2011), which could have positive or negative effects on biodiversity. As mentioned in Section 4.2.2, innovation is not a neutral process driven mainly by the curiosity of researchers and innovators. The general pattern of world market prices of natural resources is a sharp decline during the past fifty to one hundred years. At the same time the price for labour has increased dramatically, augmented by the tax system (Eurostat, 2017b). Technological innovation has therefore not targeted resource efficiency, but instead labour productivity (Lorek & Spangenberg, 2014).

Energy and resource efficiency have become political targets. The literature suggests a very high potential for, for example, energy supply and storage, green information technology transportation, foodstuffs, agricultural engineering, design strategies, lightweight construction, as well as the concept "using instead of owning" (Rohn *et al.*, 2014). Realising this potential requires support from institutional and economic drivers (Ayres *et al.*, 2013), and ultimately cultural-religious drivers. For example, if cultural beliefs support "modern" high-input agriculture and if new European Union member States in the Baltic Sea drainage area adopt the same use of fertilizers as Denmark, Sweden and Finland, the eutrophication of the Baltic Sea will accelerate (Larsson & Granstedt, 2010). If the Baltic countries want to achieve the Baltic Sea Action Plan, then climate smart and "Baltic Sea smart" technologies and farm systems are needed.

4.4 DRIVERS OF NATURAL RESOURCE EXTRACTION AND ITS EFFECTS ON BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE

This category of driver is often called "overexploitation", focusing on overfishing (MEA, 2005b). As mentioned before we have chosen a more neutral term, extraction. This section assesses two biotic forms of natural resource extraction: fishing and hunting; and two abiotic forms: mineral and fossil fuel extraction, and water use and desalination. Agriculture, forestry (logging) and traditional land use (gathering wild plants, berries and mushrooms) are assessed under land-use change.

Natural resource extraction is, according to a synthesis based on the IUCN Red List data, "by far the biggest driver of biodiversity decline" (Maxwell *et al.*, 2016). However, that conclusion only holds if unsustainable logging is included. Still, hunting, fishing and mining together pose a considerable threat to biodiversity (Maxwell *et al.*, 2016).

4.4.1 Fishing

4.4.1.1 Effects of fishing on biodiversity and nature's contributions to people

Fishing affects 1,118 of the 8,688 assessed red list species (Maxwell *et al.*, 2016). Both marine and inland fish stocks in Europe and Central Asia have declined over recent decades. Trawling is a fishing technology with adverse effects on biodiversity, through habitat destruction. Over recent decades, trawlers have become dominant among fishing boats, especially vessels greater than 100 gross registered tons (Anticamara *et al.*, 2011). Despite regulations, half of the fish stocks exploited by the fishing fleet of the European Union are still overexploited (Guillen *et al.*, 2016). Overfishing affects genetic diversity and the age structure of the targeted fish population. Furthermore, removal of top predators through overfishing may disrupt ecological relationships, food webs structure and energy flow pathways (García-Charton *et al.*, 2008; Pérez-Ruzafa *et al.*, 2006; Pérez-Ruzafa *et al.*, 2008).

Inland waters have received less attention than global fisheries. One of the symptoms of intense over-fishing in inland waters is the collapse of particular stocks. Such collapses constitute a biodiversity crisis rather than a fisheries crisis. However, intensive fishing frequently acts synergistically with other pressures, and its consequences for inland fisheries and ecosystems are poorly understood and documented (Allan *et al.*, 2005).

Nevertheless, more stocks are recovering, and the combined effects of climate warming and reduced fishing mortalities have resulted in record large stocks of e.g. mackerel in the Norwegian Sea, plaice in the North Sea and cod in the Barents Sea. The recovery of these major stocks now impacts other parts of the ecosystems through both predation and competition. For instance, a recent collapse in the capelin stock in the Barents Sea was likely partially due to cod predation and competition with cod likely impacts the condition of marine mammals (Bogstad *et al.*, 2015).

4.4.1.2 Trends in fishing

The marine area under the jurisdiction of European Union member States is substantial — larger than the total land area of the European Union— and supports industries such as shipping, fishing, offshore wind energy, tourism, and oil, gas and mineral extraction (EEA, 2012d). Fishing effort has increased over recent decades in Western Europe and Central Europe. However, some analyses suggest a stagnating or even decreasing trend in fishing effort in European marine waters (Gascuel *et al.*, 2016). Fishing effort is a combination of fleet capacity (number of vessels or engine power) and the amount of time spent at sea. Reduced fishing effort may however be counteracted by an increase in the efficiency in detecting and catching fish.

Despite recent attempts by the fishing sector to ensure sustainable practices and recovery of fish stocks, the industry is still characterized by overfishing and declining volumes of fish catch (EEA, 2012d). During recent decades, aquaculture production has been increasing. However, some aquaculture species, like salmon and tuna, are carnivores that feed on other fish that are, themselves, overfished (Naylor *et al.*, 2000; Pauly *et al.*, 2002). Demand for fish in the European Union continues to exceed the sustainable yield and a significant proportion of the fish consumed in the European Union is imported from, for example, Norway, China, Morocco, and the USA **(Figure 4.4)**.

4.4.1.3 Drivers of fishing

The drivers of fishing are summarized in **Figure 4.5**. Overcapacity accompanied by non-compliance (illegal, unregulated and unreported fishing) are the most common immediate causes for overfishing (Boonstra & Österblom, 2014). Knudsen *et al.* (2010) identify eight main drivers of overfishing, most of them economic in nature. Fishing costs (including operational costs and fuel prices) and incomes (including fish prices and demand) are important drivers. Fishing costs increase when stocks become over-exploited, but the subsequent increase in fish price motivates investments and continued fishing. Furthermore, tax exemptions and government subsidies, especially for fuel, are very important drivers to offset the increased costs and to maintain a high fishing capacity **(Figure 4.5)**. Despite changes in fishing policies, Western Europe pays about six billion US dollars annually (of which four billion by the European Union and almost two billion by Russia) in capacity-enhancing ("harmful") fishing subsidies, which is the second most after Asia (Sumaila *et al.*, 2016).

The adoption of new technologies leading to overcapacity in vessels and engines is also a major driver for increased fishing (Knudsen *et al.*, 2010; Österblom *et al.*, 2011). Human population growth, associated demand for fisheries products, and multiple effects of pollution, coastal degradation and climate change are other important factors in the analysis of trends in fisheries (Garcia & Rosenberg, 2010). Small changes in temperature affect distribution and abundance of fishes, but can be positive or negative for local fisheries depending on the species and regions (Pörtner & Peck, 2010; Roessig *et al.*, 2004).

For the majority of the stocks, political decision-makers have not followed recent scientific advice, for example from the International Council for the Exploration of the Sea (ICES) and the Mediterranean Advisory Council (MEDAC), and have set Total Allowable Catch (TAC) to levels higher than the scientific recommendation (Voss *et al.*, 2017). Institutional drivers are beginning to change, thanks to information and recommendations from universities, consultative councils and international organizations, with a resulting increase in public awareness. This in turn drives both the market, by avoiding red listed fish, and the political system to regulate fishing and enforce illegal fishing **(Figure 4.5)**. For example, the European Union's 2014 update of The Common Fisheries Policy (CFP) illustrates institutional capacity in that regulations have been passed for restoring and maintaining fish stocks above levels capable of producing maximum sustainable yield. However, half of the fish stocks exploited by the European Union fishing fleet are still overexploited (Guillen *et al.*, 2016).

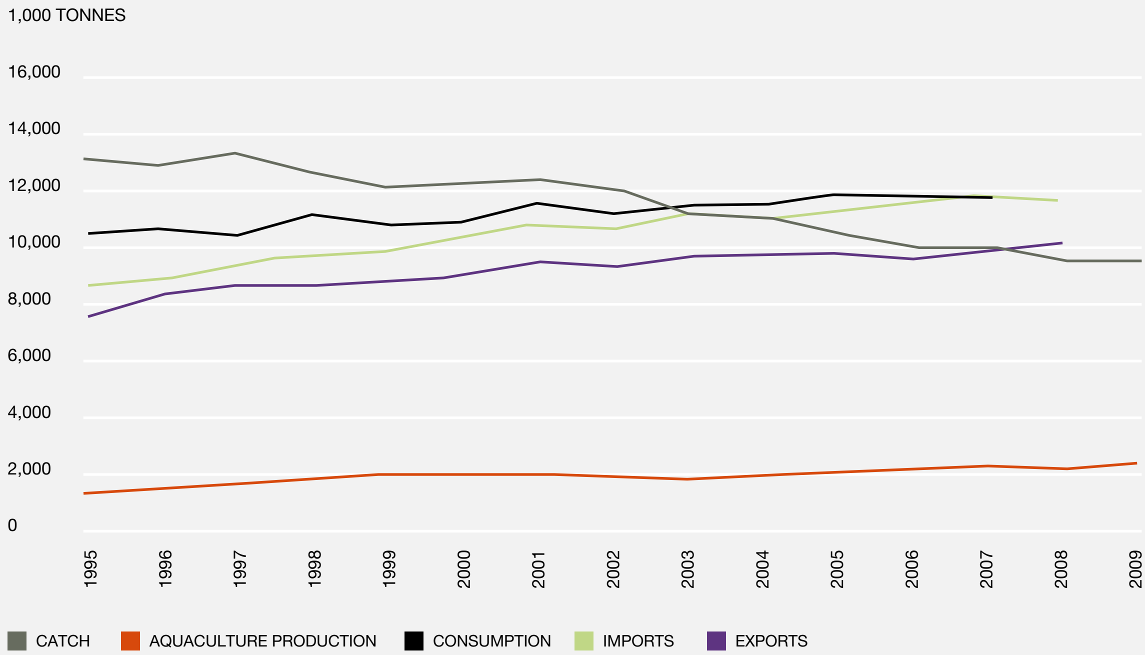
Resource users who are limited to local resources have an incentive to sustain these resources because they do not have a substitute, while users who can access global resources have no such incentives. Therefore, good stewardship depends on institutions where users are held accountable for sustaining the local resources (Berkes *et al.*, 2006). Consumers and citizens are not reached by the feedbacks of natural resource depletion such as price signals and physical scarcity. Three reasons why price fails to provide an accurate signal of declining fish stocks to globally distributed consumers have been proposed by Crona *et al.* (2016). First, the costs of depleting the resource through habitat damage by trawling and by-catch of endangered megafauna have little effect on yield or revenue, as these costs are not reflected in the market price. Second, better fishing technologies can maintain or even increase harvest levels despite declining fish stocks. Third, when declining stocks are substituted by global tradefrom other regions, market signals to consumers also fail. All of these factors result in "masking" and "dilution" of the feedbacks to consumers and citizens by preventing increases in prices and hence in awareness (economic and cultural drivers), thereby reducing public pressure for institutional responses (Morato *et al.*, 2006).

4.4.2 Hunting

4.4.2.1 Effects of hunting on biodiversity and nature's contributions to people

Hunting is practiced across a wide spectrum of cultural, institutional, economic and environmental contexts within Europe and Central Asia. Whilst hunting clearly impacts the populations of the hunted species, the effects on

Figure 4 4 **Total fish catches, aquaculture production, consumption, imports and exports for European Environmental Agency (EEA)-33 countries (except Liechtenstein) and the western Balkans*, 1995 to 2009. Consumption refers only to human consumption. Source: EEA (2012d).**



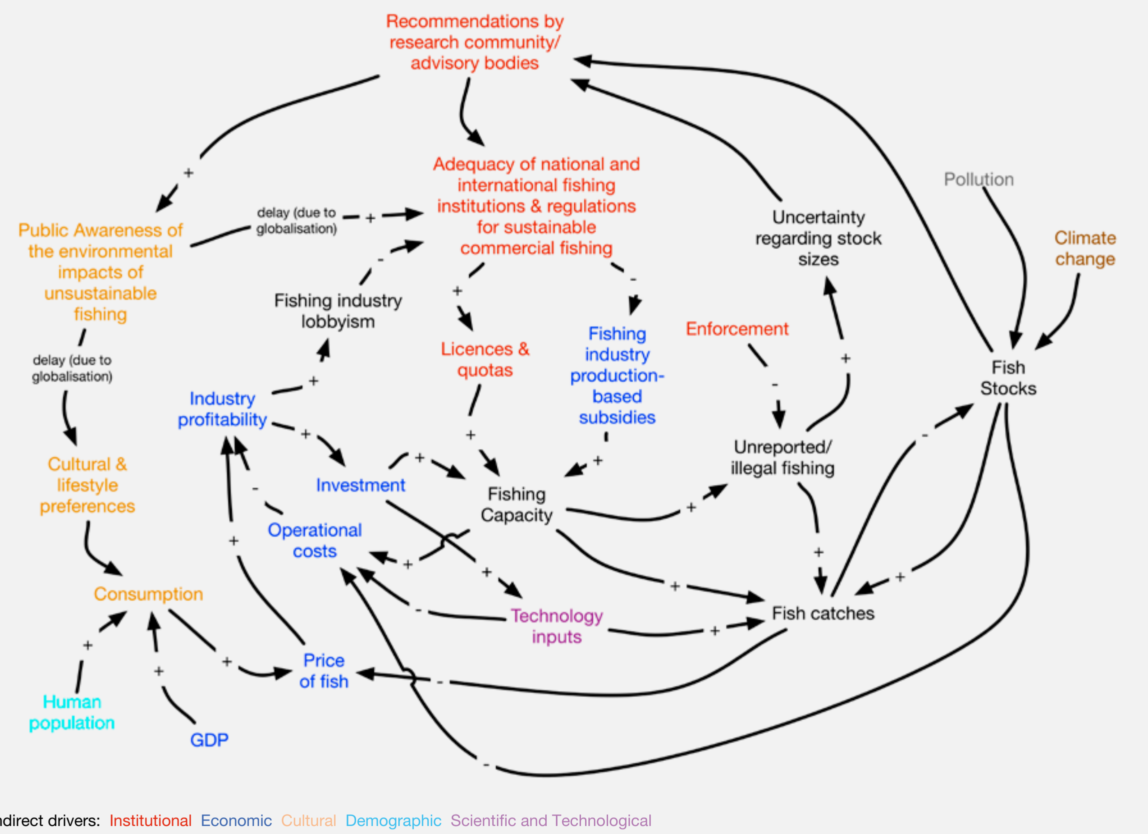
* The EEA currently has 33 member countries and six cooperating Balkan countries. The 33 member countries include the 28 European Union member States together with Iceland, Liechtenstein, Norway, Switzerland and Turkey. The six West Balkan countries are cooperating countries: Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro, Serbia as well as Kosovo.

biodiversity and nature's contributions to people vary. Hunting takes several forms and is done for various reasons, including management, subsistence, and recreation (Fischer *et al.*, 2013). Under "management hunting" the population densities of certain large-bodied game species are controlled by hunters with potentially positive impacts on biodiversity and forestry (Brainerd, 2007). On the other hand, these game species are sometimes kept at high densities for recreational hunting purposes, resulting in overgrazing, over-browsing and trampling of forest ecosystems by large herbivores, leading to reduced diversity of the understory vegetation and stunted or no regrowth of forest trees and understory plants. Browsing and grazing by wild ungulate game species (such as several deer species or wild boar) are a significant cause of plant species loss regardless of the type of forest management (Pollock *et al.*, 2005; Schulze *et al.*, 2014). Beyond the direct mortality impact on hunted animals, therefore, altered vegetation dynamics can also change animal communities, and the current high densities of ungulate populations in Germany, and Romania and other Central and Eastern European countries, are a major threat to the biodiversity of deciduous forests (Schulze *et al.*, 2014). Hence, the hunting sector and its management is also a main driver of forest change.

Management hunting also provides material (meat) and non-material contributions to people, for example by maintaining traditions and promoting social relations (Fischer *et al.*, 2013). This is also the focus in indigenous or subsistence hunting where cultural identity is emphasized. However, there are signs that indigenous or subsistence hunting is declining, for example in traditional communities in Faroe Islands due to the changing cultural values of younger generations (Nieminen *et al.*, 2004).

Sport and trophy hunting are not motivated by ecological objectives (if so, we would call it management hunting). Sport hunting, including the trapping of individuals, has been mostly aimed at large game species in Europe and Central Asia. These include predatory mammals such as bears, wolves and lynx; herbivorous mammals such as red deer, moose, elk, ibex and chamois; omnivorous mammals such as wild boar; and birds (mainly ducks, geese, waders, doves and several passerines). This has resulted in the extinction of, for example, Caucasian moose and wisent, Carpathian wisent, and ibex on the Iberian Peninsula. The hunting, trapping and poaching of migratory birds is a chronic conservation problem, particularly in the Mediterranean countries, where birds, even small passerines, have been

Figure 4 5 Causal loop diagram of fishing, illustrating causes of the present situation of overfishing. See text for further clarification. Source: Own representation.



traditionally hunted and trapped for human consumption or for sport (Vickery *et al.*, 2014).

4.4.2.2 Trends in hunting

In the European Union, the Birds Directive currently allows the hunting of 82 species (25 ducks and geese, 15 gallinaceous species, 22 waders, shorebirds and gulls, five doves, 12 passerine species and three rallied species) of which 24 can be hunted in all member States (Annex II of Birds Directive). Many species that are declining at an alarming rate, may still be hunted in several European countries (for example skylark, lapwing, curlew, black-tailed godwit, garganey, taiga bean goose, pintail, snipe, quail and turtle Dove). In addition to hunting, selective trapping is allowed in several European Union member States (Art. 9 of Birds Directive), where net traps and cage traps lead to the killing of tens of thousands of skylarks, Ortolan buntings, golden plovers, turtle doves, quail and lapwings in France, and millions of thrushes in Malta, Spain (Catalonia) and Italy annually (Fenech, 1992; Hirschfeld & Heyd, 2005).

Since the 1950s there has been a general decrease in the size of the annual wild bird hunting bag (total catch) in Western Europe. Hunting pressure is still high, although uncertain in the south and east of the region (Weinbaum *et al.*, 2013). In 2005, the total hunting bag in the EU-27 was around 102 million individuals of 82 bird species (Hirschfeld & Heyd, 2005). Hunting bag data also suggest a recent short-term increase in hunting pressure for mammals. For instance, the hunting of red deer (*Cervus elaphus*) has increased exponentially in eight of 11 Western and Central European countries studied (Milner *et al.*, 2006).

4.4.2.3 Drivers of hunting

The culture of hunting is based on a value system that is deeply rooted in traditions in Europe and Central Asia. However, traditions emerging from subsistence hunting are today based on identity and life-style, expressed as sport and trophy hunting or management hunting, with wild meat as a bonus (Fischer *et al.*, 2013). Demographic drivers like urbanization do not seem to change these cultural drivers; there is still a high density of hunters per km^2, 50 in Cyprus, followed by 47 in Malta, 5.0 in Ireland, 3.8 in Denmark, 3.3 in the UK, 2.5 in Italy and Portugal, 2.4 in France, and 2.0 in Greece (Hirschfeld & Heyd, 2005). Illegal hunting and trapping is still common in the south and east of the Europe and Central Asia region (Arizaga & Laso, 2015; Michel, 2008).

Hunting is well regulated in most countries in Europe and Central Asia, however, law enforcement is lagging behind in many Central Asian countries and the southern parts of Western and Central Europe (Michel, 2008). Hunter associations are powerful interest groups in many countries and the governance trend is to foster stewardship and sustainable management hunting for vulnerable species rather than imposing hunting bans (Dusseldorp *et al.*, 2004). Tensions between hunters and anti-hunting groups have escalated, e.g. in Malta, with rural surveillance systems and local raids by anti-hunting groups, physical fights between anti-hunting activists and hunters or poachers, use of drones for observations, and police or army interventions (Veríssimo & Campbell, 2015).

4.4.3 Water use and desalination

4.4.3.1 Effects on water use and desalination on biodiversity and nature's contributions to people

Water is extracted from streams, rivers, lakes and wetlands for drinking and bathing, irrigation for agriculture, cooling for energy production (power plants), as coolant or reagent in various industries and as a leaching agent in mining. Freshwater ecosystems host disproportionately high numbers of species relative to their surface area, yet their biodiversity is declining faster than either terrestrial or marine biodiversity (Dudgeon *et al.*, 2006; Strayer & Dudgeon, 2010; WWF, 2008). In addition, ecosystem services provided by freshwater systems (streams, rivers, lakes, wetlands) were estimated to contribute to 20% of the value of all ecosystem services (Costanza *et al.*, 1997).

Groundwater overexploitation, often due to irrigation, results in lowering the groundwater table, which increases the risk of desertification. In addition, the chemical composition of groundwater is often suboptimal for irrigation due to its high salt/mineral or metal content and irrigation with groundwater often leads to salinization or alkalinization of the soils. This is a problem in Estonia, Latvia, Poland, Hungary, Romania, Moldova and Spain (EEA, 2007) and in many areas of Eastern Europe and Central Asia. The intrusion of salt water from the sea in the place of groundwater is an acute problem in coastal areas of Denmark, and in coastal Mediterranean areas of Spain, Italy and Turkey, mostly due to the water needs of mass tourism facilities and irrigation (EEA, 2007).

Desalination of seawater is increasing to satisfy demand for water due to the present water shortage, mainly in semiarid and arid coastal regions (Llamas *et al.*, 2015). It has a long history in the Middle East and Mediterranean (Einav & Lokiec, 2003; Roberts *et al.*, 2010), but studies on the impacts of desalinization on biodiversity are recent and still scarce. The greatest environmental and ecological impacts have occurred around older multi-stage flash plants discharging salt into water bodies with little flushing. Effects include substantial increases in salinity and temperature and the accumulation of metals, hydrocarbons and toxic anti-fouling compounds in receiving waters (Al-Taani *et al.*, 2014; Höpner & Lattemann, 2003; Roberts *et al.*, 2010) and sediments (Alharbi *et al.*, 2012).

Effects on ecosystems range from no significant impacts on benthic communities, to reduced leaf growth and higher incidence of leaf necrosis, drop in photosynthetic performance and mortality in seagrasses, and widespread alterations to community structure in seagrass, coral reef and soft-sediment ecosystems when discharges are released to poorly flushed environments (Del-Pilar-Ruso *et al.*, 2015; Del-Pilar-Ruso *et al.*, 2008; Pagès *et al.*, 2010; Roberts *et al.*, 2010).

4.4.3.2 Trends in water use and desalination

Water management has become one of the main concerns for humanity, also in areas where water has until now been considered an unlimited resource. The availability of freshwater resources in a country is determined by geology, climate, land use and external (transboundary) water flows. In Western and Central Europe, the largest freshwater resources are in Norway, Turkey, Germany, France and Sweden (Eurostat, 2015). Many countries receive the majority of freshwater resources externally, with Serbia, Hungary, the Netherlands, Slovakia and Bulgaria receiving over 80% of their freshwater from upstream areas in other countries. The amount of potable freshwater per inhabitant is highest in Iceland, Norway, Serbia, Croatia and Finland, whereas low levels (<3,000 m^3 per inhabitant per year are found in Denmark, Romania, Belgium, the Czech Republic, Cyprus and Malta, and in countries with large human populations (France, UK, Spain, Germany, Italy and Poland) (Eurostat, 2015). In 2012, total water extraction from surface waters was highest in Turkey, Spain, Germany and France (over 24 billion m^3 from surface waters, over 5 billion m^3 from groundwater) (Eurostat, 2015). Between 2003 and 2013, the amount of freshwater extracted increased most in Malta (43%, mostly groundwater), Slovenia (36%, mostly surface water) and decreased the most in Lithuania (80%, mostly surface water) and Slovakia (39%, mostly surface water) (Eurostat, 2015).

Around 63% of desalinated water worldwide is used for satisfying urban demand for drinking water, 26% for industrial uses, and 6% in power stations for electricity generation (Ziolkowska & Ziolkowski, 2016). The cost of desalinated water is decreasing, thanks to technological and efficiency improvements of the membrane filters, which reduces energy demand (Semiat, 2000; Ziolkowska & Ziolkowski, 2016).

4.4.3.3 Drivers of water use and desalination

Water regulations are cornerstones of national environmental regulations. The rapid decrease in water use in Lithuania and Slovakia mentioned above is mainly a result of institutional drivers (regulations and a better price system). Other important Institutional drivers are regulations and investments in, or subsidies for, wastewater and desalination ("recycling" in **Figure 4.7**). Depletion (unsustainable use) of ground and surface water is driven by high domestic material consumption (DMC) fuelled by urbanization and GDP growth.

Similarly, seawater desalination is driven by growth in human population, income and domestic material consumption in general and growth and urban development, agriculture and tourism in particular (EEA, 2007; Gladstone *et al.*, 2013).

4.4.4 Mineral and fossil fuel extraction

4.4.4.1 Effects on biodiversity and nature's contributions to people

The minerals industry is divided into four sectors: fossil fuels (e.g. coal and oil), metallic minerals (e.g. iron, copper and zinc), construction minerals (e.g. natural stone, sediments and other aggregates, gravel) and industrial minerals (e.g. borates, talc, silica and limestone).

In Western and Central Europe, extraction of abiotic resources is highly dominated by construction and industrial minerals, and to a more limited extent fossil energy (Bahn-Walkowiak *et al.*, 2012). Dredging and pumping operations have a direct effect on the local biological communities and cause changes in the composition of fauna (Pérez-Ruzafa *et al.*, 2007), and reduction in species diversity, abundance, and biomass (Bolam *et al.*, 2015; Sutton *et al.*, 2009). This changes food webs, particularly lower trophic levels including detritivores, with impacts on carbon cycling (Tecchio *et al.*, 2016).

In Central Asia the extraction and processing of minerals, including poor governance practices and economic pressures (Honkonen, 2013), leads to various environmental impacts including depletion of non-renewable resources and consequent disturbance of the landscape, biodiversity and nature's associated contributions to people (Azapagic, 2004; Starikova, 2014), particularly in vulnerable arid and mountainous territories (Lukashov & Akpambetova, 2012).

The environmental effects of the mining and minerals industry include gas emissions, discharge of liquid effluents (including acidification of waterways) and generation of large volumes of solid waste, as well as direct destruction or disturbance of natural habitats. Additionally, contamination of water can continue when mining or mineral extraction activity ceases due to acid mine drainage and other toxic leachates. Large water bodies and land are being polluted by natural resource extraction in Central Asia (Jakupov, 2013; Kalmenova, 2014) and methane leaks from gas infrastructure and coal mines pollute soil and the Caspian Sea (Dahl & Kuralbayeva, 2001; Karenov, 2006; Mukanova, 2015). Oil production in the Caspian Sea has had a direct impact on ecosystem functioning through pollution (Netalieva *et al.*, 2005). An increase in the rate of glacier melting has been observed as a consequence of dumping of mine spoil on receding and thinning glacier snouts in Kyrgyzstan (Evans *et al.*, 2015; Jamieson *et al.*, 2015; Kronenberg, 2014). Uranium mining sites pose a threat to biodiversity exposed to high radiation doses (Oughton *et al.*, 2013; Bekbolotova & Toychubekova, 2014; Jolboldiev, 2016; Karsenov, 2011).

4.4.4.2 Trends in mineral and fossil fuel extraction

Fossil fuels and rare earth minerals are the largest contributors to GDP of Central Asia and in the last decade the volume of coal mining has doubled in this subregion (Kabirova, 2009; Plakitkina, 2014). The mineral extraction industry in Central Asia has been driven by trade liberalization and increasing world market prices. The largest share of foreign direct investment in Central Asia is in the natural resource extraction industry. Central Asian Governments seek foreign direct investments as a way to boost local incomes while the high environmental risks and lack of transparent governance have had little effect on economic development (Dikkaya & Keles, 2006; Doroshenko *et al.*, 2014).

Since the 1950s most metallic mineral resources have been imported into Western and Central Europe (Calvo *et al.*, 2016; Schaffartzik *et al.*, 2016; Schoer *et al.*, 2012). However, while domestic extraction of metallic mineral has been reduced, extraction of sediments is increasing mainly in coastal areas. Domestic material consumption (DMC) is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. It has increased since 1970 **(Figure 4.6)** but decreased from 7.7 to 6.7 billion tonnes in the period 2000-2016 in EU-28. Greece, Spain and Italy almost halved their domestic material consumption since the financial crisis in 2008 and without these countries the domestic material consumption in the European Union has been stable since 2000 (Eurostat, 2017a). Recently there has been an increase in prospecting for resources in previously unexploited and fragile environments such as the Arctic and on the ocean floor, which consequently increases the pressure on ecosystem resilience in sensitive environments (Martin *et al.*, 2012).

4.4.4.3 Drivers of mineral and fossil fuel extraction

The European Union is aiming to become a resource-efficient, green and competitive low-carbon economy through absolute decoupling of economic growth and environmental degradation (EEA, 2014e). Recent changes in indirect drivers include climate and energy policies, natural resource taxation, subsidizes to recycling schemes (Söderholm, 2011) and regulating producers' responsibility for the waste (Ekvall *et al.*, 2016). This has resulted in reduced use of fossil fuels for energy production, improved energy efficiency and increased resource efficiency. However, domestic material consumption is only beginning to decline from a very high level and the increases in environmental taxes have only kept pace with other taxes and the GDP, hence the environmental tax reforms called for by the Green Economy (UNEP, 2011) and Convention on Biological Diversity (Aichi Biodiversity Targets) have not progressed since 2002 (Section 4.3.2). On the contrary, some aspects of public support to mineral extraction can be seen as harmful subsidies. In 2010, the metal mining sector in Sweden received subsidies of € 40 million compared to only € 0.6 million for the metal recycling sector (Johansson *et al.*, 2014). Furthermore, mining companies only pay 0.2% of the revenues from mining as resource tax (Koh *et al.*, 2017).

Conversely, in Central Asia, economic growth is currently closely associated with mineral and fossil fuel extraction (Ondash, 2011), which is anticipated to continue in the future (Doroshenko *et al.*, 2014). Central Asia has initiated policies for increased resource efficiency, mainly targeted at energy efficiency (Government of Kyrgyzstan, 2014; Pomfret, 2011). However, global initiatives (e.g. the Extractive Industries Transparency Initiative) have so far had a limited effect on sustainable use of natural resources (Furstenberg, 2015).

4.4.5 Drivers of natural resource extraction

Drivers of natural resource extraction are indirect drivers of biodiversity change, as synthesized in **Figure 4.7**. Natural resource extraction basically follows increases in GDP and human population growth (Peet & Hartwick, 2015). Urban sprawl increases this pressure (Schewenius *et al.*, 2014). GDP growth is still the goal of the European Union, but recently the goal has been reformulated toward smart, sustainable and inclusive growth (European Commission, 2017a).

The ecological footprint is an area-based measure of material consumption driving natural resource extraction. Western and Central Europe's ecological footprint is twice the size of its area and consumption patterns remain very high by global standards (EEA, 2014a). Due to institutional drivers, increasing productivity and the financial crisis of 2008, Western and Central Europe's domestic material consumption has decreased recently (4.4.4).

Population changes influence GDP, which drives the rate of production intensity and thereby extraction of natural resources (EEA, 2012b). However, formal institutions drive the taxation of natural resources, which influences the rate of domestic material intensity and the material intensity of GDP (domestic material consumption divided by GDP), affecting extraction rates. Institutional drivers also regulate producers' responsibility and influence the rate of recycling through regulations and economic incentives. Environmental regulations may restrict availability of natural resources but technological innovation typically increases availability by facilitating extraction (Litovitz *et al.*, 2013). Finally, institutions like the German energy transformation also influence technological innovation pathways, impacting the material intensity of GDP **(Figure 4.7)**.

Natural resource extraction may result in depletion of natural resources as well as unintended environmental

Figure 4 6 **Domestic material consumption (DMC) in EU-12 and EU-15 has increased historically except as a result of the financial crisis in 2008. Source: Martin *et al.* (2012).**

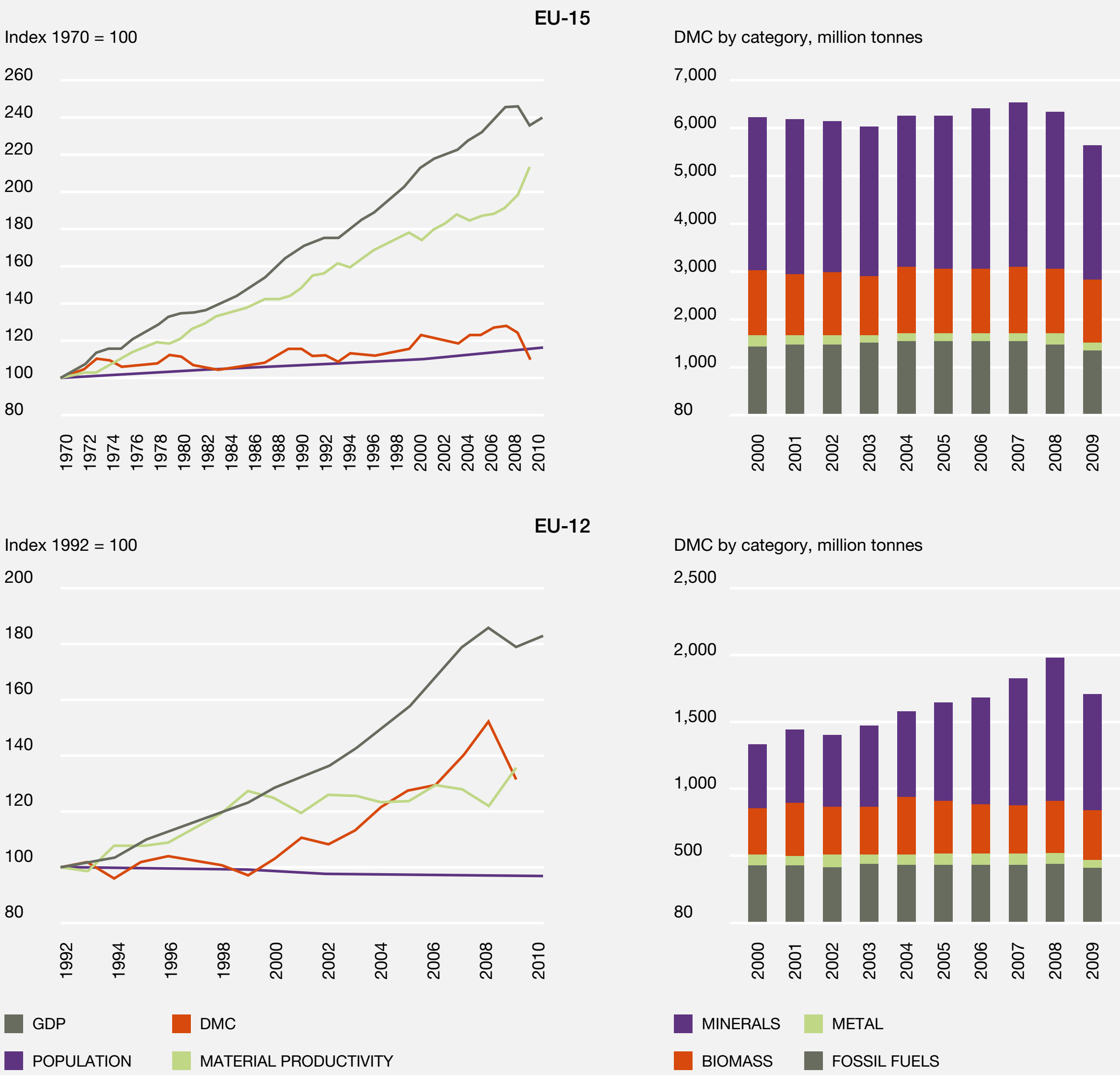
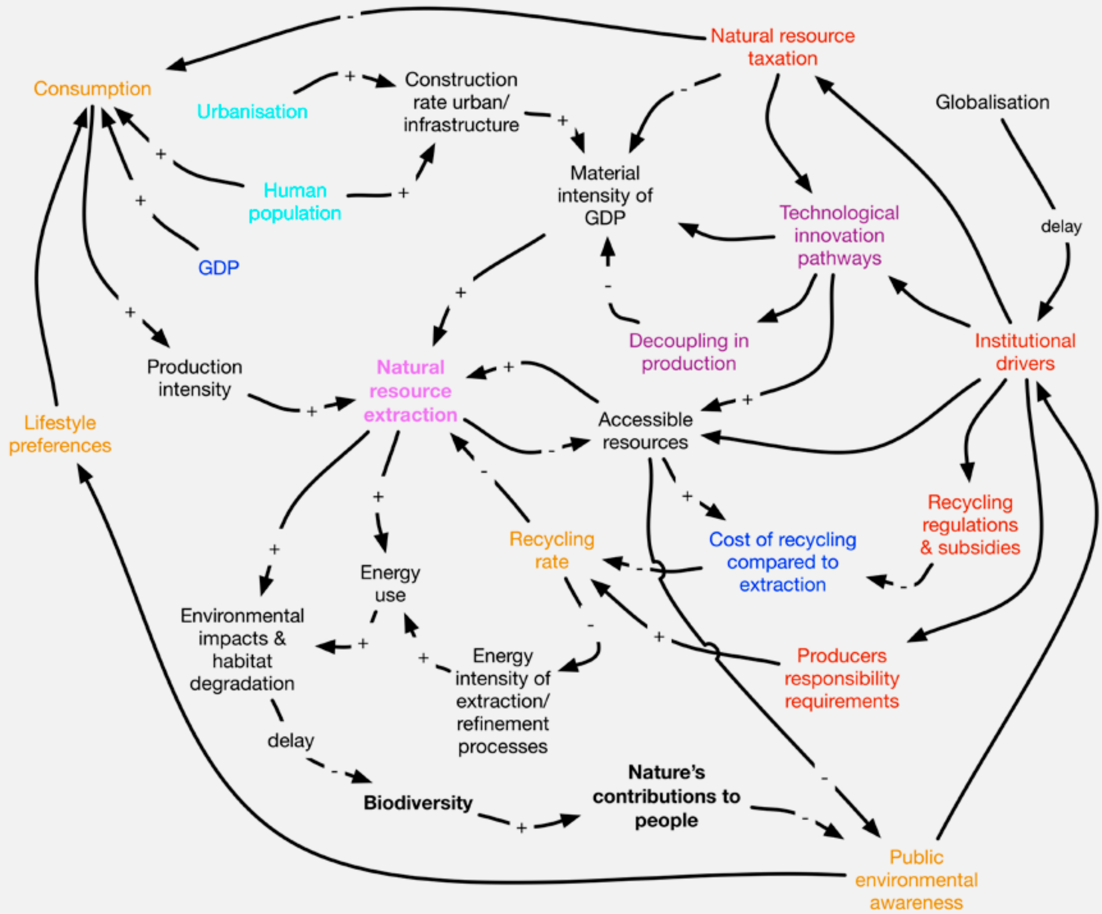


Figure 4 7 **Causal loop diagram illustrating drivers of natural resource extraction. Source: Own representation.**



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

impacts and habitat degradation. These effects may increase public awareness which in turn influences lifestyle preferences and becomes a driver of institutional change (Nolan & Schultz, 2015). Global trade, on the other hand, may disguise these effects and thereby delay institutional responses (4.4.1.3).

In summary, cultural drivers (growth oriented development), demographic and economic drivers (urban sprawl, tourism, consumption, etc.) continue exerting a pressure on natural resource extraction in Europe and Central Asia. Institutional drivers have been used to reduce this pressure. However, economic drivers in terms of environmental taxes have so far not been employed to support these advances in institutional drivers and therefore the technological innovative potential is not realized.

4.5 DRIVERS AND EFFECTS OF LAND-USE CHANGE

4.5.1 Effects of land-use change on biodiversity and nature's contributions to people

In Europe and Central Asia land-use change is one of the most important drivers of changes in biodiversity and the provision of nature's contributions to people (Aguilar *et al.*, 2006; CBD, 2014; EEA, 2015c; Fischer & Lindenmayer, 2007; Frankham *et al.*, 2014; Garibaldi *et al.*, 2011; Gil-Tena *et al.*, 2015; Gonthier *et al.*, 2014; Humphrey *et al.*, 2015; IPBES, 2016a, 2016b; Leimu *et al.*, 2010; Rusch *et al.*, 2016; Tscharntke *et al.*, 2007). Mitigating the adverse effects of land-use change is crucial to halting the loss of biodiversity and nature's contributions to people (Alkemade *et al.*, 2009; CBD, 2014; Dirzo & Raven, 2003; Hoekstra *et al.*, 2005; MEA, 2005a).

4.5.1.1 Effects of conventional agricultural intensification

Intensification of conventional agriculture has a multi-factorial impact on biodiversity and nature's contributions to people. The actual impacts often vary with an organisms' taxonomic or functional group and hence evolutionary history, within and between geographic regions (Báldi *et al.*, 2013; Billeter *et al.*, 2008; Flohre *et al.*, 2011; Gabriel *et al.*, 2013; Gonthier *et al.*, 2014; Guerrero *et al.*, 2011; IPBES, 2016a; Le Féon *et al.*, 2010; Redhead *et al.*, 2015; Sjödin *et al.*, 2008; Tsiafouli *et al.*, 2015; Woodcock *et al.*, 2005). In Europe and Central Asia, the impact of conventional intensification of agriculture has been manifest through loss of (semi-) natural habitats, landscape homogenization and intensive use of agri-chemicals (Gonthier *et al.*, 2014, see Chapter 3). The focus on maximising agricultural production since World War II has transformed and modified natural habitats and traditional semi-natural ecosystems physically, biologically and chemically with profound implications for biodiversity and nature's contributions to people (Gabriel *et al.*, 2013; Gil-Tena *et al.*, 2015; IPBES, 2016a; Sanderson *et al.*, 2013; Stoate *et al.*, 2009; Tscharntke *et al.*, 2005; UNEP, 2016). For example, a negative relationship between crop yield and most elements of biodiversity (plants, bumblebees, solitary bees, butterflies, epigeal arthropods) were found in a study of eight paired landscapes of organic and conventional management farms (Gabriel *et al.*, 2013). In Europe and Central Asia agricultural intensification (defined as the number of pesticide applications, tillage operations, fertilizer levels or crop types) relates to reductions in species richness and diversity of plants, wild bees and birds, but not ground beetles, at scales from field to region (Billeter *et al.*, 2008; Flohre *et al.*, 2011; Le Féon *et al.*, 2010). Among grazed and mown grasslands biodiversity of plants, animals and microorganisms declines with increasing mean land-use intensity, while this decline is at least ameliorated by variation in land-use intensity between years (Allan *et al.*, 2014).

Landscape homogenization is an outcome of conversion of semi-natural habitats based on traditional land-use practices into intensively managed arable or grazing land, which has reduced biodiversity and a number of nature's contributions to people across Europe and Central Asia (Billeter *et al.*, 2008; Flohre *et al.*, 2011; Le Féon *et al.*, 2010; Munteanu *et al.*, 2014; Newbold *et al.*, 2016; Pe'er *et al.*, 2014; Stoate *et al.*, 2009; Tscharntke *et al.*, 2005; Van Zanten *et al.*, 2014; Vanbergen *et al.*, 2006; Vanbergen, 2014; Yoshihara *et al.*, 2008; Zhu *et al.*, 2012). Although large-scale, intensively-managed agricultural monocultures can provide food and habitat resources for organisms adapted to exploit it, this resource is insufficient to cater for most elements of biodiversity (Diekötter *et al.*, 2014; IPBES, 2016a; Kovács-Hostyánszki *et al.*, 2013, 2017; Riedinger *et al.*, 2015; Rundlöf *et al.*, 2014; Schweiger *et al.*, 2007; Tscharntke *et al.*, 2005; Vanbergen *et al.*, 2010; Westphal *et al.*, 2009).

Intensive use of agri-chemicals (such as herbicides, insecticides, or inorganic fertilizers) is linked to transformation of ecological communities and directly contributes to declines of species, some of which providing important contributions to people (Brittain *et al.*, 2010; Chiron *et al.*, 2014; Deguines *et al.*, 2014; Dormann *et al.*, 2007; Gabriel *et al.*, 2013; Gonthier *et al.*, 2014; Hawes *et al.*, 2003; IPBES, 2016a; Rundlöf *et al.*, 2015; Storkey *et al.*, 2012; Woodcock *et al.*, 2016). For example, intensive use of herbicides and inorganic fertilizers act as environmental filters eliminating wild plant species, especially those adapted to conditions of intermediate fertility, with implications for the higher trophic levels, such as insect pollinators and seed feeding birds, which depend on such wild plant species for food resources (Chiron *et al.*, 2014; Hawes *et al.*, 2003; IPBES, 2016a; Storkey *et al.*, 2012). Further, agricultural insecticides target pest populations, they also pose a direct hazard to non-target insects, such as pollinators, that are crucial for the maintenance of biodiversity in natural ecosystems and deliver important services to pollinator-dependent crops (Deguines *et al.*, 2014; IPBES, 2016a).

Genetically modified crops can possess traits for herbicide tolerance or resistance to pests and their large-scale cultivation may drive changes to species and populations in agricultural landscapes either directly on gene pools or indirectly on dependent biodiversity. The direct hazard for biodiversity and nature's contributions to people is relatively low, although where lethal impacts of insect-resistant crops on biodiversity occur they tend to be on species closely related to the targeted pest (IPBES, 2016a, 2016b; Marvier *et al.*, 2007; Mommaerts *et al.*, 2010; Nicolia *et al.*, 2014; Potts *et al.*, 2016). Reductions of pesticides that may accompany the use of insect-resistant crops could lower overall pesticide pressure on non-target organisms, but the emergence of secondary outbreaks of non-target pests or primary pest resistance can lead to a resumption of pesticide use (Barfoot & Brookes, 2014; IPBES, 2016a, 2016b; Lu *et al.*, 2010). Most risk to biodiversity and nature's contributions to people from genetically modified crops comes both from their management and direct impacts per se. Intensive herbicide use on herbicide-tolerant crops will eliminate wild plants, with concomitant effects on other biodiversity components through the network of interactions, although this and the effects on nature's contributions to people remains little-studied (Bohan *et al.*, 2005; IPBES, 2016a, 2016b; Morandin & Winston, 2005).

If continued, conventional intensive agriculture will jeopardize both sustainable land management and food production.

Erosion of natural capital (such as pollinators, natural enemies of pests, soil biodiversity and others) poses a substantial risk to the sustained and resilient production of food (IPBES, 2016a; Kovács-Hostyánszki *et al.*, 2017; Tsiafouli *et al.*, 2015). Studies focusing on the comparison of conventional intensive management with less-intensive agricultural systems indicate that there is considerable potential for alternative approaches to management that secure farm production and conservation of nature's contributions to people (Bommarco *et al.*, 2013; Kovács-Hostyánszki *et al.*, 2017; Pywell *et al.*, 2015).

4.5.1.2 Effects of agri-environment schemes

A wealth of studies shows that diversity or activity densities at local (field to farm) scales can be enhanced through agri-environment schemes (Albrecht *et al.*, 2007; Batáry *et al.*, 2011; Carvell *et al.*, 2011; Doxa *et al.*, 2010; Fuentes-Montemayor *et al.*, 2011; Gonthier *et al.*, 2014; Haaland *et al.*, 2011; Hiron *et al.*, 2013; Holzschuh *et al.*, 2007; Kovács-Hostyánszki *et al.*, 2011; Krauss *et al.*, 2011; Pywell *et al.*, 2012; Scheper *et al.*, 2013). Certain agri-environmental schemes in the European Union clearly benefit target organisms (e.g. wildflower strips and bees - Carvell *et al.*, 2017; organic farming and plants - Batáry *et al.*, 2013; Henckel *et al.*, 2015; Tuck *et al.*, 2014). Evidence for increasing biodiversity is sometimes equivocal, complex and unpredictable (e.g. organic farming effects on insects and mammals - Bengtsson *et al.*, 2005; Gabriel *et al.*, 2010, 2013; Krauss *et al.*, 2011; Ponce *et al.*, 2011; Tuck *et al.*, 2014).

Landscape complexity and the ecological contrast with other habitats at field scales influence the efficacy of agri-environment schemes, with typically the greatest uplift in local biodiversity in highly homogenized landscapes that lack remnant semi-natural habitats providing resources for wildlife (Batáry *et al.*, 2011; Gabriel *et al.*, 2010; Heard *et al.*, 2007; Hiron *et al.*, 2013; Holzschuh *et al.*, 2007; Kleijn *et al.*, 2011; Rundlöf & Smith, 2006; Scheper *et al.*, 2013, 2015; Tscharntke *et al.*, 2005; Tuck *et al.*, 2014). Agri-environment schemes have a less expected impact in high-diversity cultural landscapes where they slow down, prevent or even reverse the abandonment process and thus help maintain high nature-value grasslands (Babai *et al.*, 2015).

Recent evidence points to population-level increases when diverse habitat resources are provided and sustained at the landscape scale (Carvell *et al.*, 2017; Carvell *et al.*, 2015; Doxa *et al.*, 2010; Tschumi *et al.*, 2016; Wood *et al.*, 2015). Emerging evidence suggests that targeted habitat creation or protection of ecological infrastructure in the landscape can contribute towards achieving a more sustainable agriculture (Bommarco *et al.*, 2013; IPBES, 2016a, 2016b; Kovács-Hostyánszki *et al.*, 2017; Potts *et al.*, 2016; Pywell *et al.*, 2015; Tittonell, 2014). There are concerns about the efficacy of agri-environment schemes for conserving rare, specialized species and there is a level of geographic bias in the available evidence (Batáry *et al.*, 2015; Scheper *et al.*, 2013; Sutcliffe *et al.*, 2015). Effectiveness of agri-environment schemes' interventions could be improved by tailoring to targets for biodiversity or nature's contributions to people considering local ecological and landscape context, and different socio-economic settings (Babai *et al.*, 2015; Batáry *et al.*, 2015; Bright *et al.*, 2015; Dicks *et al.*, 2016; Ekroos *et al.*, 2014; IPBES, 2016a; Mccracken *et al.*, 2015; Molnár & Berkes, 2017; Pe'er *et al.*, 2014; Pywell *et al.*, 2012; Scheper *et al.*, 2013; Sutcliffe *et al.*, 2015).

4.5.1.3 Effects of increasing intensity of management on forest land

Long-term human pressures during the last centuries (Kolář *et al.*, 2016) have resulted in the deforestation and fragmentation of forests in Europe and Central Asia (e.g., Wallenius *et al.*, 2010b) and will continue to cause species extinctions (Hanski, 2000; Niemelä *et al.*, 2005). More than 35% of European forests are in mosaic landscapes that are significantly fragmented by agricultural and artificial lands (EEA, 2016b).

One key indicator of high quality habitats is the amount of dead wood. Overall, natural forests normally harbour around 100 m^3/ha of dead wood (Jonsson & Siitonen, 2012). Currently, in Westen, Central and Eastern Europe, the volume of dead wood in forests is estimated to be 20.5 m^3/ha (including the Russian Federation) and 10 m^3/ha (without the Russian Federation; Forest Europe, 2011). Among individual countries the volumes vary considerably **(Figure 4.8)**.

Forest management intensification reduces natural forest area and degrades habitat quality due to loss of structural components (e.g. dead wood), simplified spatial stand structure (e.g. uneven age-structure) and simplification of natural processes (e.g. gap formation, decomposition) **(Table 4.5)**. This greatly impacts associated biodiversity, particularly specialist species (Brockerhoff *et al.*, 2008; Brumelis *et al.*, 2011; Esseen *et al.*, 1997; Kuuluvainen, 2002; Paillet *et al.*, 2010). For example, species richness of multiple taxa (bryophytes, lichens, fungi, saproxylic beetles, carabids) were considerably lower in managed forests than in unmanaged forests with effects most pronounced for forests that underwent clearcutting and historic changes in tree species composition (Paillet *et al.*, 2010).

Intensive forest management also includes conversion of non-forested lands to managed forest plantations, which often have detrimental effects on *in situ* biodiversity due to

Figure 4 8 **Average volume of standing and lying deadwood in 2010 (m³/ha). Source: Forest Europe (2011).**

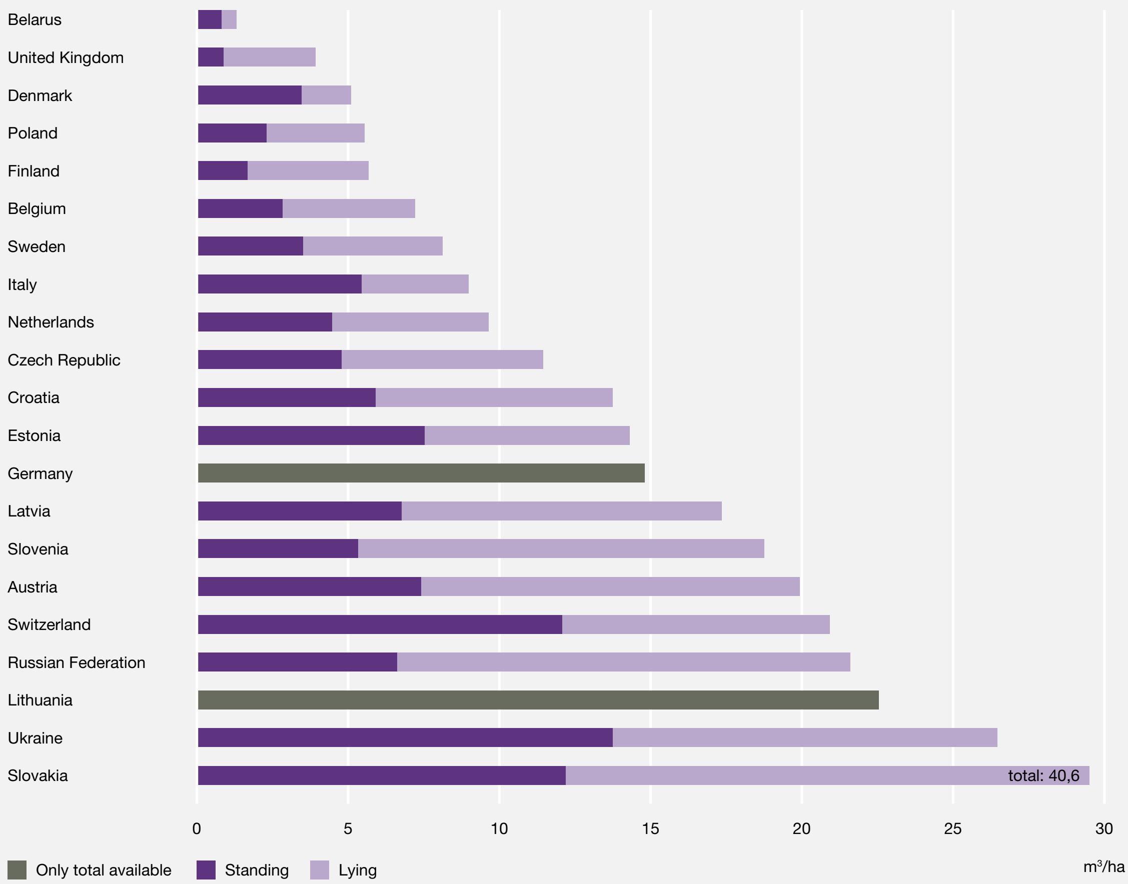


Table 4 5 **Components that are important for biodiversity in natural forests that are negatively influenced by forestry. Source: Modified after Esseen *et al.* (1997).**

Structural components

- Very old trees
- Trees with abundant growth of epiphytes
- Broken, stag-headed and leaning trees
- Trees with holes, cavities and other microhabitats
- Dead standing trees (snags)
- Fire-scarred trees, snags and stumps
- Large downed logs in various stages of decomposition

Spatial patterns

- A developed understory of tree saplings and shrubs
- Mixed stands, with both conifers and broad-leaves
- Uneven-aged stand structure
- Multi-layered tree canopies
- Patchy distribution of trees, gaps

Processes

- Post-fire succession
- Succession with tree-species replacement
- Self-thinning
- Gap formation
- Snag and log formation
- Decomposition of coarse woody debris

loss of habitat and associated species turnover (Brockerhoff *et al.*, 2008). However, afforestation of agricultural land can assist biodiversity conservation by providing ecotones and increasing forest connectivity (Brockerhoff *et al.*, 2008). Where forest cover is low, plantation on marginal land can provide habitats for rare forest adapted species (Humphrey *et al.*, 2003). Additional conservation efforts to improve forest structure can correspondingly improve the situation for biodiversity (Humphrey, 2005). Traditionally managed and used forest ecosystems such as traditional agro-silvicultural systems with wood-pastures and coppicing also support and maintain suitable conditions for many forest species (Bollmann & Braunisch, 2013; Kirby & Watkins, 2015; Plieninger *et al.*, 2015). As different types of forest management promote different facets of biodiversity or nature's contributions to people, heterogeneity of forest management practice at the landscape scale, also including unmanaged forest, is likely to maximize landscape-level forest biodiversity and forest contributions to people (Elbakidze *et al.*, 2017; van der Plas *et al.*, 2016).

4.5.1.4 Effects of decrease in land area with traditional land use and loss of traditional ecological knowledge

Much of the biodiversity in Europe and Central Asia relies on traditionally managed semi-natural habitats (EEA, 2015b; Kirby & Watkins, 2015; Liira *et al.*, 2008; Plieninger *et al.*, 2015; Stoate *et al.*, 2009; Tscharntke *et al.*, 2005; UNEP, 2016). The loss and abandonment of traditionally managed systems due to multiple factors has been an important driver of decline in biodiversity and nature's contributions to people (Bergmeier *et al.*, 2010; Bubová *et al.*, 2015; Fuller, 1987; Helm *et al.*, 2006; Henle *et al.*, 2008; MacDonald *et al.*, 2000; Middleton, 2013; Plieninger *et al.*, 2015; Rotherham, 2015; van Swaay *et al.*, 2006). Abandonment of traditional land management allows reassertion of successional and other ecological processes (e.g. increase in interspecific competition) leading to loss of specific habitats that support biodiversity of high conservation value (Bergmeier *et al.*, 2010; Middleton, 2013; Rotherham, 2015). The evidence for a negative impact of abandonment is particularly strong for semi-natural grassland systems (Bergmeier *et al.*, 2010; Dengler *et al.*, 2014; Rotherham, 2015), mountainous areas (MacDonald *et al.*, 2000) and for particular taxa (e.g. butterflies, farmland birds and plants - van Swaay *et al.*, 2006; Bubová *et al.*, 2015; Liira *et al.*, 2008). Since World War II, the cover of open cultural woodlands in Western and Central Europe has rapidly declined and been replaced with agricultural fields and closed forests. This led to a decline in light-dependent specialist species of open woodland and increases in species typical for mesic and closed forest (Bütler *et al.*, 2013; Hédl *et al.*, 2010; Miklín & Čížek, 2014; Nieto & Alexander, 2010; Plieninger *et al.*, 2015; Saniga *et al.*, 2014; van Swaay *et al.*, 2006). There are cases where taxa benefit from abandonment of semi-natural habitats (Gulvik, 2007, for Oribatid mites, Sitzia *et al.*, 2010) but these seem to be the exception. Abandonment and loss of semi-natural habitats have also significant negative impacts on cultural and social capital and results in loss of traditional and local knowledge (Csergo *et al.*, 2013; Molnár & Berkes, 2017; Rotherham, 2015). The precise outcome often depends upon the direction of the succession (e.g., to steppe vs to forest - Dengler *et al.*, 2014; or above vs below the treeline - MacDonald *et al.*, 2000; the spatial context - Sitzia *et al.*, 2010; the time since abandonment - Lasanta *et al.*, 2015; and the pattern of farming - MacDonald *et al.*, 2000).

4.5.1.5 Effects of urban development

The expansion of urban areas and its pressure on natural and semi-natural land will continue to be one of the major land-use factors in large parts of Western and Central Europe (EEA, 2016d), and is also likely to result in considerable land take in Central Asia in coming decades (Angel *et al.*, 2011). With increasing urbanization, direct destruction of habitats, reduction of habitat areas, increasing fragmentation and degradation in both terrestrial and aquatic habitats can lead to significant negative impacts on biodiversity (Güneralp & Seto, 2013; McKinney, 2006, 2008). Urbanization affects different habitats and species groups disproportionately and often its effects are related to intensity of urbanization and regional biodiversity patterns (McKinney, 2008). In regions with less effective governance of land use, there is a greater possibility of development affecting areas with high biodiversity (Güneralp & Seto, 2013). In Western and Central Europe, urban development and its associated land take poses a major threat to soil and could have significant effects on agricultural production and food (Gardi *et al.*, 2015).

4.5.1.6 Effectiveness of landscape and habitat restoration

Restoration success depends on the ability to encompass the important ecological mechanisms that underpin ecosystem functioning (Török & Helm, 2017). For example, forest restoration success has been shown to mainly depend on time since restoration initiation, disturbance type (secondary or selectively logged forests) and landscape context (e.g. forest patch size and isolation; Crouzeilles *et al.*, 2016). It is important to restore the genetic diversity contained within an ecosystem to assure evolutionary potential and to avoid adverse effects caused by management, e.g. founder effects, where only few individuals contribute to initial genetic diversity (Brudvig, 2011; Mijangos *et al.*, 2015; Wortley *et al.*, 2013) (see **Box 4.2**).

There are numerous links between restoration, economic development, and human well-being (Aronson *et al.*, 2010; Benayas *et al.*, 2009) (see **Box 4.2**). Successful engagement of local community and other social attributes are considered highly important in determining the feasibility and cost of restoration, as well as the success of restoration and sustainability of the restoration outcome (Shackelford *et al.*, 2013; Wortley *et al.*, 2013).

Rewilding is a particular approach that aims to restore ecosystems toward a state of wilderness (Carey, 2016). The effects of rewilding on biodiversity and nature's contributions to people likely depend on initial conditions before rewilding and on the success of development of self-sustainable ecosystems. Sufficient evidence for suitable solutions is not yet available (Cerqueira *et al.*, 2015; Dixon *et al.*, 2016; Götmark, 2013; Smit *et al.*, 2015; Ziolkowska & Ziolkowski,

Box 4 2 **Restoration of grasslands has brought people back to the countryside.**

Sheep on recently restored alvar grassland in Saaremaa, Estonia. Following the abandonment of traditional land use, large part of Estonian semi-natural grasslands overgrew with shrubs. Restoration of those species rich grasslands and subsequent grazing, supported by agricultural subsidies, has led to positive impacts on both the local livelihood and on biodiversity. Photo: Ants Animägi, Estonian State Forest Management Centre.

Alvars, dry calcareous thin-soiled semi-natural grasslands once covered ca. 50,000 hectares in western part of Estonia, especially on its scenic islands Saaremaa, Muhu and Hiiumaa (Helm *et al.*, 2007). By 2013, only 2,500 hectares were managed by grazing – a traditional management method necessary for the persistence of these high nature value habitats (Government of Estonia, 2013). In an effort to save high biodiversity and traditional land-use practices related to Alvar grasslands, 600 land-owners and 41 local farmers and farming companies in 25 regions all over western part of Estonia are participating in the LIFE+ programme project "LIFE to Alvars" (LIFE13NAT/EE/000082) from 2014 to 2020. The project aims to double the area of managed Alvars in Estonia by restoring 2,500 hectares of grasslands and encouraging local people and farmers to take up grazing in those areas. Already by 2017, restoration activities, vastly changing landscapes and awareness-raising activities have had considerable impact both on the public knowledge about the value of grasslands, as well as on economic and lifestyle choices among local people. Implementation of the infrastructure necessary for grazing (fences, animal drinking places and shelters, gates), coupled with the support system for managing semi-natural areas have created incentives for local farmers to increase their livestock and move animals from cultural grasslands to restored Alvars. By 2017, following the restoration of the first 1,500 hectares of traditional grassland landscapes, 270 head of cattle and 400 sheep were added to the herds of local farmers. In addition, four families moved back to the countryside and changed their profession to livestock farmers. Open Alvar grasslands have great aesthetic, cultural heritage and recreational value and several nearby tourism facilities noted the positive effect of grassland restoration on their activities, by boosting visitor numbers and by increasing the opportunities on offer for scenic nature tours (Prangel, 2017).

2016). There is a potential for conflict as many proposed rewilding areas (see Ceaușu *et al.*, 2015) lie in regions where indigenous peoples and local communities live (e.g. Carpathians, Balkan). Considering human rights and the rights of these communities during the establishment of rewilding areas is of vital importance.

4.5.1.7 Effectiveness of protected areas

Designated conservation areas are highly important in safeguarding biodiversity and nature's benefits to people, but there is considerable evidence that protected areas alone cannot prevent biodiversity loss (e.g. Mora & Sale, 2011), particularly for migratory species (e.g. Saiga antelope; Bull *et al.*, 2013) or habitats or species particularly sensitive to environmental change (Bull *et al.*, 2013; Dudley *et al.*, 2014; Strayer & Dudgeon, 2010). A global systematic review shows that individual protected areas were effective at protecting habitats, particularly forests, but less effective at conserving populations of species (Geldmann *et al.*, 2013). There is great variation across Europe and Central Asia in the efficacy of formally protected areas for biodiversity conservation. Recent evaluations of the European Union Natura 2000 network of protected areas found it to be effective in providing coverage to most species listed in Annex II of the Habitats Directive (http://ec.europa.eu/environment/nature/legislation/fitness_check/docs/nature_fitness_check.pdf).

Natura 2000 sites do not only therefore serve the purpose of protecting Annex 1 (Birds Directive) and Annex II (Habitats Directive) species, but also protect certain more common (non-Annex) species, in particular breeding birds and butterflies, but less so amphibians and reptiles (van der Sluis *et al.*, 2016). However, the Natura 2000 network is not completely effective because there are exceptions for particular taxa (e.g., Zehetmair *et al.*, 2015a, 2015b) or in the way different member States implement it. For example, certain species (e.g. those dependent on traditional land management) or ecological zones (e.g. lowland versus upland) were either over- or under-represented, and gaps exist in the protection of biodiversity in certain habitats (e.g. marine and temporary freshwater habitats) (Gruber *et al.*, 2012; Maiorano *et al.*, 2007; McKenna *et al.*, 2014; van der Sluis *et al.*, 2012).

Natura 2000 represents one of the most systematic efforts for developing new protected areas, but the effectiveness of implementation of Natura 2000 for biodiversity conservation has not been sufficiently evaluated (Gaston *et al.*, 2008). A major challenge for forest protected areas is that current conditions are not pristine due to past management and suppression of natural disturbance processes (Hedwall & Mikusiński, 2015; Lõhmus *et al.*, 2004; Meyer *et al.*, 2011). Protected areas also tend to be too small to accommodate the full range of natural processes and hence unable to maintain sufficient ecological memory to re-organize after disturbances (Bengtsson *et al.*, 2003). In some forest reserves, "natural" state is contingent on traditional management (e.g. livestock grazing, coppicing, pollarding or small-scale felling). The introduction of such methods may be needed to secure forest biodiversity, but is so far rarely implemented mainly for economic reasons (Bernes *et al.*, 2015; Götmark, 2013; Sebek *et al.*, 2013). Measures to improve environmental status within conservation areas, combined with landscape-scale approaches that improve matrix quality for native biodiversity, are therefore urgently needed if their efficiency is to be improved.

The degree of monitoring and enforcement of protected areas can be critical for their efficacy in protecting biodiversity (e.g. Wendland *et al.*, 2015). For instance, almost 40% of the protected areas in the Barents Euro-Arctic region remain vulnerable to disturbance from human activities, including logging, mining, drilling and construction (Aksenov *et al.*, 2014). The efficacy of protection often varies among countries. For example, protected forest areas in the eastern Carpathians have proved effective at halting illegal logging in Poland and Slovakia but have been less so in Ukraine (Kuemmerle *et al.*, 2007) and protection in one country can lead to displacement of adverse impacts to adjoining territories (Mayer *et al.*, 2006). In certain circumstances, proximity to humans can sometimes affect the efficacy of protected areas in conserving biodiversity. For example, in Kyrgyzstan proximity of villages to protected areas was linked to a lowering of effectiveness for conserving non-ungulate large mammals (McCarthy *et al.*, 2010). In eastern Russia, Siberian tiger survival was inversely linked to roads bordering or crossing the strictly protected Sikhote-Alin State Biosphere Zapovednik (Kerley *et al.*, 2002). In summary, the proportion of protected areas is an important indicator of conservation efforts, although it needs to be combined with other indicators to fully assess the efficacy of measures aiming to conserve biodiversity (e.g. management plans, restoration actions, population indices of target species etc.).

The European Union Biodiversity Strategy Target 1 ("fully implement the Birds and Habitats Directives") and Target 2 ("maintain and restore ecosystems and their services") define actions to ensure habitats and ecosystems protection. There is a progress on those targets in the European Union, but in insufficient rate: 16% of the habitats assessments are favourable, 4% are unfavourable, but improving, 33% are unfavourable and stable, 30% are unfavourable and deteriorating, 10% are unfavourable with unknown trend and 7% are unknown (European Commission, 2015). The network of Natura 2000 sites has progressed and is largely completed for terrestrial habitats, since 2010 it has grown for 1.4% and covering in 2015 18.1% of the European Union land. Overall, the mid-term assessment indicates the progress as the one with an insufficient rate (European Commission, 2015). Therefore, the European Union Biodiversity Targets 1 and 2 may not to be fully met by 2020 if the rate of the progress remains at the current level.

Regarding the Aichi Biodiversity Targets, reaching Target 11 ("protected areas increased and improved") for terrestrial ecosystems implies an increase in terrestrial protected areas, with an increased focus on representativeness and management effectiveness (Leverington *et al.*, 2008). A focus on representativeness is crucial as current protected area networks have gaps, and some fail to offer adequate protection to many species and ecosystems. These gaps include many sites of high biodiversity value such as Alliance for Zero Extinction sites and Important Bird Areas (Butchart *et al.*, 2010; Ricketts *et al.*, 2005). The global data sets statistically prove the progress in the increased coverage of protected area and sites of significance that ensure ecosystems connectedness in Europe and Central Asia. The data includes the World Database on Protected Areas (WDPA) (UNEP-WCMC & IUCN, 2014). Data on sites contributing significantly to the global persistence of biodiversity, or "key biodiversity areas" (KBAs) are provided by BirdLife International (2017) for Important Bird & Biodiversity Areas and by the Alliance for Zero Extinction sites holding the entire population of at least one highly threatened species (Brooks *et al.*, 2006; Ricketts *et al.*, 2005).

4.5.2 Trends and indirect drivers of changes in agricultural land use

4.5.2.1 Trends in agricultural land use

Agricultural land-use changes are constrained and driven by biophysical conditions and sets of inter-related indirect drivers (e.g. policies, political changes in Eastern Europe and Central Asia, demands for food and ecological products etc.). Across the region there are two principal trends: (1) intensification of conventional agriculture; and (2) decreasing land-use intensity and abandonment of conventional agricultural land.

Trend 1: Intensification of conventional agriculture

This model of agricultural production is characterized by large-scale monocultures specializing on few crops that are supported by high levels of agrichemical inputs or irrigation, management of high livestock densities, and mechanization to increase production (Foley *et al.*, 2005; Goldewijk, 2001; Henle *et al.*, 2008; Robinson & Sutherland, 2002; Tilman *et al.*, 2001; Tscharntke *et al.*, 2005; van Vliet *et al.*, 2015; EEA, 2015a). Agricultural intensification has been a dominant driver of land-use changes in Europe and Central Asia since the 1950s (Jepsen *et al.*, 2015; EEA, 2015a). The area of agricultural holdings and their role in the agricultural sector are constantly growing (BEFL, 2016; Petrick *et al.*, 2013; Visser *et al.*, 2012; Visser *et al.*, 2014). They are especially large in the most favourable regions for agriculture. For example, in Russia 43 companies cultivate in total 10.4 million hectares (BEFL, 2016). Although the temporal and spatial patterns and intensity of agricultural land use vary considerably within the region, intensive agriculture is expected to remain among the prevailing land-use practices in the region into the future (Jepsen *et al.*, 2015).

In Western Europe, conventional intensive agriculture has been the prevailing model of agricultural production since the 1950s (EEA, 2015a). This has led to considerable landscape homogenization (Curado *et al.*, 2011; Stoate *et al.*, 2009). Landscape homogenization also occurred in many parts of Central Europe during the socialist period (1945 – 1990) (Fraser & Stringer, 2009; Munteanu *et al.*, 2014). In Eastern Europe and Central Asia, Russia, Ukraine and Kazakhstan, conventional agricultural intensification happened mainly after the break-up of the USSR in 1991; and these three countries became major exporters of agricultural products products (Liefert *et al.*, 2009). Currently, Russia is among the major world grain exporting nations due to an increase of land-use intensity and partial re-cultivation of abandoned lands after 2000 (Medetsky, 2016).

In Central Asia irrigated agricultural areas have increased at the expense of natural pastures since the 1960-1970s, for instance in the vicinity of the Syr Darja and Amur Darja rivers. This is mainly due to cotton production (Kaplan *et al.*, 2014), which has doubled since the 1960s and now accounts for nearly half of all irrigated arable land. Irrigation is currently used for 33% (13 million ha) of cultivated areas in Central Asia. However, poor maintenance of drainage systems has resulted in millions of hectares of irrigated areas suffering from salinization and waterlogging. In Uzbekistan 51% (2.1 million ha) and Turkmenistan 68% (1.3 million ha) of irrigated areas are salinized and further widespread degradation of agricultural land is expected in these countries (Frenken, 2013; Horion *et al.*, 2016).

Trend 2: Decrease of land-use intensity and abandonment of conventional agricultural land

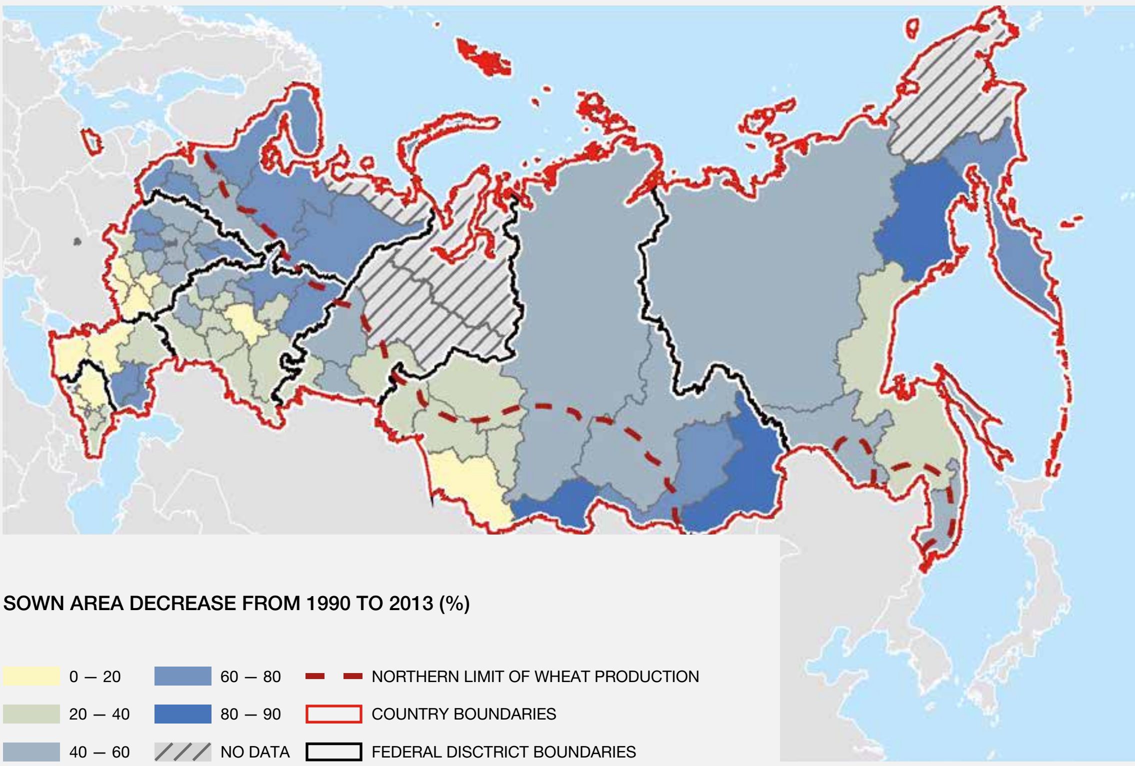
Agricultural land abandonment is widespread in Europe and Central Asia (Benayas *et al.*, 2007; Díaz *et al.*, 2011; Prishchepov *et al.*, 2013; Wang *et al.*, 2016). The available evidence indicates that it is reasonable to expect that farmland abandonment will continue over the next few decades, particularly in the case of extensively grazed lands (Keenleyside & Tucker, 2010). However, some projections of land-use change are limited by a lack of appropriate data on historical legacies, local conditions and drivers (Biró *et al.*, 2013; Feranec *et al.*, 2010; Hatna & Bakker, 2011; Temme & Verburg, 2011). Overall, the largest abandonment extent is in the East European forest steppe and Pontic steppe zones, in Sarmatic mixed forests and in the boreal zone (Schierhorn *et al.*, 2013).

Agricultural land abandonment leads to complete termination of agricultural activity and reforestation through silviculture or natural succession to shrubs and forest (Alcantara *et al.*, 2012; Baldock *et al.*, 1996; Baumann *et al.*, 2011; van der Zanden *et al.*, 2017). For example, in Western and Central Europe an increase of forest and semi-natural habitats after abandonment of agricultural land occurred widely in Italy, Hungary, Poland and Germany and to a lesser extent in France and Greece, while in Spain the transition was in the opposite direction (Petersen, 2006). Agricultural land abandonment has tended to be concentrated in areas that are marginal for agriculture, for example, on unproductive soils and areas limited by other biophysical conditions (temperature, high precipitations etc.) (Ioffe, 2005; Meyfroidt *et al.*, 2016; Prishchepov *et al.*, 2013, 2016). Abandoned farmland was converted to urban residential areas or infrastructure in some places or, more often, became forested or afforested (Grădinaru *et al.*, 2015; Plutzar *et al.*, 2015; Schierhorn *et al.*, 2013).

In the European Union cropland area has decreased by almost 1.2 million hectares in recent decades (Dixon *et al.*, 2009; Grădinaru *et al.*, 2015; Munton, 2009). In Central European countries, including Poland, Czech Republic, Slovakia, Hungary, Romania and Bulgaria, during the 1990s and 2000s the prevailing land-use trend was abandonment of arable land and grassland, reductions of livestock densities and agrochemical use and reforestation (Biró *et al.*, 2013; Sutcliffe *et al.*, 2013). For example, in Poland 17.6%, in Estonia 10.1% and in Latvia 21.1% of agricultural land was abandoned by 2002 (Keenleyside & Tucker, 2010). However, expansion of the European Union and implementation of its Common Agricultural Policy in new member States has resulted in the reclaiming of abandoned farmland for intensive agriculture – a trend that is likely to continue (Keenleyside & Tucker, 2010; Kuemmerle *et al.*, 2009; Sutcliffe *et al.*, 2013).

Eastern Europe and Central Asia have been hotspots of cropland abandonment since the 1990s (Keenleyside & Tucker, 2010; Kuemmerle *et al.*, 2009; Sutcliffe *et al.*, 2013). The collapse of the socialistic collective farming system resulted in the abandonment of more than 58 million hectares of former croplands in Russia and Kazakhstan (Kurganova *et al.*, 2015) (**Figure 4.9** and **Figure 4.10**). This was mirrored by substantial reductions in livestock (e.g.

Figure 4 9 **Decrease in sown area from 1990 to 2013 across Russia. Source: CISSTAT (2017).**



>30% reductions from 1990 levels in cattle densities in 2005 and 2015) (Chibilyov, 2016; Lescheva & Ivolga, 2015; Rosstat, 2017). In Kazakhstan and in stock farming steppe regions of Russia the collapse of livestock populations and state farms were combined with the private acquisition of former state assets, including livestock (Kerven *et al.*, 2016; Robinson *et al.*, 2016; Suleimenov & Oram, 2000). Livestock declines of up to 80% in sheep and cattle took place in Kazakhstan (Kamp *et al.*, 2011), creating a vast area of un-grazed grasslands (Kerven *et al.*, 2016). Grazing patterns changed significantly, and intensive grazing became restricted to areas around villages, which have been rapidly degrading due to overgrazing (Kamp *et al.*, 2011, 2012; Kandalova & Lysanova, 2010; Kitov & Tsapkov, 2015; Kühling *et al.*, 2016; Morozova, 2012; Suleimenov & Oram, 2000).

4.5.2.2 Indirect drivers of trends in agricultural land use

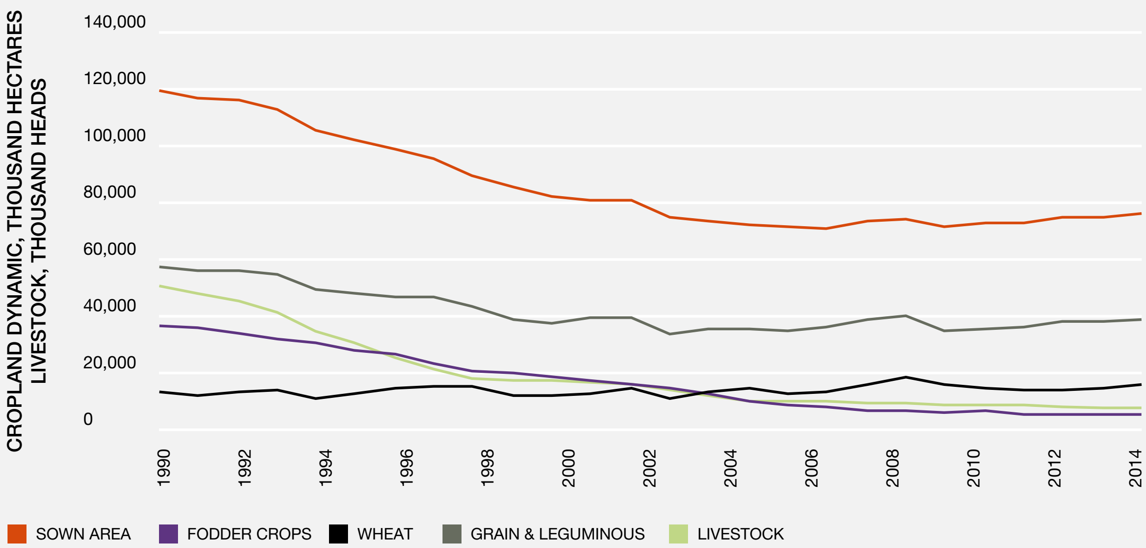
Changes in agriculture are driven by multiple interconnected institutional, economic, cultural and technological drivers **(Figure 4.11)**.

4.5.2.2.1 Institutional drivers of trends in agricultural land use

Until the 1980s, the European Union Common Agricultural Policy became the major incentive for the conventional intensification of agriculture (Van Zanten *et al.*, 2014) through a subsidy scheme based primarily on price pegging. Since 1992, it has increasingly been adapted to better serve the aims of sustainability by means of a fundamental reform process designed to move away from a policy of price and production support to a policy of direct income aid and rural development measures, including agri-environmental schemes. The 2003 Common Agricultural Policy reform (Council Regulation (EC) No. 1782/2003) brought forward environmental concerns in agriculture. It reinforced a number of measures that encourage land use and practices compatible with the protection of environmental resources. Agri-environmental schemes became compulsory for every member State.

From the 1990s, in Central Europe radical changes in political, social and economic systems brought about the restitution of private property and the land market with consequential economic drivers. State support diminished, former export markets within the socialist sphere of influence disappeared, prices were liberalized, and farmers suddenly faced strong external competition even though they often lacked the necessary inputs (e.g., fertilizer) and technology (e.g., access to machinery) to sustain high yields (Lerman *et al.*, 2004; Rozelle & Swinnen, 2004; Skokanová *et al.*, 2016). These politico-economic drivers instigated further agricultural intensification in fertile regions, and abandonment of less fertile or less accessible land (Fonji & Taff, 2014; Jepsen *et al.*, 2015; Skokanová *et al.*, 2016; van Vliet *et al.*, 2015). During the transition from planned to market economy the agricultural cooperatives were dismantled and much of their land was privatized to new owners or re-privatized to the former owners, which led to establishment of numerous smallholder farms. Many

Figure 4 10 **Change in cropland areas and livestock numbers in Eastern Europe and Central Asia. Source: Data from CISSTAT (2017); ESTstat (2017); LATVstat (2017); LITHstat (2017).**

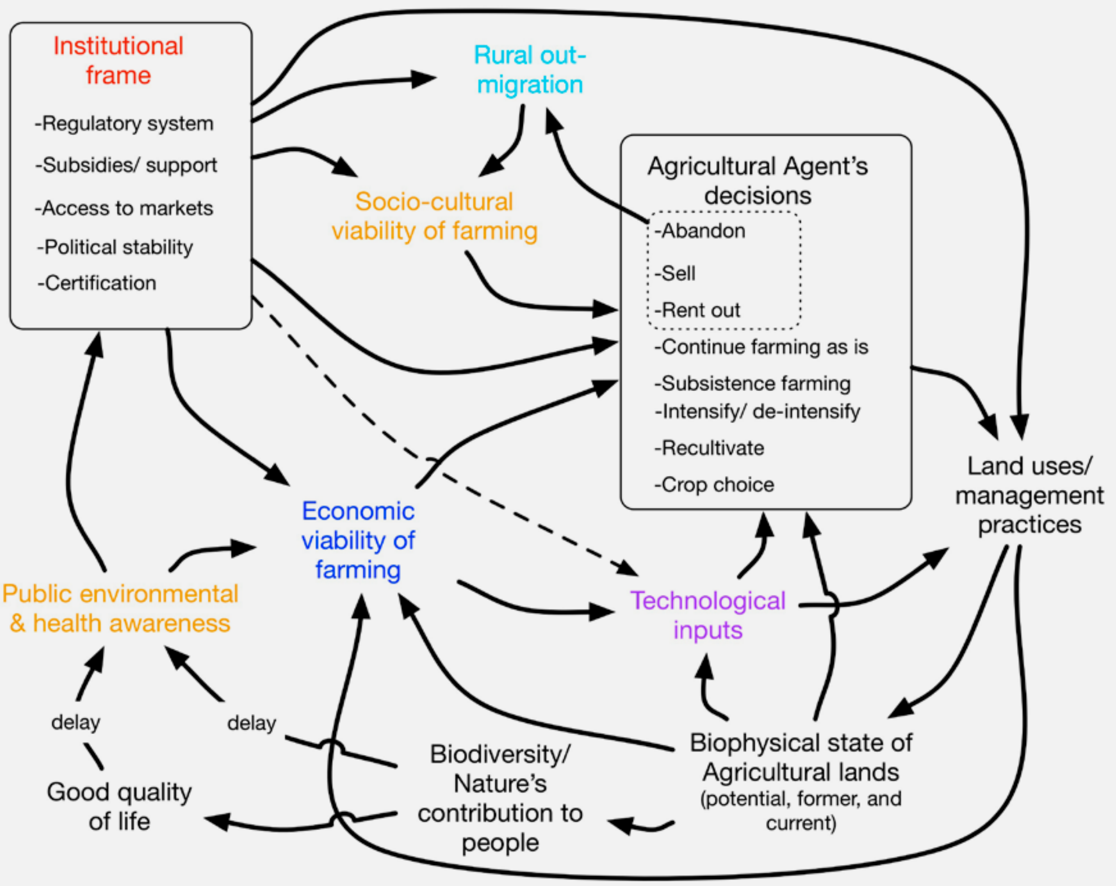


smallholders had no interest or knowledge, or adequate financial resources and equipment to profitably cultivate the agricultural land and thus quit farming or resorted to subsistence farming on small parcels of land scattered across the landscape (Biró *et al.*, 2013). The rapid privatization (Skokanová *et al.*, 2016), ownership insecurity (e.g. in Romania, see Kuemmerle *et al.*, 2009), and a lack of interest or knowledge in agriculture of the new landowners resulted in large-scale land abandonment and decreased management intensity in large areas of Central Europe (Liira *et al.*, 2008; Palang & Printsmann, 2010; van der Sluis *et al.*, 2015; van Vliet *et al.*, 2015). After 2004, when many Central European countries joined the European Union, the land tenure system stabilized through the introduction of the European Union Common Agricultural Policy, which has helped to restore farming activities in many areas, especially mountain regions, and has stabilized agricultural development in some countries of Central Europe (Bezák & Mitchley, 2014; Ruskule *et al.*, 2013; van der Sluis *et al.*, 2015). Agricultural subsidies introduced with the accession to the European Union increased the economic viability of agricultural land, leading to agricultural expansion and intensification. Agricultural subsidies, however, also caused problems as they enhanced regional inequality by excluding small-scale farmers in remote areas (Bezák & Mitchley, 2014) or by causing damage to areas of conservation interest (e.g. ploughing high-diversity grasslands and meadows) **(Figure 4.12)**.

In Eastern Europe and Central Asia, the political changes since the 1990s were accompanied by radical large-scale land reforms, involving the elimination of the state

Figure 4 11 **An illustration of the key drivers and systemic interconnections dominating agricultural land-use change in Europe and Central Asia. Source: Own representation.**

The specific ensemble of land uses and agricultural practices employed on a given farm are largely the aggregate of a set of decisions made by the agricultural agent, which in turn are shaped by the economic and socio-cultural viability of farming in the region, the availability of technological inputs, as well as the institutional frame in which agriculture is situated. These inter-relationships are further unpacked in a series of sub-models below (see further figures).

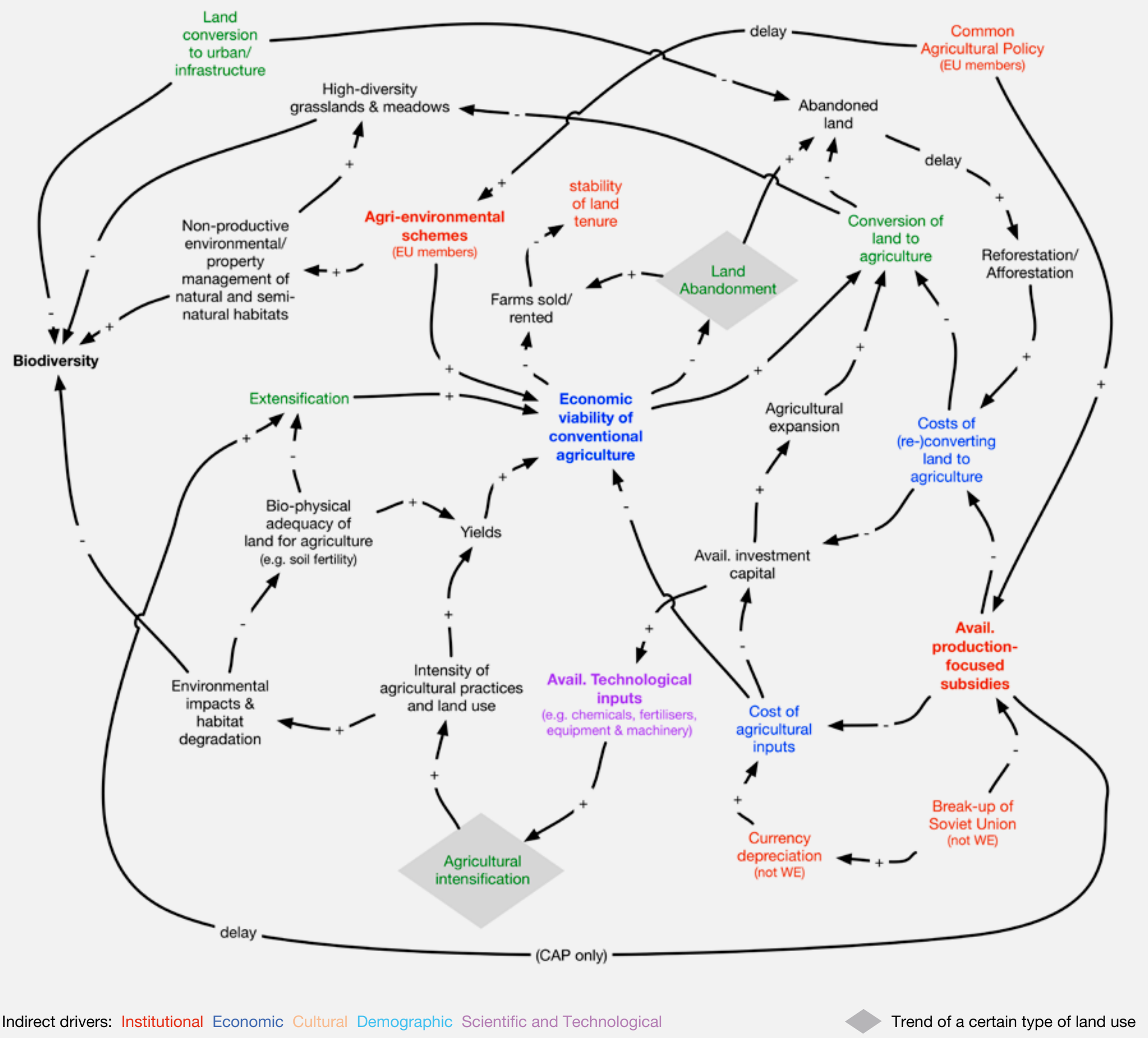


Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

monopoly and division of land ownership (state, collective, and private) (Lerman *et al.*, 2004; Liefert & Liefert, 2012; Liira *et al.*, 2008; Rozelle & Swinnen, 2004; Smelansky, 2003; Swinnen *et al.*, 2017) **(Figure 4.12)**. Since then, the areas of large private agricultural companies owned by agro-holdings and their role in the agricultural sector has constantly expanded (BEFL, 2016; Nefedova, 2016; Petrick *et al.*, 2013; Visser *et al.*, 2012, 2014), especially in the most favourable regions for agriculture, (e.g., south-western Russia, south-eastern Ukraine, and Kazakhstan). However, subsistence farming has played the main role in the food security of citizens in villages, towns and cities. For example, in Russia, the economic crisis in 2008 led to a 2-fold increase in the number of rural residents engaged in subsistence farming, and in the cities the number increased by 2.8 times. Subsistence farms produced 98% of potatoes, vegetables and fruit crops, 82% of milk, 68% of meat and 54% of eggs (Martyn & Yevsiukov, 2009; Swinnen *et al.*, 2017). Appropriate legislation is important for biodiversity conservation on agricultural lands. However, currently for the majority of Eastern European countries there is a lack of links between environmental legislation and legislation related to land, territorial development and agriculture (Smelansky, 2003). For example, Russian

Figure 4 12 **The availability, or unavailability, of agricultural subsidies has been a major driver of agricultural land-use change in Europe and Central Asia. Source: Own representation.**

Production-based subsidies have generally led to the intensification of farming. The sudden unavailability of subsidies in large parts of the region following the dissolution of the Soviet Union was a major driver of agricultural land abandonment, as well as intensification on the most fertile soils. The introduction of non-production-based subsidies, for example agri-environmental schemes in the European Union, has improved the ability of small-scale farmers to maintain lower-intensity agricultural practices with long-term benefits for biodiversity.



legislation does not identify grasslands as a separate category of agricultural land. Several legal regulations address pastures (grazing lands) and hay-making lands (Bakirova, 2011; Smelansky, 2003; Smelansky & Tishkov, 2012); the federal law provides some legal framework for constraining grassland transformation into other land uses but it has been insufficient to protect grasslands outside protected areas.

Land ownership is another institutional driver that has changed across Europe and Central Asia from having many small landowners in the agricultural sector to increasingly larger areas of land being managed by fewer farmers – either after being purchased by farmers or based on an increase in rented land. For the latter, concern is raised that managers' connection with, and sense of responsibility to the land is decreasing, especially in the case of short term rental agreements. This may result in poor management, including less environmental considerations (Forbord *et al.*, 2014; Lobley & Potter, 2004; Stokstad, 2010). This problem is especially vital in some countries of Central Europe (e.g. in the Czech Republic) where the original small owners sold or leased their land to new owners from elsewhere after restitution in the 1990s (Skokanová *et al.*, 2016).

4.5.2.2.2 Economic drivers of trends in agricultural land use

Economic factors often underpin decisions about cultivation or termination of agricultural production **(Figure 4.12)**. Agricultural expansion and intensification on fertile, productive land often coincides with land abandonment on marginal land (Beilin *et al.*, 2014; Skokanová *et al.*, 2016). These two trends are largely driven by global trade of the agricultural market since the 1950s (van Vliet *et al.*, 2015). As a result of global trade, the size of farms and their specialization have increased (Lobley & Butler, 2010).

In Eastern Europe and Central Asia, economic factors include prices for agricultural products (outputs), and the parity of the prices between inputs and outputs. This was most likely one of the primary reasons for widespread termination of farming and livestock production in these subregions (Rozelle & Swinnen, 2004; Schierhorn *et al.*, 2016) **(Figure 4.13)**. In some countries of Eastern Europe and Central Asia, an inability to fill budget gaps led governments to reduce subsidies for agricultural production and consumption by 95% (Prishchepov *et al.*, 2013). The agricultural sector, and particularly livestock sector, immediately faced a mismatch between increased prices for inputs and output production (Sedik, 1993). Additionally, the removal of subsidies led to domestically produced beef and milk becoming non-competitive compared to subsidized imported goods (Schierhorn *et al.*, 2016). Lack of cash flow to cover production costs led to a reduction in livestock numbers and concomitant reduction in fodder crop production (Prishchepov *et al.*, 2017; Rozelle & Swinnen, 2004; Schierhorn *et al.*, 2013; Sedik, 1993) which resulted in widespread agricultural land abandonment (Ioffe *et al.*, 2004; Liefert & Liefert, 2012; Prishchepov *et al.*, 2012; Schierhorn *et al.*, 2013). The wheat production sector was also affected, but to a lesser extent than other grain and fodder crops. Maize, sunflower and beets continued to be cultivated at almost the same levels as in 1990. Availability of the domestic market and accessibility to international markets, distances to the markets and transportation costs may have determined the decision to abandon or re-cultivate agricultural land (Prishchepov *et al.*, 2013). For instance, discovery of new markets for Russia's wheat most likely stimulated partial re-cultivation in the Russian south, in proximity to water ways and sea ports (FAO, 2009). Similarly, growing demand in the Chinese market triggered re-cultivation of abandoned lands for soya production in the Amur region of Russia (Rosstat, 2016). The economic advantages or disadvantages of the agricultural sector compared to other sectors, may drive the decision to quit farming or to pursue alternative income sources. For instance, the value added by agriculture to total GDP declined by 32% from 1990 to 2000 (Prishchepov *et al.*, 2017). Additionally, low taxation, which was based on normative average yields during the Soviet era, did not stimulate either the cultivation of lands, or a concentration on yield increases. Land transaction costs and legal burdens themselves preclude fast transactions and limit incentives for the re-cultivation of abandoned land (Meshkov, 2014; Uzun, 2011).

4.5.2.2.3 Cultural drivers of trends in agricultural land use

Socio-cultural attributes of individual farmers have had a bearing on the extent of land-use intensification or change, thereby slowing down the effects of specialization and global trade (Lobley & Butler, 2010). "Property management" or property-related issues play a vital role in the farmer's practice; and values related to family and individual strategies may often explain why landowners undertake land-use changes that are not profitable (Kristensen, 2016) **(Figure 4.14)**.

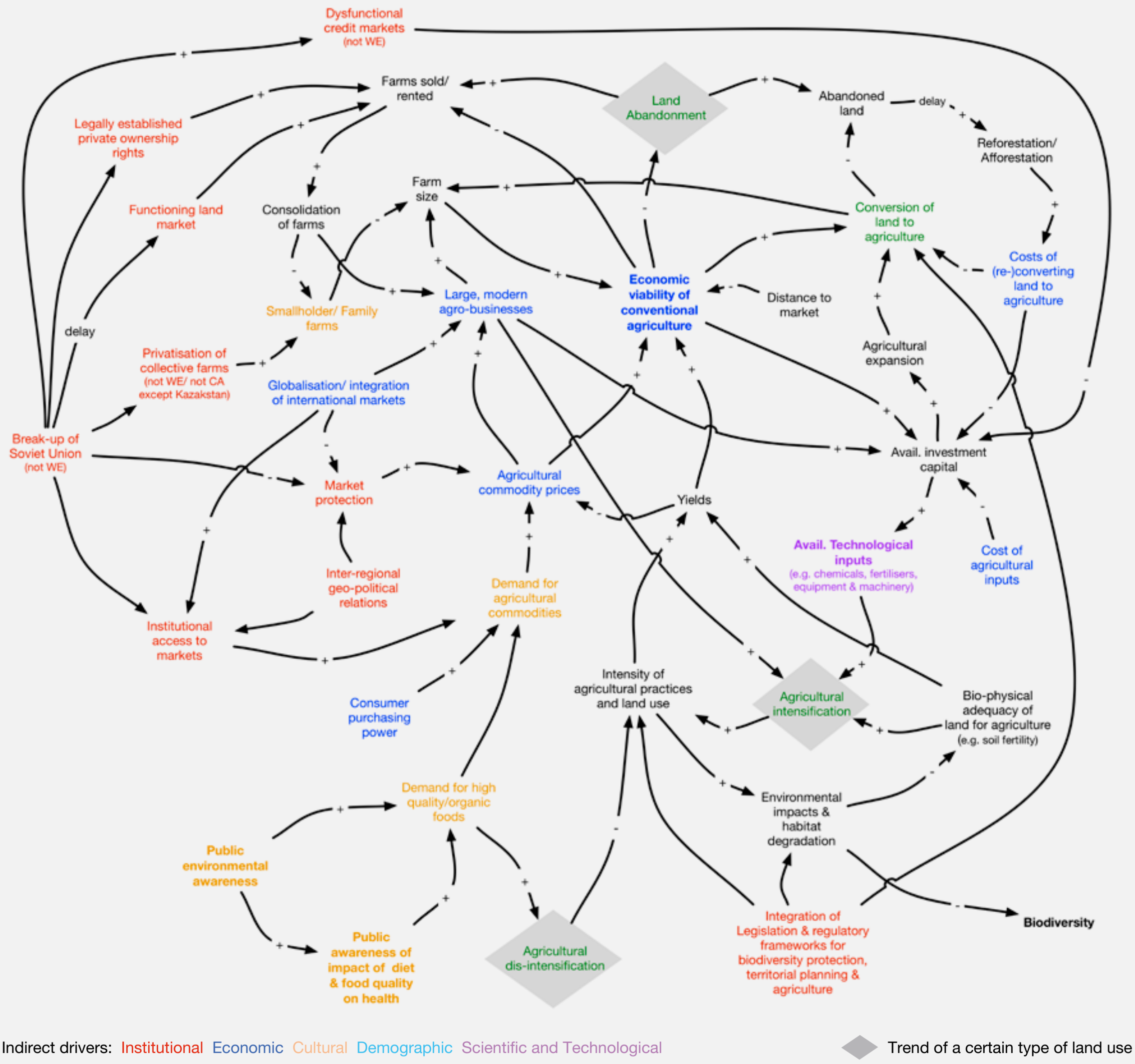
In Western Europe, farm and farmer characteristics have been particularly important drivers of specialization (Breen *et al.*, 2005; Gorton *et al.*, 2008; van Vliet *et al.*, 2015). Choices of crops and farming systems are largely controlled by economic and legal factors (markets and state subsides/regulation); however, local traditions may still moderate the rate of change (Beilin *et al.*, 2014; Curado *et al.*, 2011; Elmhagen *et al.*, 2015; Forbord *et al.*, 2014) **(Figure 4.14)**. Ethical and cultural trends have gradually brought changes in diet and food consumption as well as leisure activities. There is a growing number of consumers who are particularly interested in how and where food was produced and, sometimes, in participating in the production process (Guarino *et al.*, 2015). Additionally, there is also a growing interest in leisure farming and hobbyhorses. Quality products, related to high natural value farmlands and often linked to community-led local development policies, and in 2010 reached a substantial weight, worth about 18% (excluding wine) of the gross saleable production in the European Union agricultural sector (http://ec.europa.eu/agriculture/quality/schemes/index_en.htm). At the same time, in Western and Central Europe, organic products comprise about 1% of total food sales, but trends are increasing (FiBL, 2015).

In Central Europe since the 1990s many livestock farms have collapsed due to termination of subsidies for external inputs (e.g. fertilizers) for fodder production during the socialist period. This resulted in the large-scale movement of people with agricultural experience into cities or abroad (Bell & Muhidin, 2009), leading to widespread abandonment of farmland (Munteanu *et al.*, 2014; van Vliet *et al.*, 2015).

In Eastern Europe and Central Asia during the Soviet era, agricultural enterprises fulfilled many obligations related to providing jobs and services to local population (e.g., schools, shops, centres of culture, libraries etc.) **(Figure**

Figure 4 13 **Land, credit and commodity markets have had important impacts on the economic viability of conventional agriculture across Europe and Central Asia, and as such have been key factors in regional intensification and abandonment trends. Source: Own representation.**

The dissolution of the Soviet Union was a source of considerable institutional turmoil affecting the function of these markets in many countries in the region. The recent trend towards agricultural de-intensification in some parts of Europe and Central Asia is largely driven by growing public environmental and health awareness.

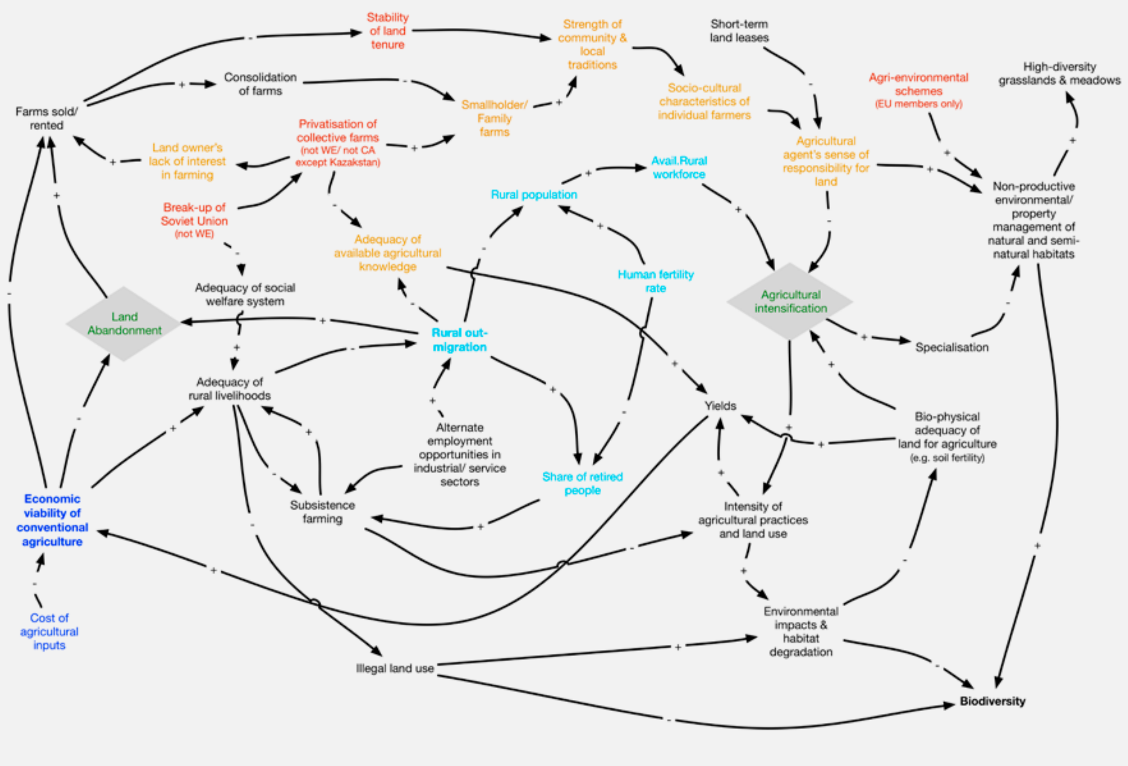


4.14). Since the 1990s these obligations have been transferred to local governments, which have not had resources to fulfil them (Ioffe *et al.*, 2012). This led to a sharp increase in the burden on the biological resources of rural areas (e.g. through poaching and illegal logging); destructive extraction of soil and mineral resources (e.g. through sale of fertile topsoil and illegal mass extraction of building materials and coal); as well as growing poverty in rural areas (Allina-Pisano, 2007; Ovcharova & Pishnyak, 2003; Petrick *et al.*, 2013; Visser & Schoenmaker, 2011). Since the 1990s a large proportion of agricultural land has been freely transferred to multiple private owners who had a share in the property of former collective farms. This has led to the appearance of a significant number of non-agricultural enterprises (Lerman & Shagaida, 2007; Petrick *et al.*, 2013; Shagaida, 2005) operated by managers often with a lack of adequate professional knowledge in agriculture (Maslak, 2015; Sabluk *et al.*, 2015). For example, in Ukraine land reform has led to the privatization of 12,000 collective or state farms; and the majority of the agricultural land (27 million ha, 66% of all agricultural land of the country) was distributed among 6.9 million citizens (http://land.gov.ua; Khodakivs'ka, 2015). This has created a precondition for widespread land abandonment.

In general, quantitative studies confirm that agricultural land abandonment is strongly linked to a decrease in rural population density, ageing population, and lower birth rates (Ioffe *et al.*, 2004; Meyfroidt *et al.*, 2016; Prishchepov *et al.*, 2017). Demography legacies also played a crucial role in explaining the patterns of land abandonment, such as reduced population due to World War II in western Russia (e.g., Smolensk province), and outmigration in the 1960s and 1970s from the non-Chernozem region (Ioffe, 2005; Prishchepov *et al.*, 2013). It has been proposed that agricultural production looses its economic feasibility when rural population density falls below five people/km^2 (Ioffe *et al.*, 2004). The regions with higher birth rates and higher population density were found to be more favourable for re-cultivation (Meyfroidt *et al.*, 2016; Shagaida, 2005).

Figure 4 14 **Agricultural intensification and abandonment trends in Europe and Central Asia are also influenced by socio-cultural and demographic factors. Source: Own representation.**

Whilst the consolidation of farms has led to some improvements in economic viability, it is also linked to the erosion of local traditions and of a sense of long-term custodial responsibility for the land, which are important for the continuation of non-productive management practices for biodiversity. Rural outmigration is also linked to the loss of key forms of agricultural knowledge.



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

Trend of a certain type of land use

4.5.2.2.4 Technological drivers of trends in agricultural land use

Technological drivers such as biotechnology and mechanization (e.g. tractors) are important drivers of change in the agricultural sector (Jepsen *et al.*, 2015). Better production technology, for instance application of high power tractors and other machinery, may encourage farmers to cultivate more land, thus stimulating re-cultivation of abandoned plots. However, improvement of technological production can also be strongly influenced by whether economic factors favour investment in technological advances (Jepsen *et al.*, 2015).

4.5.3 Trends and indirect drivers of changes in forestry

4.5.3.1 Trends in forestry

Forest management systems vary across Europe and Central Asia. In the boreal zone forest management with clear-cuts followed by intensive silviculture dominates in Fennoscandia (Granhus *et al.*, 2015), and wood mining without silviculture in boreal Russia (Naumov *et al.*, 2016) (**Figure 4.15** and **Figure 4.16**). Forestry in the temperate zone utilizes a wider spectrum of management systems. This includes different harvest and regeneration systems ranging from clear-cut management with tree plantations to continuous cover forestry with single-tree harvest and natural regeneration (Kuuluvainen *et al.*, 2012; Pommerening & Murphy, 2004).

Almost all forest management systems result in simplified forests with loss of structural complexity and biodiversity at multiple spatial scales. In the Mediterranean, agroforestry systems are widespread, which incorporate combinations of trees, grasslands and rotation cereal cropping. In Western, Central and Eastern Europe, traditional agroforestry systems have been key elements in the European cultural landscapes throughout history (Eichhorn *et al.*, 2006; Erixon, 1960) **(Figure 4.17)**. As an example, the Spanish dehesas and Portuguese montados form extensive agro-silvo-pastural savannahs, which cover about 5 million ha in south-western Spain and Portugal (Joffre *et al.*, 1988; Plieninger *et al.*, 2003).

The main trends in forestry across Europe and Central Asia are as follows: (1) increasing intensity of management on forested land; (2) continued logging of intact forests; (3) rehabilitation of forest land after overgrazing, overexploitation, and desertification; and (4) efforts to implement sustainable forest management. These trends are assessed in more detail below.

Trend 1: Increasing intensity of management on forested land

Increasing intensity of management of forested land includes: (i) increasing extraction of bioenergy resources; (ii) increasing area of plantations; and (iii) intensification of forest management. Production of forest biomass for energy purposes includes increasing use of more intensive management methods and extraction of a larger fraction of biomass during harvest operations, including tree-tops,

Figure 4 15 **Even-aged A Scots pine (*Pinus sylvestris*) and B Norway spruce (*Picea abies*) forests with simplified vertical and horizontal structures are the outcomes of forest management systems aiming at maximum sustained yield with even-aged silvicultural system (Bergslagen region, Sweden). Photo: Per Angelstam.**

Generally, forest management is based on silviculture using the gradient between even-aged and uneven-aged systems. There are three general types of age-class structures that are managed for: (1) even-aged systems that include clear-cutting or seed tree systems; (2) the intermediate double-cohort systems with shelterwood cutting, and (3) uneven-aged systems with single tree and group selection. The different systems can be understood better if considered as located in a continuum of proportion trees removed at each treatment and the size of the treatment unit.

A

B

Figure 4 16 **Remaining intact forest landscapes in Western, Central and Eastern Europe are subject to on-going wood mining. Photo: Intact forests in the Komi Republic, Russian Federation. Marine Elbakidze.**

Initially single high value trees, and later entire stands in naturally dynamic forests are harvested without plans for future forest development. This leads to frontiers of wood felling that develop as market demands spread into increasingly remote regions. In Fennoscandia, this process began about 150 years ago and in remote parts of north-western Russia it began in the 1960s (Naumov *et al.*, 2016), and is still on-going (Potapov *et al.*, 2017).

Figure 4 17 **Dehesa and montado agroforestry systems integrate use of forest, grasslands, and fields (Pardo & Gil, 2005). Photo: Montado system in Portugal. Marine Elbakidze.**

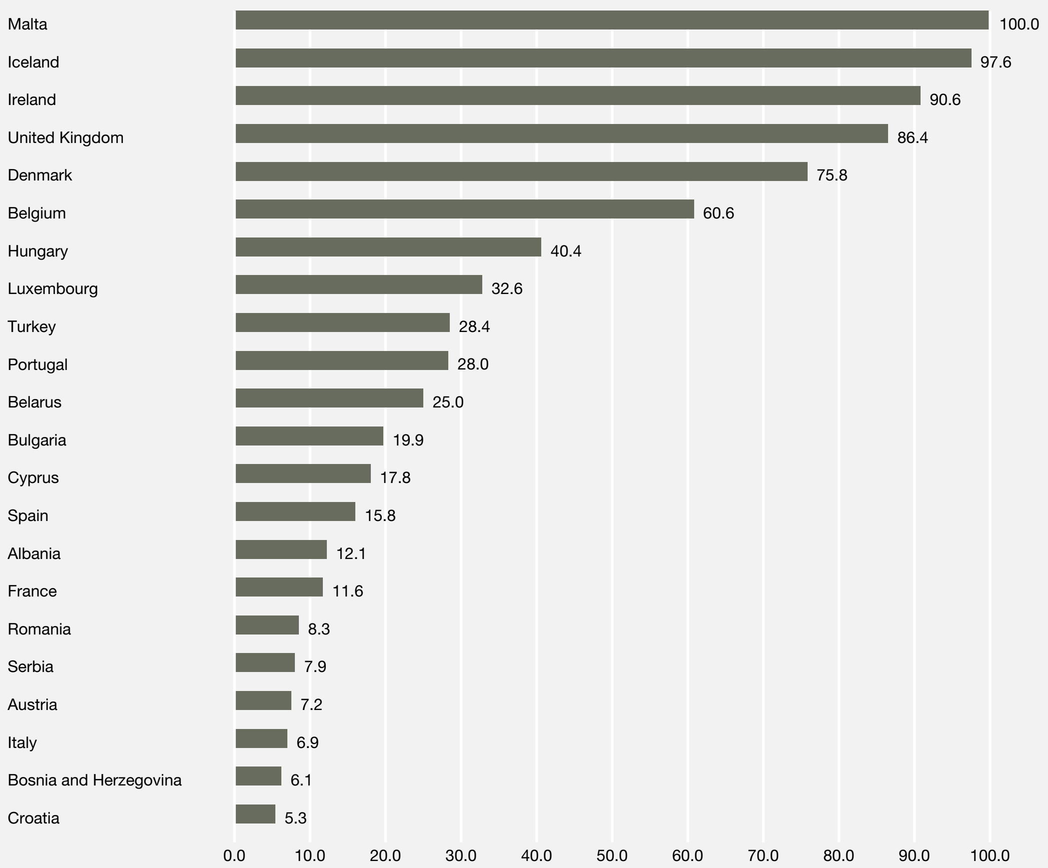
These cultural landscapes host outstanding biodiversity (Bugalho *et al.*, 2011; Diaz *et al.*, 2013) and provide multiple contributions to people that enhance quality of life. The importance of traditional agroforestry landscapes has been recognized at the European Union level and the relevance of traditional practices to deliver multiple contributions of nature to people has been acknowledged (Bergmeier *et al.*, 2010; Eichhorn *et al.*, 2006; Marañón, 1988; Rackham, 2003). However, at present these landscapes are deteriorating due to farmland abandonment, intensification of agriculture or creation of forest plantations (Garrido *et al.*, 2017).

branches and roots (Bouget *et al.*, 2012). It is theoretically possible to increase the availability of forest biomass significantly beyond the current level of resource utilization (Verkerk *et al.*, 2011). Intensification of biomass removals from forests has raised concerns about its environmental impacts on forest productivity, biodiversity, soil quality, and climate change mitigation potential, as well as social values (Aherne *et al.*, 2012; Bouget *et al.*, 2012; Forsius *et al.*, 2016; Triviño *et al.*, 2015). The trade-offs between increasing biomass output and delivery of diverse contributions of nature to people are recognized as a major challenge for forestry in Europe and Central Asia (Verkerk *et al.*, 2011). These concerns have resulted in the development of sustainability criteria for bioenergy production (European Commission, 2009). However, several studies have pointed to the need to include landscape-scale segregated approaches to define appropriate indicators for long-term sustainability, including energy wood production (Fu *et al.*, 2013; Nelson *et al.*, 2009; Vihervaara *et al.*, 2015). This applies in particular to resolving potential impact on biodiversity, soil carbon, nutrient store and leaching (Forsius *et al.*, 2016), but also to forests as an asset for recreation and nature-based tourism.

Plantation forestry in Europe constituted 9% of the forested area in 2015 with an increase during the last 20 years of 3.8 million hectares (Forest Europe, 2015). The fraction of plantation forests varies among countries in Western Europe and Central Europe **(Figure 4.18)**.

The growing stock of forests in continental Europe has increased at an annual average of 1.4% or, in absolute terms, by 403 million cubic meters per year over the last 25 years (Forest Europe, 2015). Growing stock has increased despite a significant increase in annual felling. During the period 1990 – 2010, annual felling increased by more than 20% (from 216 to 263 million cubic meters) in Europe. Thus, only over half of the growth is harvested. Additionally, there are combined effects of increased CO_2 concentration and nitrogen deposition. Sweden and Finland are viewed as role models for the development of maximum sustained yield wood production in Europe (e.g. Elbakidze *et al.*, 2013a; Lindahl & Westholm, 2010). However, there are arguments that sustained yield forestry as a single-use management (Behan, 1990) focused on wood, changes forest composition and structure, and alters the natural

Figure 4.18 Western, Central and Eastern European countries with a share of over 5 per cent of plantations of the total forest area. Source: Forest Europe (2015).



dynamics in forest landscapes (Bawa & Seidler, 1998; Holling & Meffe, 1996; Luckert & Williamson, 2005). As a consequence, forest ecosystems lose native species, habitats, and ecological processes, which affect ecological integrity and resilience (Farrell *et al.*, 2000). The Russian Federation currently aims to increase the sustained yield of wood by intensifying wood production in accessible areas previously harvested by wood mining (Naumov *et al.*, 2017). This requires changes in forest management that include silvicultural methods, for example, scarification, planting or seeding, pre-commercial thinning and even fertilization (Elbakidze *et al.*, 2013a).

Trend 2: Continuous logging of intact forest landscapes

Industrial forestry has expanded throughout Europe over the centuries, basically from south-west to north-east (Lotz, 2015; Lundmark *et al.*, 2013). According to Potapov *et al.* (2017), industrial timber extraction, resulting in forest landscape alteration and fragmentation, was the primary global cause of intact forest landscape area reduction. Three countries comprise 52% of the total reduction of intact forest landscapes area: Russia (179,000 km^2 of IFL area lost), Brazil (157,000 km^2), and Canada (142,000 km^2). In Europe and Central Asia clear-cutting was the main intact forest landscape loss cause in the temperate and southern boreal zones (54%). Proportional to the year 2000 IFL area, the highest percentages of intact forest landscape area reduction were found in Romania (Central Europe), which lost all of its intact forest landscapes. Russia has approximately 20% of the world's forests, and human influence on forests has been growing over recent decades, mainly as a consequence of logging activities including both clear-felling and selective logging (Achard *et al.*, 2006; Naumov *et al.*, 2017). Easily accessible Russian forest resources are being exhausted (e.g., Naumov *et al.*, 2016). Despite a huge forested area there is a serious shortage of accessible wood resources demanded by the forest industry. Large sawmills, pulp and paper enterprises, especially those focused on output with low added value, are heavily reliant on low transportation costs for the delivery of raw materials from the forest. Thus, increasingly, forest logging companies harvest in protective forests and other valuable forests (Naumov *et al.*, 2017) that support biodiversity conservation and rural development.

Trend 3: Rehabilitation of forest land after overgrazing, overexploitation, and desertification

This trend is prominent in Central Asia, where forest cover is about 5% of the subregion. Distribution of forested areas is uneven with the largest forested areas in Turkmenistan and the smallest in Tajikistan. Due to overall arid environments, the wood production in this subregion is low, and its economic/monetary contribution is insignificant (Kleine *et al.*, 2009). However, forests deliver diverse contributions to people, including water regulation, soil protection, climate mitigation, fire wood, and recreational value at multiple scales. Nevertheless, significant degradation of forests has taken place since World War II, while not necessarily decreasing forested area. Main causes include converting forested area into agricultural land, overgrazing and overexploitation, including illegal logging, and fires (Baizakov, 2014; Toktoraliev & Attokurov, 2009). Major concerns are related to the disappearing Aral Sea, leaving a large area of degraded land. Attempts to afforest this area are being made to increase the area of land defined as forests in Kazakhstan. The forest management in this subregion is mainly focusing on rehabilitation of degraded forested land. This includes reforestation and afforestation as well as planting trees and shrubs to combat desertification (Meshkov, 2014).

Trend 4: Multifunctional forestry

For the past four centuries sustained yield forestry has been focused mainly on wood for construction, fibre, or fuel. However, the normative interpretation of sustainability in forestry became broader when sustainable forest management policies appeared at the end of the twentieth century (MCPFE, 1998, 2001; Wang & Wilson, 2007). Sustainable forest management aims at maintaining, now and in the future, sustainable ecological, economic, social, and cultural functions of managed forests through multi-stakeholder participatory approaches (Hahn & Knoke, 2010; MCPFE, 1998, 2001; Wiersum, 1995). This requires that forest managers consider the use of a broad range of nature's contributions to people through adaptive management and governance to be able to handle potentially conflicting demands at multiple spatial scales (Bawa & Seidler, 1998; Behan, 1990; Bouthillier, 2001; Farrell *et al.*, 2000; Hahn & Knoke, 2010; Sandström *et al.*, 2011; Wiersum, 1995). Lindahl *et al.* (2017) noted that this pathway is influenced by ideas of ecological modernization and the optimistic view that existing resources can be increased, thus prioritizing the economic dimension of sustainability. At present, society's interest in sustainable forest management is growing. This is mainly linked to bioenergy production and energy security as well as climate change adaptation and mitigation (Spittlehouse & Stewart, 2003). There are arguments that timber supply-oriented sustained yield concept is no longer appropriate (Wiersum, 1995), and forest managers need to "develop from being crop managers to ecosystem managers" (Farrell *et al.*, 2000).

Countries in Europe and Central Asia have diverse natural, historical, societal, and economical legacies and thus have different starting points in their trajectories of development toward sustainable forest management (Angelstam *et al.*, 2011; Lehtinen *et al.*, 2004). For example, recent analyses of the future development of boreal forests in Western Europe (Claesson *et al.*, 2015) indicate that this process will divide forest landscapes into intensively managed stands with harvest return intervals of 60-80 years and only scattered remnants of old growth forests set aside for biodiversity conservation purposes **(Figure 4.19)**. To counteract this segregated trend there is an increasing focus on integrative approaches in forest management (Kraus & Krumm, 2013). These initiatives include green tree retention, identification of small valuable forest habitats, and promotion of mixed forest stands (e.g. Brang *et al.*, 2014; Johansson *et al.*, 2013). Similarly, integrative approaches may benefit the protection of wooded grasslands - habitats that have declined dramatically during the 20th century (Axelsson *et al.*, 2007) – with their ecological and social values (Hartel & Plieninger, 2014).

4.5.3.2 Drivers of trends in forestry

The overview model **(Figure 4.20)** shows the dynamic inter-relationships within and between indirect and direct drivers of change in forestry identified via the literature review process. This overview model is then further unpacked at a variety of levels of detail to examine the major dynamics of indirect drivers of changes in forestry.

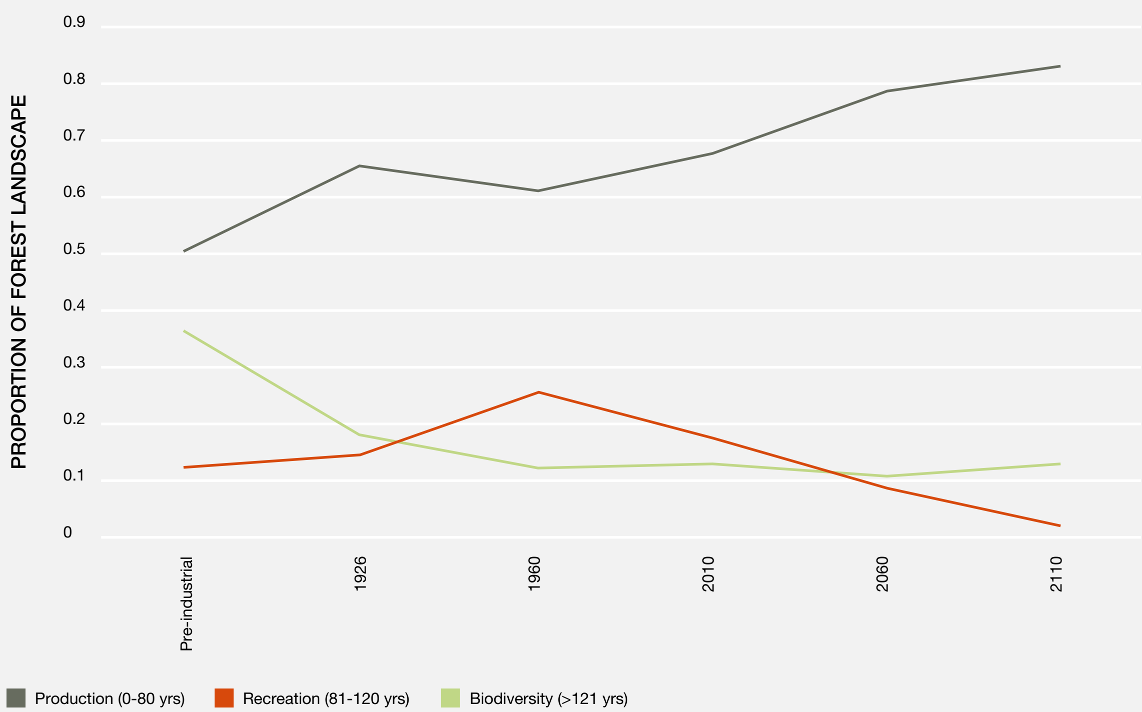
4.5.3.2.1 Legal frameworks

Regulatory frameworks for forest management have a long history in Europe and Central Asia. In Western Europe, they date back to at least the 17th century. Starting already in the beginning of the 19th century, forest management for wood production was regularly taught at forestry schools aiming for efficient silviculture. After two centuries of maximum sustained forestry yield, in recent decades the international policy pendulum (e.g. CBD, 2010; European Commission, 2013; MCPFE, 1998, 2001) has swung towards multiple use and benefits. Initially, this was focused on biodiversity conservation and later also on rural development (Kennedy *et al.*, 2001).

The Montréal Process developed sustainable forest management principles for the temperate and boreal forests; and the Ministerial Conference on Protection of Forest in Europe (Pan-European process or Forests of Europe) for

Figure 4 19 **Past, current and projected proportions of three forest stand age classes in Sweden representing maximum sustained yield wood production (0–80 yrs), recreation (81–120 yrs) and biodiversity conservation (>121 yrs).**

Source: Pre-industrial data from Angelstam and Kuuluvainen (2004), and other periods from Claesson et al. (2015). Note, however, that for biodiversity conservation these statistics overestimate the functionality of areas >121 yrs as functional habitat networks. Three reasons are loss of the ecologically most important forest, say >180 yrs with dead wood in different decay stages, small patch sizes and limited functional connectivity.

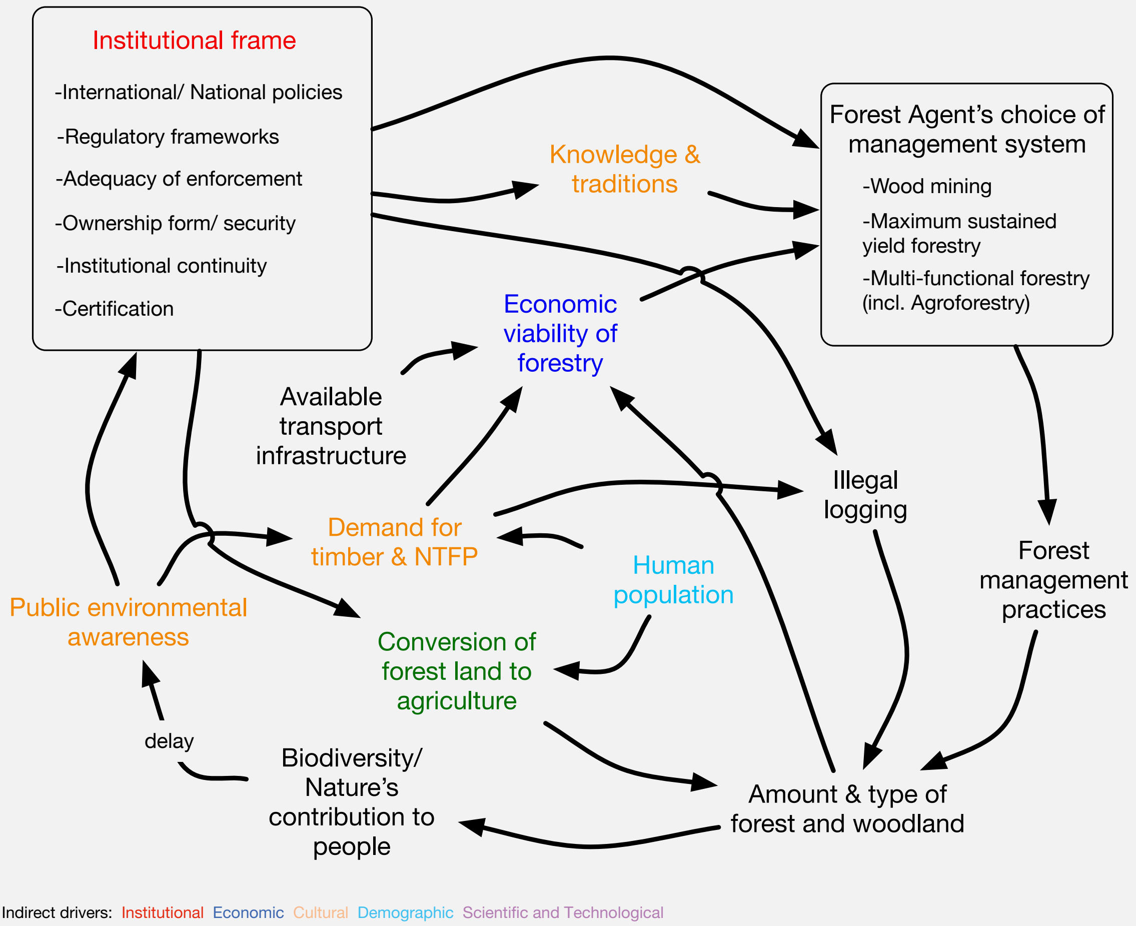


countries in Western, Central and Eastern Europe (Forest Europe, 2011). The Pan-European criteria and indicators provide guidelines for sustainable forest management at the national and sub-national levels, and to operationalize and complement the existing (MCPFE, 1998, 2013). There is a common strategy for 46 countries in Western, Central and Eastern Europe on how to sustainably manage their forests (Forest Europe, 2015). The sustainable forest management concept is an overarching guiding principle at the policy level. However, there is considerable variation in how this concept is implemented among countries (Lehtinen *et al.*, 2004), different forest owner categories, and over time in a given country. In 2011, Forests Europe presented "European forests 2020 Goals and Targets" (Forest Europe, 2011) that requires the sustainable management of all European forests, including multiple forest functions and enhanced use of forest goods and services **(Figure 4.21)**.

Regarding agroforestry systems, the agricultural subsidy regime within the European Union is considered unfavourable towards silvo-arable practices (e.g. Fragoso *et al.*, 2011; Plieninger *et al.*, 2004); and there is a need to reinforce and promote alternative agricultural and non-agricultural economic activities in rural areas. New functions include leisure and recreation (García Pérez, 2002; Pinto-Correia, 2000; Surová & Pinto-Correia, 2009). Indeed, Gaspar *et al.* (2009) showed that mixed livestock dehesa farms made optimal use of resources, and had little dependence on external subsidies. Given uncertainties about the European Union subsidies, this type of farm might

Figure 4 20 **An overview of the key drivers and systemic interconnections leading to changes in forestry in Europe and Central Asia. Source: Own representation.**

Given the long lag times for forest regeneration, past choices of forest management systems continue to exert a major influence on the amount and types of forest and woodland available in Europe and Central Asia. The choice of forest management system is influenced by a broad set of institutional drivers, the availability of relevant knowledge, regional forestry traditions, and considerations of economic viability. Multi-functional forestry, for example, is dependent on extant demand for non-timber forest products, such as wild foods, or for social values, such as recreation and tourism. Illegal logging and the conversion of forested land to agricultural land are also important drivers in parts of Europe and Central Asia. These inter-relationships are further unpacked in the following sections.

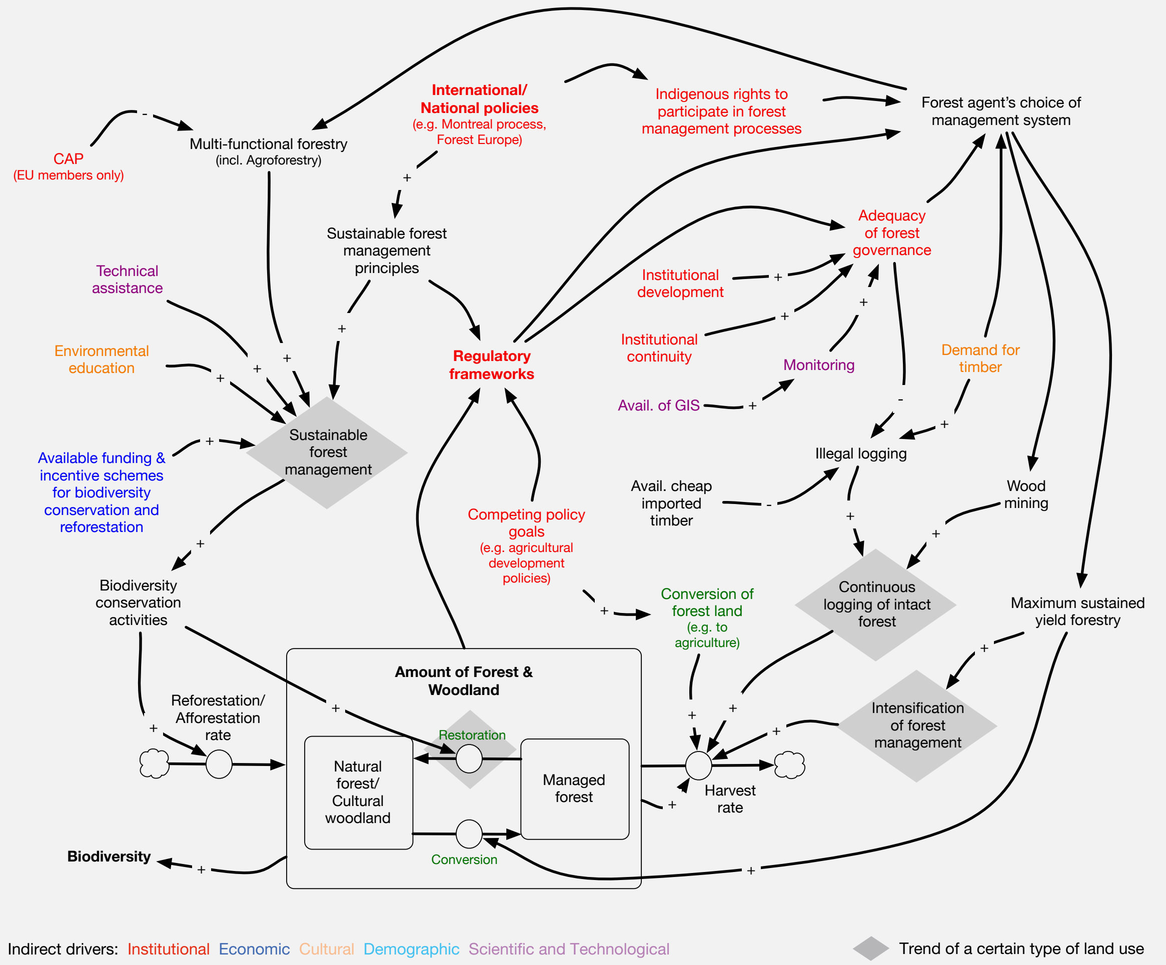


be a goal for dehesa farmers. Thus, the maintenance of the traditional agroforestry systems in Spain and Portugal is a good example of how a diversity of forest and woodland management regimes sustains multiple goods, services and landscape values (Linares, 2007). However, Pinto-Correia (2000) and Plieninger *et al.* (2004) pointed out that this requires a holistic landscape approach including conservation-incentive schemes, environmental education, and technical assistance.

In Central Asia at the beginning of the 1990s, national agricultural policies such as converting forests into arable land and pasture continued to reduce forested areas. For instance, in Uzbekistan the area of tugay forests – a form of riparian forest or woodland associated with fluvial and floodplain areas in arid climates – decreased to less than one-tenth of the original area. Walnut forests in Kyrgyzstan decreased by 50% while mountain slope desertification increased by 31% (Toktoraliev & Attokurov, 2009). Since the 1990s, forest management organizations at different levels have gone through many reforms (Baizakov, 2014) and political and economic uncertainties, and severely weakened forest governance had caused growth of illegal logging and forest fires. The stabilization of economies in the region has shifted the attention to the forest crisis in the region. For example, Kazakhstan has prohibited cutting of saxaul forests, and Kyrgyzstan has announced a moratorium on cutting of walnut forest. The import of wood from Russia was renewed, and the pressure on forests has declined. Institutional development strengthened forest protection in the region. Also, introduction of GIS technologies enabled forestry to collect and monitor the forest data more effectively (Government of Kyrgyzstan, 2007; Karibayeva *et al.*, 2008).

Figure 4 21 **Legal frameworks are key drivers of change in forestry in Europe and Central Asia. Source: Own representation.**

A number of recent international processes have led to the evolution and adoption of a set of principles supporting sustainable forest management, and strengthening regulatory frameworks, which govern norms and practices associated with other forms of forest management. However, these new institutions require further integration to reduce conflicts with other policies and institutional legacies.



4.5.3.2.2 Forest certification

Forest certification is a market-driven instrument that is becoming increasingly important in forest management in Europe and Central Asia. The Forest Stewardship Council certification operates in 33 countries in Europe and Central Asia, covering almost 96 million hectares (FSC, 2016); and the PEFC (the Programme for the Endorsement of Forest Certification) operates in 23 countries in the region, covering almost 84 million hectares (PEFC, 2016). While many Governments in Europe and Central Asia have favoured command and control mechanisms to address policy targets, a growing number of private and civil society actors have pioneered non-state voluntary instruments as a means to achieve responsible forest management that aims at maintaining, protecting and sustaining ecological, economic and social-cultural values of forests. This complex landscape of state and non-state governance has shifted the power dynamics of environmental governance, raising questions about whose interests and priorities are being served, in which contexts, and with what consequences for social equity and biodiversity conservation (Cashore *et al.*, 2003, 2005).

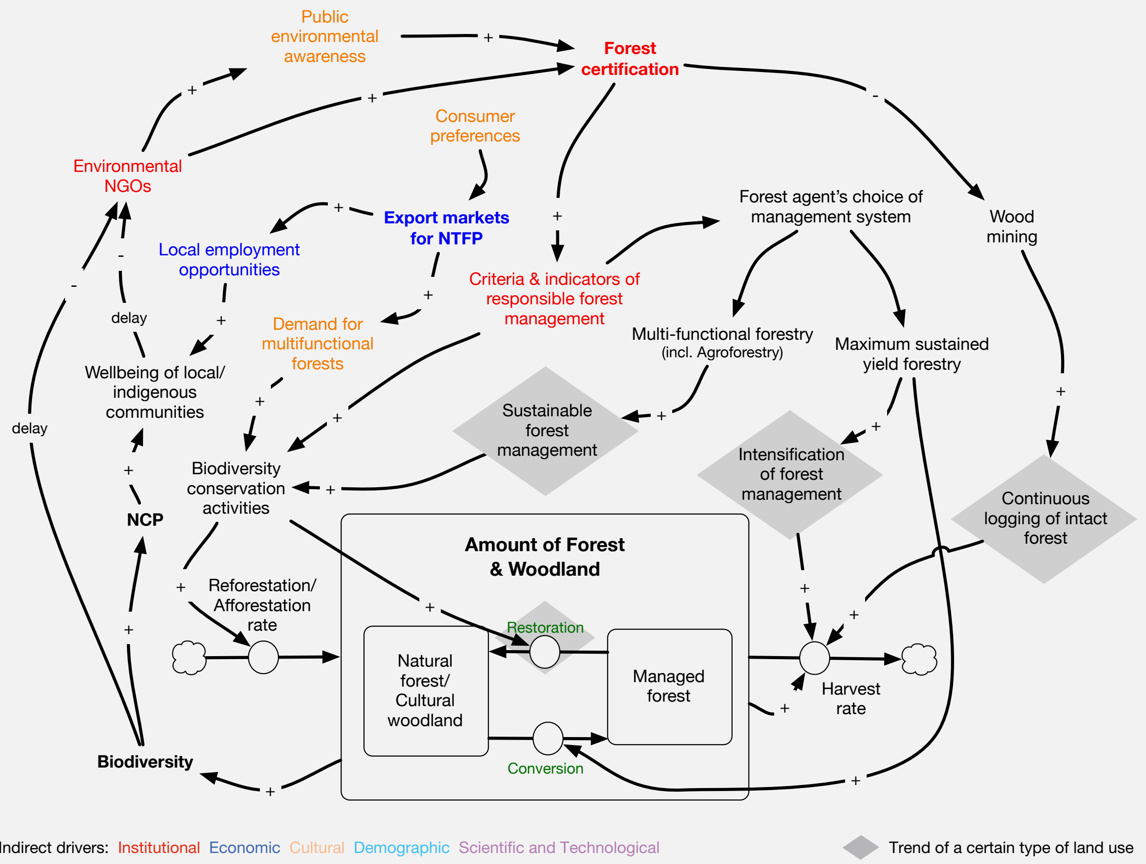
Forest certification growth has provoked considerable public debate (Angelstam *et al.*, 2013; Elbakidze *et al.*, 2011; Lindahl & Westholm, 2010; Sandström *et al.*, 2011), highlighting how the design and implementation of certification inevitably involves struggles for power amongst diverse interests with differing standards and impacts across countries (see **Figure 4.22**).

4.5.3.2.3 Markets of non-timber products

Emergence of new export markets for non-timber products, primarily medical plants and walnuts, has increased reliance of local populations on forests. The evidence shows that the

Figure 4 22 **Forest certification and the development of export markets for non-timber forest products are increasingly important drivers of forest management in Europe and Central Asia. Source: Own representation.**

Environmental NGOs have played a key role in the adoption of forest certification schemes, which have reduced “wood mining” of remaining intact forests and have led to the inclusion of biodiversity conservation criteria and indicators in forest management systems. The establishment of functioning markets for non-timber forest products is important to grow demand for multi-functional forests, which promote forest biodiversity.



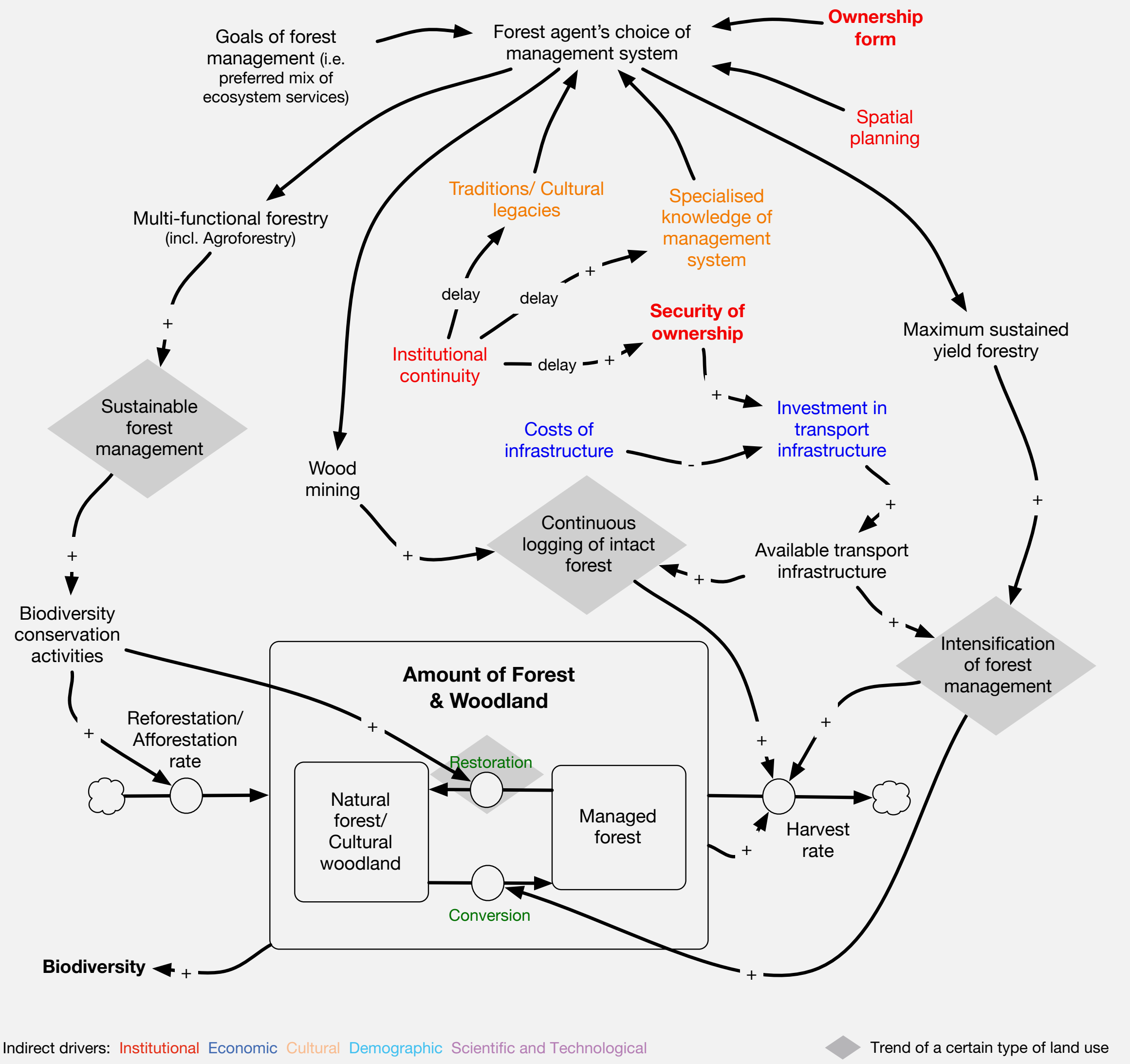
health of forest ecosystems that produce these products greatly improves the quality of life of local households (Fisher *et al.*, 2004).

4.5.3.2.4 Forest ownership

The forest harvest rate, land conversion and management system is decided by the choices of forest managers – individual managers and land owners – but a wide range of drivers influence their decisions in an interrelated and complex way. These drivers are depicted in **Figure 4.23** summarizing the causal links influencing forest ecosystems. The choice of management system is influenced primarily by cultural legacies (managers' world views of forestry), laws and policies (institutional drivers), the demand for specific forest products (e.g. increasing use of biofuels) as well as by costs, e.g. related to development of infrastructure. For example, the opportunity for introducing intensified forest management in Eastern Europe based on pre-commercial and commercial thinning is hampered by short forest leasing periods (Naumov *et al.*, 2017). A permanent transport infrastructure, which is available not only for harvesting, but for silviculture is also necessary. To pay for these

Figure 4 23 **The choice of forest management system is influenced by the preferred mix of nature's contribution to people, the form and security of land ownership, and the knowledge and forestry traditions embodied in individual managers. Source: Own representation.**

Investment in transport infrastructure, vital to intensive silviculture, is also highly dependent on secure, long-term land ownership.



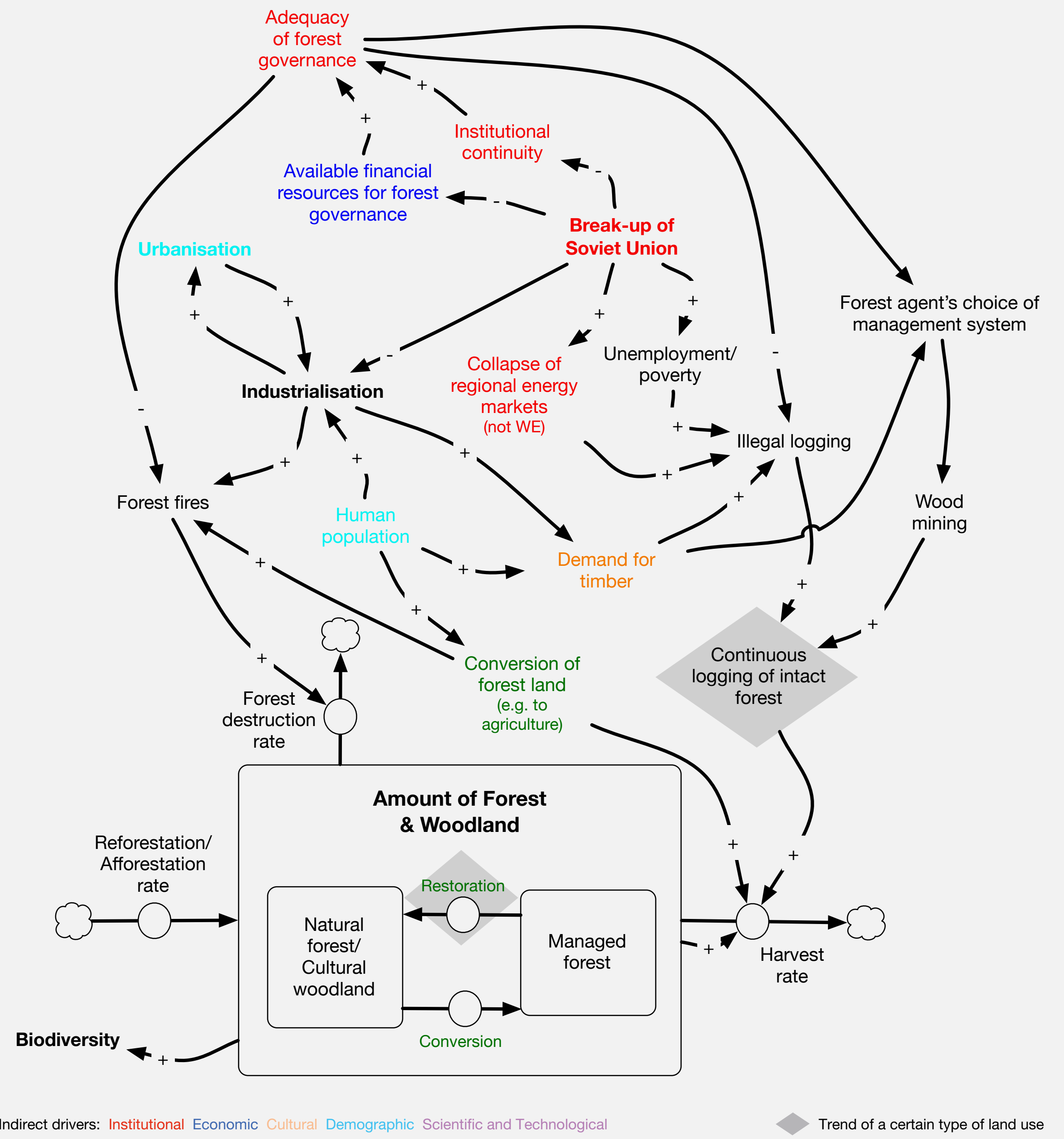
costs, commercial thinning usually delivers inadequate financial net values (Brukas & Weber, 2009). Additionally, transport cost to remote, not yet harvested, areas need to be considered when investing in roads for harvest only, or also for silvicultural treatments. However, the costs of investing in transport infrastructure are high, and there are uncertainties regarding ownership and long-term maintenance (Naumov *et al.*, 2016).

4.5.3.2.5 Urban development

Urban development has had profound effects on forest. For instance from 1930 to 2000 in Central Asia, overharvesting decreased the area of spruce forests in Kyrgyzstan by 50% (Musuraliev *et al.*, 2000; Toktoraliev & Attokurov, 2009). Growing industrialization and population and rise of collective farming increased human-caused fires in forests.

Figure 4 24 **Population growth, industrialization and urban development are drivers of demand for timber. Source: Own representation.**

As a result, a "wood mining" frontier has slowly moved from south-west to north-east Europe during recent centuries, leaving a long-standing legacy of impaired forest biodiversity. The dissolution of the Soviet Union had a variety of institutional impacts on forests, and led to increases in illegal logging in Central and Eastern Europe as well as Central Asia.



In 1954-1960 only 31% of fires were caused by man, while in 1981-1990 this number increased to 66% (Baizakov, 2014). Future change in forested area in Central Asia is likely to be strongly linked to the direct and indirect effects of ongoing climate change in combination with effects from changing demography, economy, technology, lifestyle, and policies (Moss *et al.*, 2010) **(Figure 4.23)**.

4.5.3.2.6 Radical changes in political, economic and social contexts as triggers of changes in forestry

Since 1991, after the dissolution of the Soviet Union, radical changes in political, social and economic contexts put pressure on forest areas in Eastern Europe and Central Asia, causing a decline in financial resources for forest management, and a decline in control measures. Forest management institutions lacked financial and political support (Baizakov, 2014). At the same time, local households experienced shortages in the supply of oil, firewood and coal, which led to increased illegal logging in rural areas. The regional market for coal and oil collapsed, which increased the use of forest wood for heating purposes. Rise of unemployment and poverty contributed further to forest destruction. For the past 20 years, forest area with tree species such as saxaul, pistache, almond and walnut have been reduced considerably (Demidova, 2013) **(Figure 4.24)**.

4.5.4 Trends and indirect drivers of changes in protected area development

4.5.4.1 Trends in protected area development

In Europe and Central Asia, the total coverage of protected areas is 10.2%, with 13.5% of its terrestrial area and 5.2% of its marine area (within the Exclusive Economic Zone) being protected **(Figure 4.25)** (UNEP-WCMC & IUCN, 2014). Key biodiversity areas cover 5.5% of Europe and Central Asia for Important Bird & Biodiversity Areas and 0.01% for the Alliance for Zero Extinction sites. As of 2017, the proportion of Key biodiversity areas fully covered by protected areas in Europe and Central Asia is 33.3% of Alliance for Zero Extinction sites and 28.1% of Important Bird & Biodiversity Areas.

In Western and Central Europe, the total coverage of protected areas is 14.9%, with 26.7% of the terrestrial area and 6.8% of the marine area being protected **(Figure 4.25)**. These subregions have the highest proportion of terrestrial and marine areas, and also the highest proportion of protected area coverage in Europe and Central Asia. Key biodiversity areas cover 6.4% of Western and Central Europe for Important Bird and Biodiversity Areas, and only

Figure 4 25 **Proportion of protected area coverage in Europe and Central Asia and subregions. Source: Own representation based on data from UNEP-WCMC & IUCN (2017).**

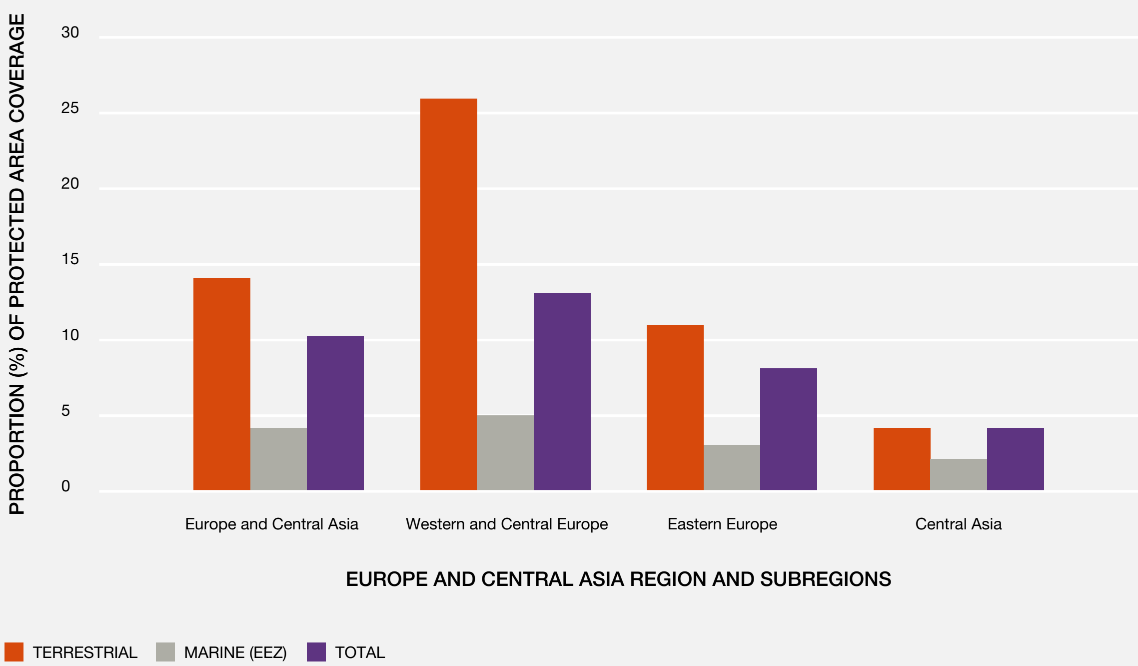


Figure 4 26 **Growth in the proportion of key biodiversity areas completely covered by protected areas in Europe and Central Asia. Source: Brooks *et al.* (2016).**

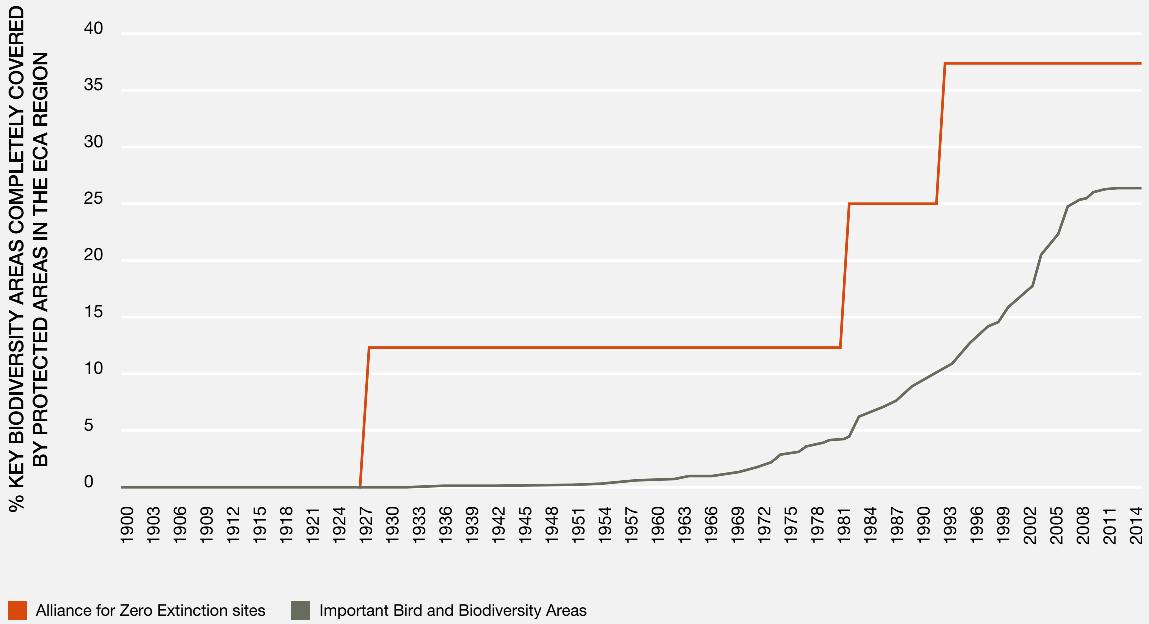
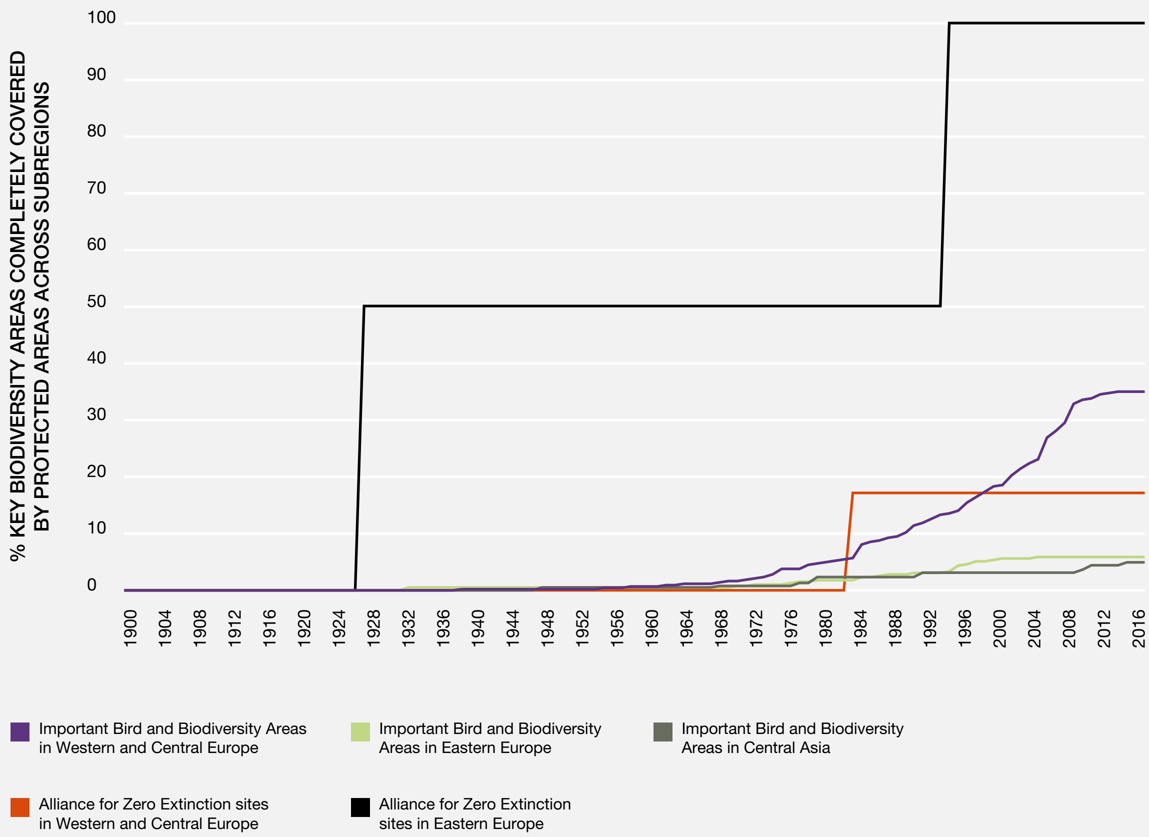


Figure 4 27 **Growth in the proportion of key biodiversity areas completely covered by protected areas in the subregions of Europe and Central Asia. Source: Brooks *et al.* (2016).**



0.01% for Alliance for Zero Extinction sites. As of 2017, the proportion of Key biodiversity areas fully covered by protected areas in Western and Central Europe is 14.3% of Alliance for Zero Extinction sites and 35.5% of Important Bird and Biodiversity Areas **(Figure 4.27)**. In Eastern Europe, the total coverage of protected areas is 7.5%, with 9.5% of the terrestrial area and 2.9% of the marine area (within the Exclusive Economic Zone) being protected **(Figure 4.25)**. Key biodiversity areas cover 4.8% of Eastern Europe for Important Biodiversity Areas, and 0.01% for Alliance for Zero Extinction sites. As of 2017, the percentage of Key biodiversity areas fully covered by protected areas in Eastern Europe is 100% of Alliance for Zero Extinction sites and 5.42% of Important Bird and Biodiversity Areas **(Figure 4.27)**. In Central Asia, the total coverage of protected areas is 4.1%, with 4.2% of the terrestrial area and 2.4% of the marine area (within the Exclusive Economic Zone) being protected **(Figure 4.25)**. Key biodiversity areas cover 5.4% of Central Asia for Important Bird and Biodiversity Areas, and there are no Alliance for Zero Extinction sites in the subregion. As of 2017, the proportion of key biodiversity areas fully covered by protected areas in Central Asia is 4.65% **(Figure 4.27)**.

The main trend in protected area development in Europe and Central Asia is increasing area under protection. Increase within the European Union has been significant, amounting to about 25% of land cover (UNEP-WCMC & IUCN, 2016). Superficially, this suggests that the European Union has already met Aichi Biodiversity Target 11 of 17% protected terrestrial area. However, the bio-geographical and ecological representativeness as well as connectivity (e.g., Angelstam *et al.*, 2011) of protected area needs further research. Consequently, tools for monitoring and analytic prioritization are clearly needed (Branquart *et al.*, 2008; Rosati *et al.*, 2008; Schultze *et al.*, 2014).

Analysis of the development of protected areas in the boreal zone in Western and Eastern Europe over the last 100 years (Elbakidze *et al.*, 2013b) shows that the areal extent of protected areas has increased from approximately 1,500 ha in 1909 to 23 million ha in 2010 **(Figure 4.28)**. The area proportion, size and management profiles of protected areas were very different over time among boreal countries. Throughout this 100-year study period, the least productive northern boreal forest was preferentially protected (**Figure 4.28** and **Figure 4.29**). The uneven representation of protected areas among boreal zone in Western and Eastern Europe was maintained over almost the entire previous century and presents a big challenge for boreal forest conservation (e.g. Hanski, 2011; Uotila *et al.*, 2002; Virkala & Rajasarkka, 2007). Another challenge for ecological sustainability is that the vast majority of boreal protected areas are small. According to many studies concerning the requirements of species with different life histories (Belovsky, 1987; Biedermann, 2003; Edenius & Sjoberg, 1997; Jansson & Angelstam, 1999; Jansson & Andrén, 2003; Linnell *et al.*, 2005; McNab, 1963; Meffe &

Figure 4 28 **Cumulative growth of terrestrial protected areas in northern, middle, and southern boreal forests in Western and Central Europe and the European part of Russia by decade. Source: Elbakidze *et al.* (2013b).**

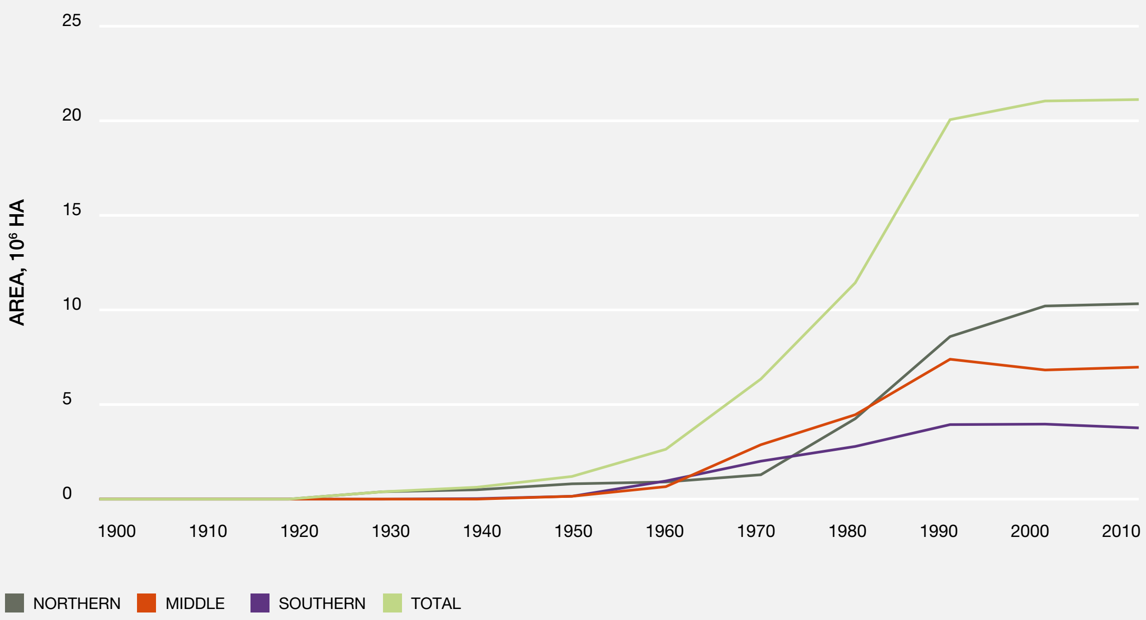
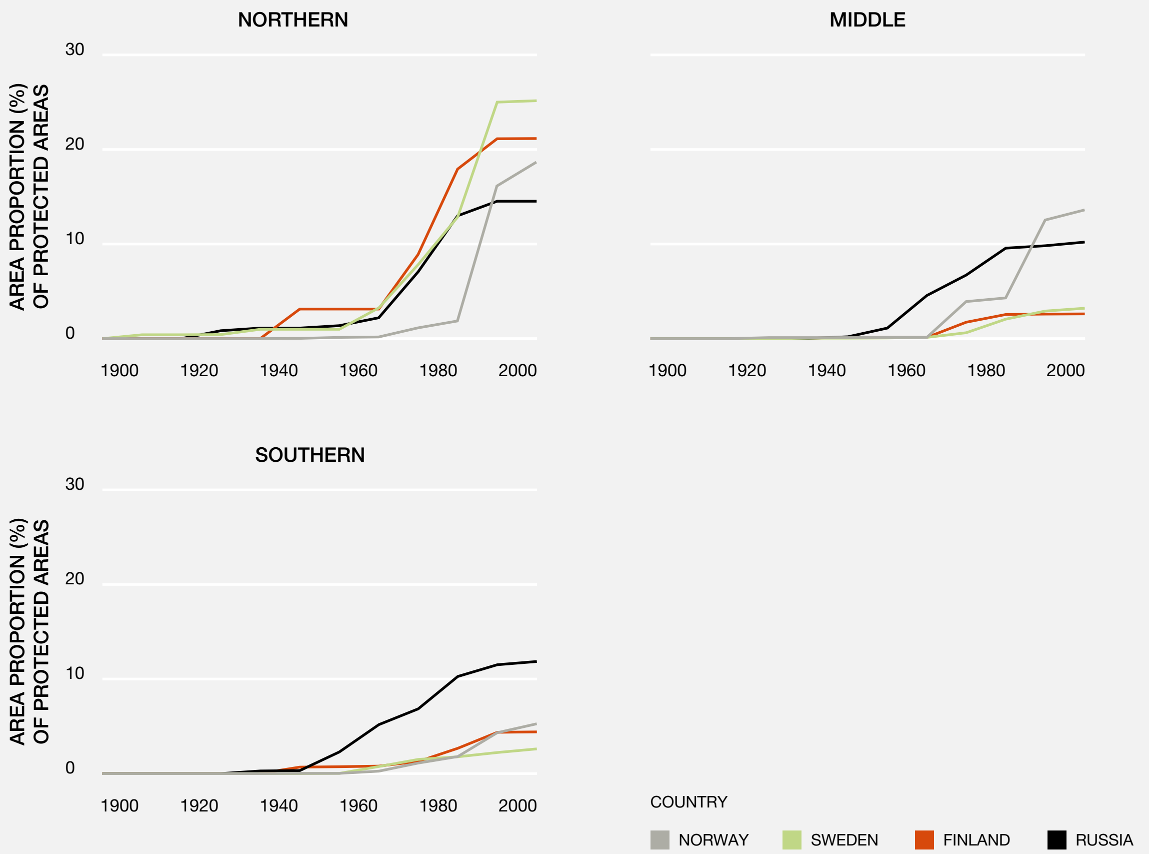


Figure 4 29 **Cumulative growth of the area proportion of terrestrial protected areas in northern, middle and southern boreal forests in Western and Central Europe and the European part of Russia. Source: Elbakidze *et al.* (2013b).**



Carroll, 1994; Menges, 1991; Roberge & Angelstam, 2004) it is evident that many protected areas are too small for focal and umbrella species such as specialized birds and area-demanding mammals.

The number of marine protected areas around the world has increased in recent decades, including in the European Union, aiming at the enhancement of local fisheries (Jones *et al.*, 1993; Lubchenco *et al.*, 2003) following the failure of traditional management measures (Batista & Cabral, 2016; Devillers *et al.*, 2015; Fenberg *et al.*, 2012; Jones *et al.*, 1993; Lubchenco *et al.*, 2003; Waters, 1991). Marine protected areas are generally strongly advocated as an ideal tool for resource management – specifically of coastal fisheries, as well as for preserving biodiversity (Agardy & Tundi Agardy, 1994; Costello & Ballantine, 2015; Dugan & Davis, 1993; Gaines *et al.*, 2010; Lubchenco & Grorud-Colvert, 2015; NOAA, 1990; Roberts & Pollunin, 1991). In 2016, Mediterranean Marine Protected Area Network and Regional Activity Centre for Specially Protected Areas reports 1,231 marine protected areas in the Mediterranean covering 18 million hectares, or 7.1% (MAPAMED, 2017) (http://www.medpan.org/en/mapamed) **(Figure 4.30)**. The expectation is that marine protected areas will continue to increase in number and area across the Mediterranean and North East Atlantic **(Figure 4.31)**.

However, marine protected areas design differs between Atlantic and Mediterranean areas (Pérez-Ruzafa *et al.*, 2017). Northern marine protected areas (the so-called fish boxes or fisheries closures; Pastoors *et al.*, 2000) generally cover hundreds of thousands of hectares, and are intended to protect one or more target or by-catch species (e.g., plaice, sole, cod, herring, sprat, haddock). Mediterranean marine protected areas (Fenberg *et al.*, 2012; Planes *et al.*, 2006), meanwhile, usually over hundreds of hectares or less (Gabrié *et al.*, 2012; Portman *et al.*, 2012), are in general located in areas that are biologically unique. Both types include differences in management strategies that can affect their efficiency as fisheries and biodiversity conservation tools (Pérez-Ruzafa *et al.*, 2017).

Figure 4 30 **Distribution of marine protected areas (MPAs) in Western and Central Europe. Source: Pérez-Ruzafa *et al.* (2017).**

4.5.4.2 Indirect drivers of trends in protected area development

There are several key drivers of protected areas in Europe and Central Asia **(Figure 4.32)** that are unpacked below in **Figures 4.33 – 4.39**.

4.5.4.2.1 Legal frameworks

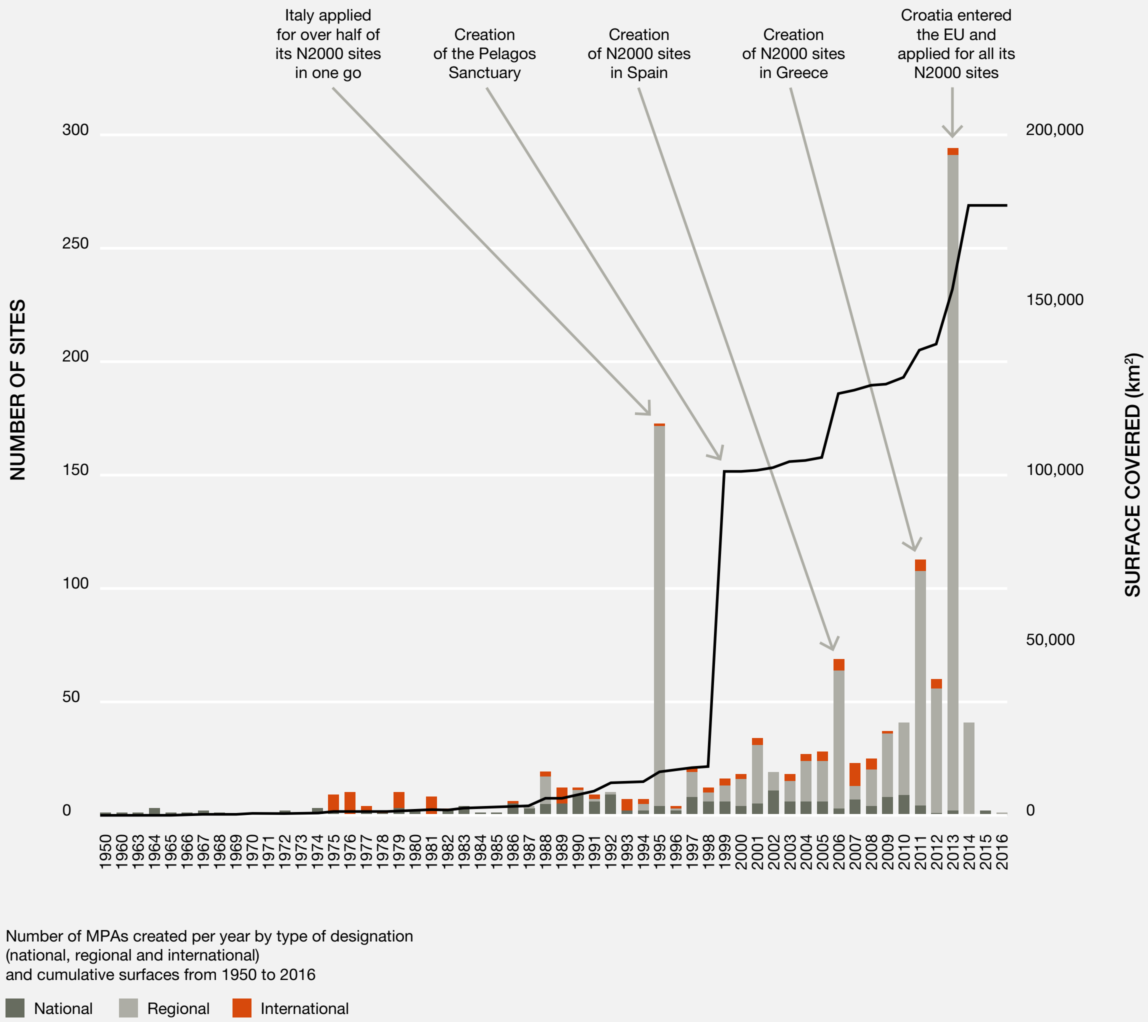
An increasing number of global, regional and national legal frameworks have been a key driver of protected area development in Europe and Central Asia. Agreements such as the Convention of Biological Diversity (CBD, 2010) and associated Aichi Biodiversity Targets, have led to the adoption of a number of strategic plans and quantitative targets for protected areas. Underpinning these agreements is a growing public environmental awareness, which has influenced policy on nature protection. Another key factor has been the growing body of scientific knowledge on biodiversity and nature's contributions to people. Improved understanding regarding the negative effects of habitat fragmentation on ecological functionality, for example, has led to the consideration of functional networks of protected areas, at multiple scales, as a means of addressing biodiversity loss (e.g., European Commission, 2013; Hodge *et al.*, 2015) (see also Aichi Biodiversity Target 11 – "protected areas increased and improved").

In response to international agreements, most countries in Europe and Central Asia have developed national biodiversity strategies, in most cases including quantitative targets for protected areas (cf. https://www.cbd.int/nbsap/). In Western Europe, international plans and targets are mirrored in the EU Biodiversity Strategy (EU Parliament, 2012) and directly linked to the European Union Birds and Habitats Directive. These are subsequently enacted through national legislation. There is strong evidence that supranational conservation policy can bring measurable conservation benefits, although future assessments will require the setting of quantitative objectives and an increase in the availability of data from monitoring schemes (Donald *et al.*, 2007).

As a result of various bilateral agreements, a number of Eastern European countries (e.g. Ukraine, Belarus) are also in the process of harmonising national biodiversity protection legislation in line with European Union directives (e.g. regarding Natura 2000, and the Pan European Ecological Network). However, European Union policies are primarily based on Western European experiences. Numerous studies have shown cases where nature conservation legislation has underperformed when transplanted into new regional or local contexts (e.g. Aksenov *et al.*, 2014; Kuemmerle *et al.*, 2007; Wendland *et al.*, 2015) and a risk remains that European Union-developed approaches will prove either inefficient or

Figure 4 31 **Trends in the number and cumulative surfaces of marine protected areas (MPAs) created per year and type of designation (national, regional and international) from 1950 to 2016.**

Source: MEDPAN (2017). N2000: European Union Habitats and Birds Directives Natura 2000 sites.



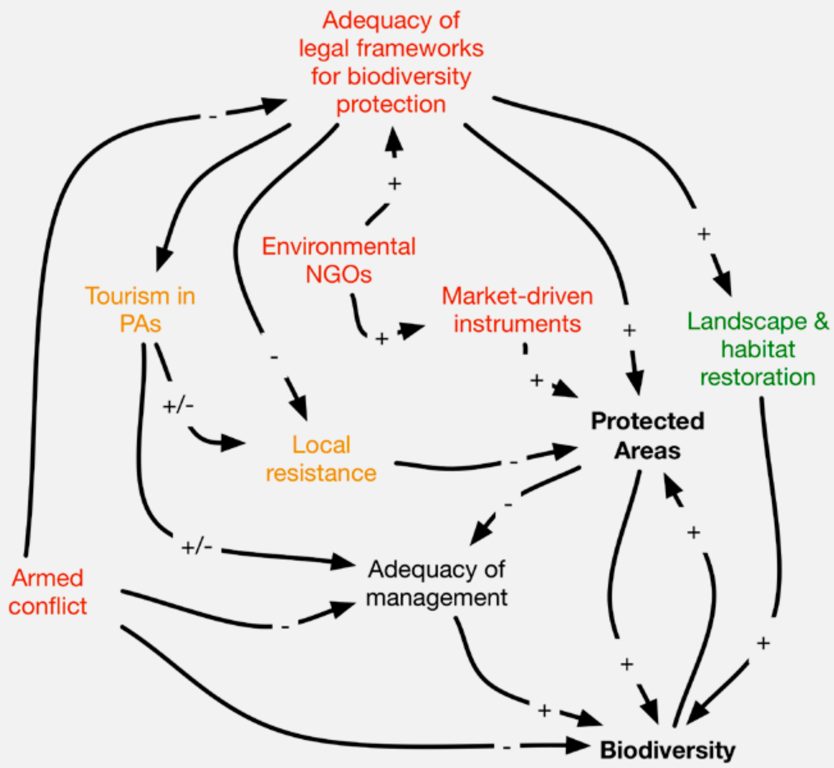
inappropriate for supporting biodiversity associated with cultural landscapes in Eastern Europe and Central Asia. Additionally, in some cases the adoption of national strategies has led to unforeseen transboundary consequences. For example, forest protection in China and Finland have both resulted in increased harvest of old-growth forests in neighbouring regions of Central Asia and north-western Russia (Mayer *et al.*, 2006) respectively. Also, some countries have weakened national and sub-national protection regulations largely in favour of regional economic development (see **Box 4.3** and **Figure 4.33**).

Regarding the Marine Protected Areas, for example, the European Union Marine Strategy Framework Directive requires that member States should reach Good Environmental Status of their waters by 2020. The strategy sees establishment of a coherent network of Marine Protected Areas as one of the approaches to fulfil this aim. It specifically refers to Maritime Spatial Planning based on ecosystem based approach as a key tool to reinforced the objectives of the European Union Marine Strategy (Douvere & Ehler, 2009; Ehler, 2008).

Experience shows that these are not empty words. A study published in Marine Policy earlier this year assessed plans in Western and Central Europe, Australia and the USA. They found that planning led to a host of benefits for the environment: it increased marine protection, ensured that industrial uses avoided sensitive habitat, cut carbon emissions, and reduced the risk of oil spills.

Figure 4 32 **An overview of causal interconnections between the major drivers of protected areas (PAs) development in Europe and Central Asia. Source: Own representation.**

Legal frameworks, particularly international agreements, have led to increased levels of biodiversity protection throughout the region. However, the general inadequacy of institutions for navigating local resistance to protected areas and regulating the negative impacts of tourism poses important problems. These drivers and interconnections are further unpacked in sub-model structures below.



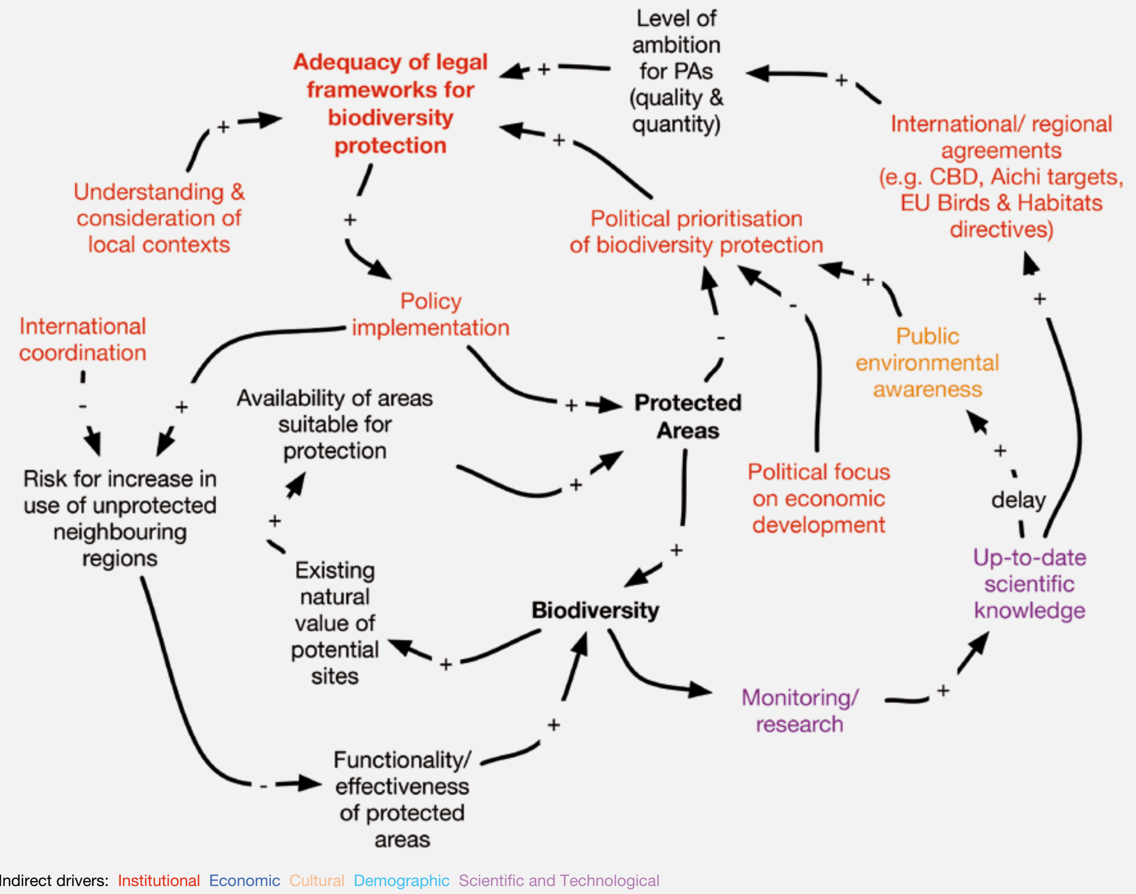
Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

Box 4 3 **Example of dynamics in legal frameworks from Eastern Europe.**

In the Russian Federation, despite adopting several fundamental legal documents, and subsequent rapid growth in protected areas during the 1990s, numerous laws or amendments have recently been passed to weaken the protection status of existing protected areas, primarily in favour of increased economic activity (Brynych, 2016; NIA-Priroda, 2016). For example, in preparation for the Sochi Olympics an amendment was made in the law "On Specially Protected Natural Areas" allowing the construction of sports infrastructure in national parks. This amendment set legal preconditions for use of lands within national parks by new ski resorts. The governmental programme "The main directions of the state policy on the development of the system of state nature reserves and national parks in the Russian Federation for the period until 2015", adopted by the Ministry of Natural Resources of Russia in 2003, was not able to stop the subsequent degradation of protected areas. Recent changes in water and forest legislation led to a weaker legal regime in the areas of water protection zones and protective forests (Naumov *et al.*, 2017). In 2013, a law was passed that eliminated the principle of perpetuity of existence of protected areas and initiated transformation of strict nature reserves into national parks. In 2016, another law was adopted allowing the allocation of biosphere polygons within the boundaries of biosphere reserves, which legalized economic development (Brynych, 2016; NIA-Priroda, 2016). Other amendments were made to the federal law "On Territories of Traditional Nature Use of the Indigenous Minorities of the North, Siberia and the Far East of the Russian Federation" (2001), according to which such territories are not considered any more as Specially Protected Natural Areas; currently it creates new challenges in the procedure of their creation. Since 2001, not a single territory of traditional land management of indigenous people of Federal importance has been created (NIA-Priroda, 2016). At national and regional levels, there are no legal frameworks that take into account the specific nature of conservation of steppe landscapes (Chibilev, 2015).

Figure 4 33 **The prioritization and implementation of adequate legal frameworks for protected areas (PAs) development has largely been driven by the adoption of international agreements, as well as an increasing public environmental awareness. Source: Own representation.**

A strong political focus on economic development goals, however, has in many cases delayed the development, and in some cases, has led to the weakening, of adequate policies.



4.5.4.2.2 Forest certification

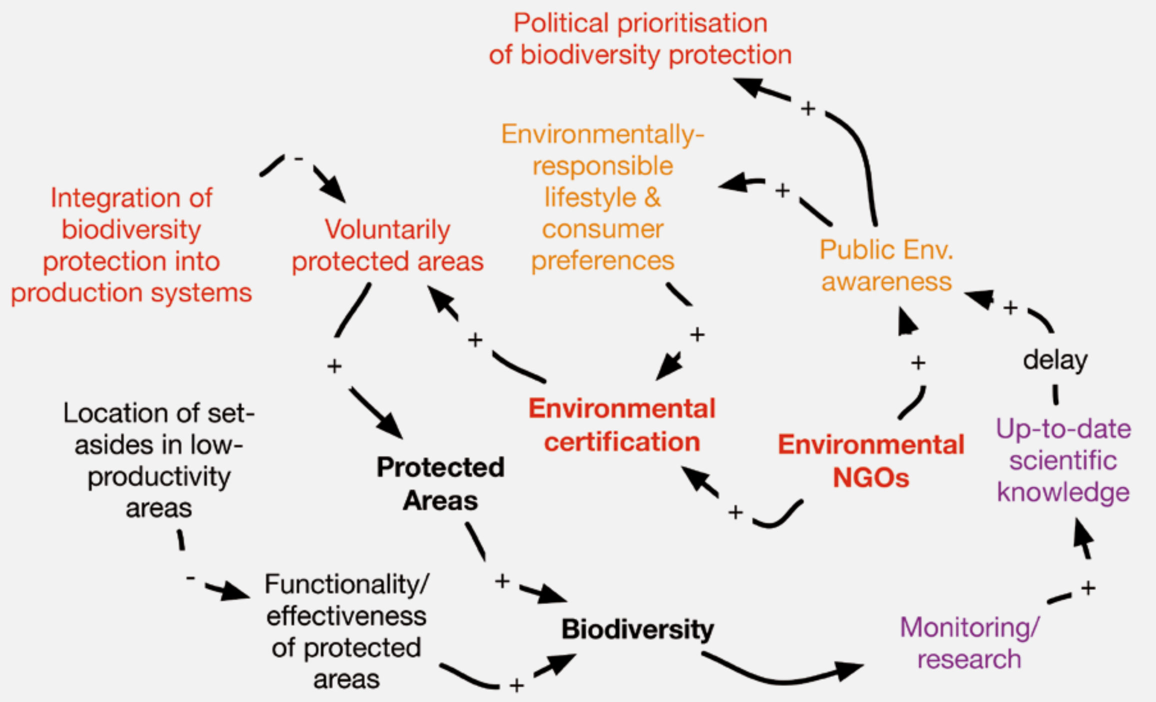
Industries have largely adopted certification requirements in response to increased consumer demand for environmentally responsible products, as a result of heightened public environmental awareness globally and across Europe and Central Asia. Voluntarily set-asides, driven in large part by the requirements of various production certification schemes, are also important for protected areas in Europe and Central Asia. For example, market-driven forestry certification schemes require that a certain fraction of the certified forest holding is set-aside for biodiversity conservation (often around 5% of the land holding, e.g. www.fsc.org). Certification systems highlight protection of forest areas as a means to maintain forest biodiversity (FSC, 2016; PEFC, 2010) and hence their national standards regularly include targets for voluntary set-asides. Both increased forestry certification as well as the adoption of national and global targets for protected areas have resulted in an increased area of formally protected forests and voluntary set-asides for biodiversity conservation purposes.

4.5.4.2.3 Activity of environmental non-governmental organizations

Environmental NGOs are among the key actors in shaping general public environmental awareness across Europe and Central Asia (Cashore *et al.*, 2003; Meidinger, 2003; Tysiachniouk, 2012; Tysiachniouk & McDermott, 2016). Public awareness has proved influential in creating a greater political prioritization of nature protection, as well as steering consumer preferences towards environmentally certified products. NGOs have also actively and directly lobbied industries and decision-makers to develop stricter (self-)regulatory frameworks for nature protection (e.g. marine protected areas) and to otherwise engage with various certification systems. In Eastern Europe, environmental NGOs – largely supported by foreign donors

Figure 4 34 **Environmental NGOs have had an important impact in building public awareness of the role of nature protection, leading to shifts in consumer preferences and political priorities. Source: Own representation.**

The drive to environmental certification has been important provider of voluntary protection.



– contributed considerably to protected area development and management during the long post-Soviet transition towards a market economy. The Centre for Wildlife Conservation (1994), developed strategic and management plans for protected areas (e.g. Nature protected areas, 1998), designed regional protected areas and ecological networks, coordinated ecological restoration projects, as well as carrying out many other activities. However, the last decade has seen an increase in legal and administrative pressure on the activities of environmental NGOs in some Eastern Europe countries. For example, in Russia the official list of foreign NGOs permitted to operate in the country has been reduced by 7 times, and since 2008 consists of only 12 organizations; NGOs receiving any form of foreign funding are frequently classified as "foreign agents" (Shevchenko, 2016). Russian environmental NGOs have seen funding liquidated, or have otherwise been forced to gradually cease their activities (Yablokov & Zimenko, 2009). Under such circumstances, the activity of many NGOs cooperating with protected areas in Russia has decreased considerably (Bishop *et al.*, 2000; Brynych, 2016; Buivolov & Grigorian, 2006; Steppe fires and management of fire situation in steppe PAs, 2015; Stepanytskyy & Kreyndlin, 2004; Shtilmark, 2003) **(Figure 4.34)**.

4.5.4.2.4 Adequacy of management resources for protected areas

The availability of state-based funding for protected areas varies across Europe and Central Asia. In some countries state funding is insufficient for adequate management (Stepanytskyy, 1999, 2000). Funding from external bodies, for example, European Union environmental funds and international NGO funding, has in some instances bolstered protected area management budgets. In some countries there are, however, a number of institutional impediments to accessing such funding. Recent changes to laws in Russia (see **Box 4.3**), for example, have had a negative influence on protected areas funding (Shevchenko, 2016). Many protected areas also seek to augment management budgets by generating income opportunities based on protected area resources, for example through forestry or tourism. Managing these kinds of use often requires additional resources, and has an adverse impact on the natural values provided by the protected areas. In addition, acquisition costs for protected areas are generally much higher than annual management costs and have a strong impact on the financial resources available for protection (James *et al.*, 1999). As such, high land prices can present barriers for biodiversity protection in areas where land must be purchased prior to the establishment of protected areas, with intensive land uses generally associated with higher prices (Naidoo *et al.*, 2006).

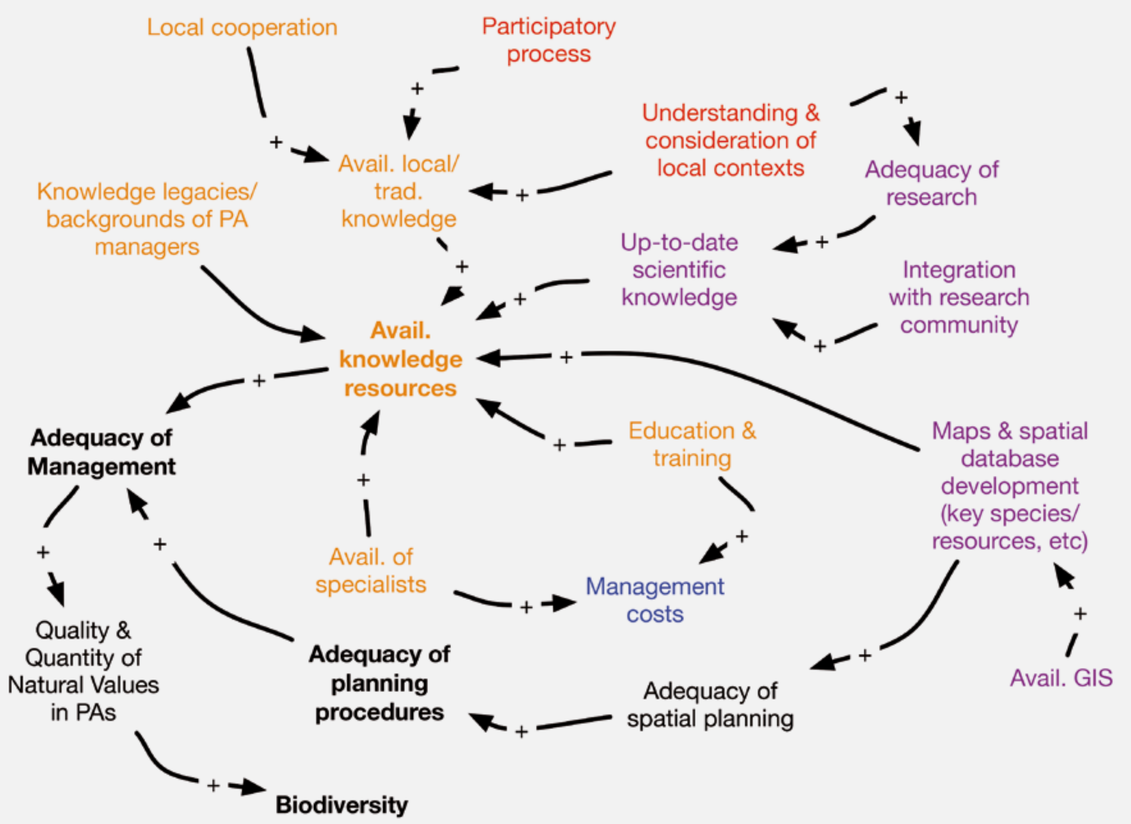
Protected area management also requires sufficient training of managers or the procurement of a variety of specialists, both of which represent additional costs. Inadequate training of young specialists has been identified as a barrier to good management in some Eastern European countries (e.g. Mashin *et al.*, 2001), where the previous, Soviet-trained generation of managers is beginning to retire. Up-to-date scientific knowledge is partly dependent on taking local contexts into account in high-quality research. In addition to formal knowledge and training, the inclusion of local knowledge is seen as an important component in ensuring adequate management (Vdovin, 2016; Shulgin, 2007) **(Figure 4.35)**.

Whilst staff are often driven by a strong desire to preserve unique natural values, low salaries (Ivanov & Chizhova, 2003) together with often poor working conditions and a general lack of focus on long-term capacity building, this has led to the demotivation of staff (Mashkin, 2007; Sidenko, 2010). Many protected areas are also reliant on the contribution of civil sector volunteers (e.g. members of NGOs or local communities). However, the degree to which these human resources are permitted to contribute to protected area management is partly dependent on the inclusion of suitable participatory mechanisms in the overall governance and management approach.

Specialized equipment (e.g. GIS, computerized species-monitoring systems) is often required to establish the baseline data for, or monitor the impacts of, protected area strategies and plans. Other more generic forms of technology, such as suitable vehicles, and infrastructure, such as protected area management offices, are also required inputs. In broad terms, many Eastern European and Central Asian protected areas suffer from poor quality or out-dated equipment, infrastructure and vehicles, or lack these entirely.

Figure 4 35 **Knowledge and planning resources are essential to adequate protected area (PA) management. Source: Own representation.**

The education and training of staff and integration of management with both research and local communities are key strategies.



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

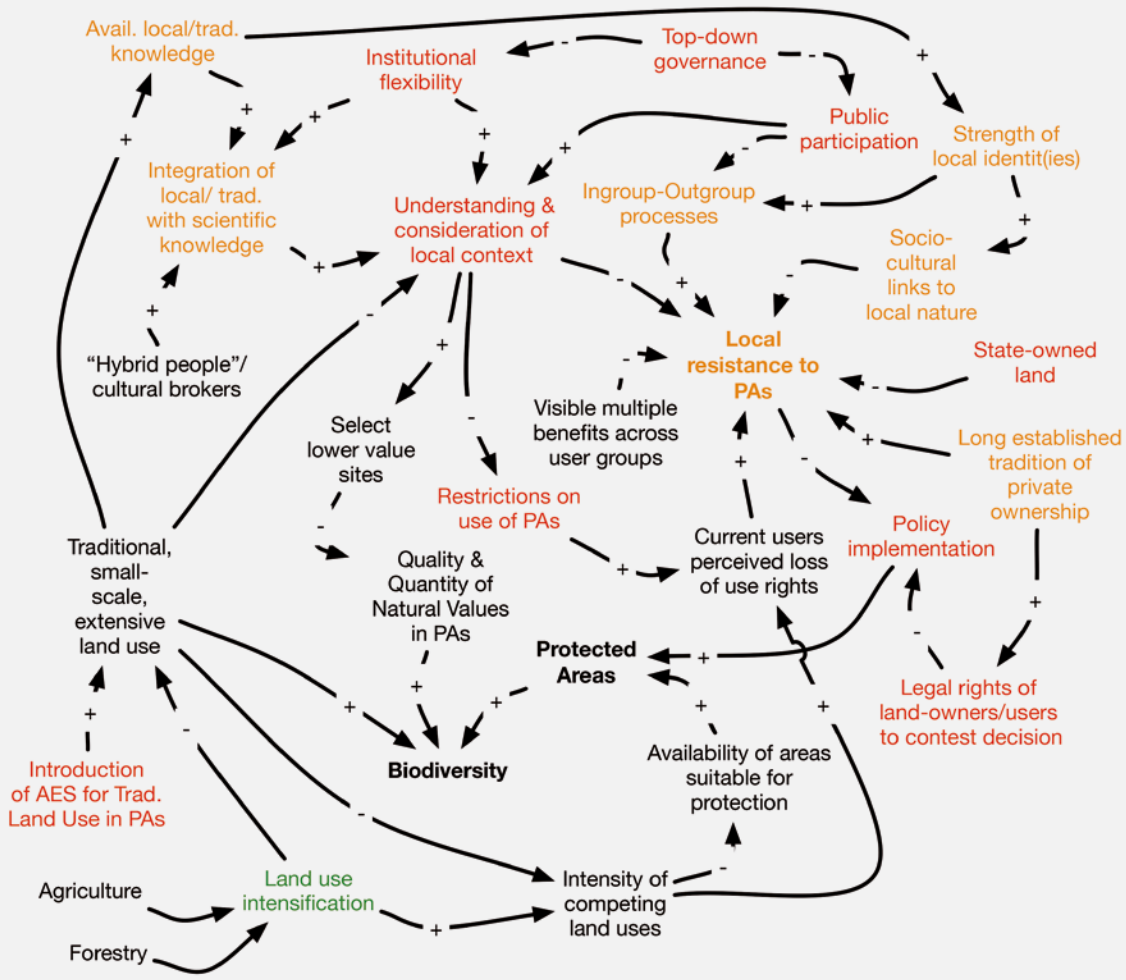
4.5.4.2.5 Local resistance

A major factor affecting the establishment or successful management of protected areas in Europe and Central Asia relates to the manner in which they navigate local use conflicts arising as a result of protection status and management (Babai *et al.*, 2016). Protected area governance and management regimes are often characterized as top-down with low levels or quality of public participation; inflexible responsible authorities and insufficient consideration of the local context; engendering negative public perceptions; and resistance amongst members of local communities (Blicharska *et al.*, 2016; Carrus *et al.*, 2005; Elbakidze *et al.*, 2013c; Grodzinska-Jurczak & Cent, 2011; Mathevet *et al.*, 2016). These factors pose significant challenges to the functionality of protected area networks (Blicharska *et al.*, 2016; Elenius *et al.*, 2017; Stenseke, 2009).

Local resistance to protected areas can be related to in-group/out-group identity processes, e.g. local communities vs central governmental authorities (Bonaiuto *et al.*, 2002; Stoll-Kleemann, 2001), or from the perceived loss of user rights as a result of protected areas' restrictions (James *et al.*, 1999). For the latter reason, land owners tend to oppose establishment of protected areas to a greater extent than other stakeholders (Brescancin *et al.*, 2017; Kamal & Grodzinska-Jurczak, 2014), particularly in countries where social values are strongly linked to long histories of private ownership. At the same time, local identity in some cases is also linked to reduced local resistance due to strong socio-cultural links to nature (Carrus *et al.*, 2005; Uzzell *et al.*, 2002).

The mutual dependence of extensive land use and conservation management has become apparent in the

Figure 4 36 **Consideration of local contexts, knowledge and identities in the design and establishment of protected areas (PAs) helps to avoid local resistance. Source: Own representation.**



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

last 20-30 years. Small-scale extensive land use often survives in protected areas only, in the form of conservation management, and is largely side-lined in regulatory frameworks. Regulations introduced to protect such areas often apparently do not consider local world views, or the effects of local practices. This results in the restriction of local people's activities (Babai *et al.*, 2016; Molnár *et al.*, 2016) and conflict between locals and the protected area's authority (Kelemen *et al.*, 2013). The adoption of a more integrated, participatory approach to the governance and management of protected areas is suggested as a potential remedy to local use conflicts, particularly in protected areas established in cultural, small-scale, or indigenous landscapes. There is a need for "hybrid people" who have knowledge of traditional practices and world views, as well as of mainstream nature conservation ideas (Molnár *et al.*, 2016). Additionally, the introduction of agro-environmental schemes in protected areas can mitigate the loss of traditional management practices and so prevent biodiversity loss accompanying land abandonment (Babai *et al.*, 2015). One approach might be for landscape- and culturally-specific agricultural regulatory frameworks and subsidy systems that include local and traditional knowledge to produce tailored local solutions that respect the strong link between natural and cultural capital (Molnár & Berkes, 2017) **(Figure 4.36)**.

Marine protected areas appear to have been more successful than terrestrial ones in combining conservation plans and management practices with visible economic benefits in terms of long-term fishery management and diving-based tourism. Marine protected area design takes greater account of geographical and cultural contexts in which users are situated (Fenberg *et al.*, 2012; Gabrié *et al.*, 2012; Pastoors *et al.*, 2000; Planes *et al.*, 2006; Portman *et al.*, 2012). However, while aiding local acceptance of marine protected areas, a strong consideration of the needs of multiple users within the local context has potentially led to the protection of areas of lower inherent conservation value (Coll *et al.*, 2012).

4.5.4.2.6 Armed conflicts

Armed conflicts have multiple negative impacts on biodiversity and nature's contributions to people. Europe and Central Asia is unfortunately the arena for a number of recent and current armed conflicts (Vasyliuk *et al.*, 2017). Whilst few studies have been conducted in the region on the specific effects of armed conflict on protected areas, the environmental effects are presumed to be identical to those in non-protected areas and include the various forms of direct environmental damage associated with the use of heavy weapons and military equipment, as well as a number of effects resulting from sudden changes in land-use regimes (see **Box 4.4**). It is apparent that legal protection status is not well-respected during times of armed conflict. Studies of conflicts outside of Europe and Central Asia suggest that protected areas, which are often remote or difficult to access, serve as refuges for fighting forces, and as such are key targets for opposing forces (D'Huart, 1996). In addition, armed conflicts exacerbate poaching pressure and other illegal use, immediately eliminate tourism activities, and drain financial and human resources from ecosystem management (Baumann *et al.*, 2015; D'Huart, 1996; de Merode *et al.*, 2007; Dudley *et al.*, 2002) **(Figure 4.37)**.

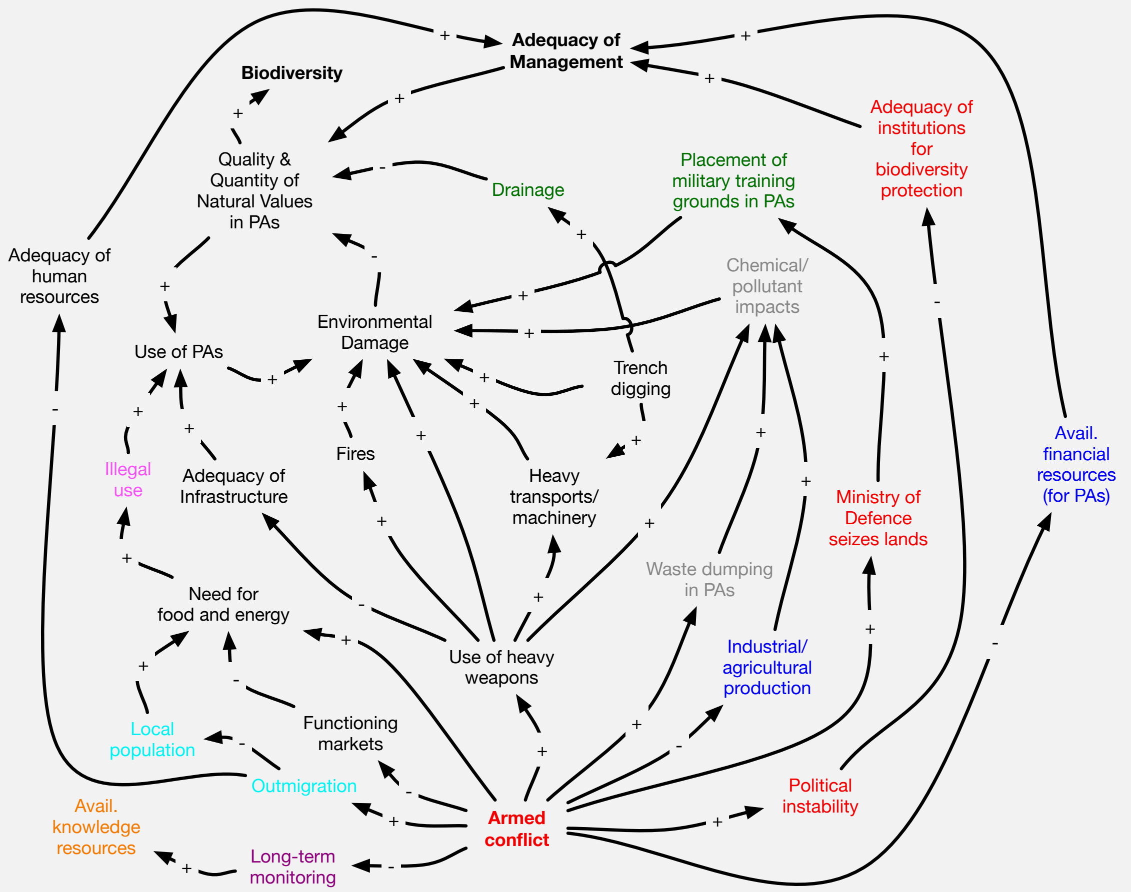
Box 4 4 Consequences of armed conflicts for biodiversity and nature's contributions to people - example from Ukraine.

Since 2014, armed conflict in the eastern region of Ukraine (Luhansk and Donetsk), in addition to a large number of human casualties and the destruction of infrastructure, has led to extensive habitat loss in existing protected areas, largely due to:

(1) Heavy military machinery driving or otherwise operating in protected areas.
(2) Explosions of munitions, resulting in the destruction of vegetation and accumulation of debris and chemicals in soils - primarily sulphur and heavy metals, e.g. experts counted about 15,500 craters from explosions in the regional landscape park "Donetsk ridge".
(3) Construction of military infrastructure, e.g. training grounds and trenches, within protected areas.
(4) Illegal logging for military purposes and fires. Pine forests of the steppe zone of Ukraine are extremely fire-prone. About 3,000 fires occurred in the military zone within protected areas during 2014. Roughly half of all protected areas in the war zone are fire-damaged.
(5) Illegal logging by local people for domestic needs, associated with the destruction of regional heating systems and gas supply; as well as for the construction of defensive infrastructure. This has resulted in intensified wind erosion and dust storms.
(6) Use of protected areas for waste storage/ dumping.

In addition, much of the institutional framework underpinning protected area governance and management in the annexed areas has been lost, and many employees have resigned. The war has also indirectly led to major reductions in national budgets for protected areas, both within and outside of the conflict zone (Melen'-Zabramna *et al.*, 2015).

Figure 4 37 **Armed conflict has many deleterious effects on protected areas (PAs), including multiple direct and indirect environmental impacts, diversion of economic resources from protected area budgets, loss of institutions and human resources, and interruption of long-term monitoring. Source: Own representation.**



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

4.5.4.2.7 Landscape and habitat restoration

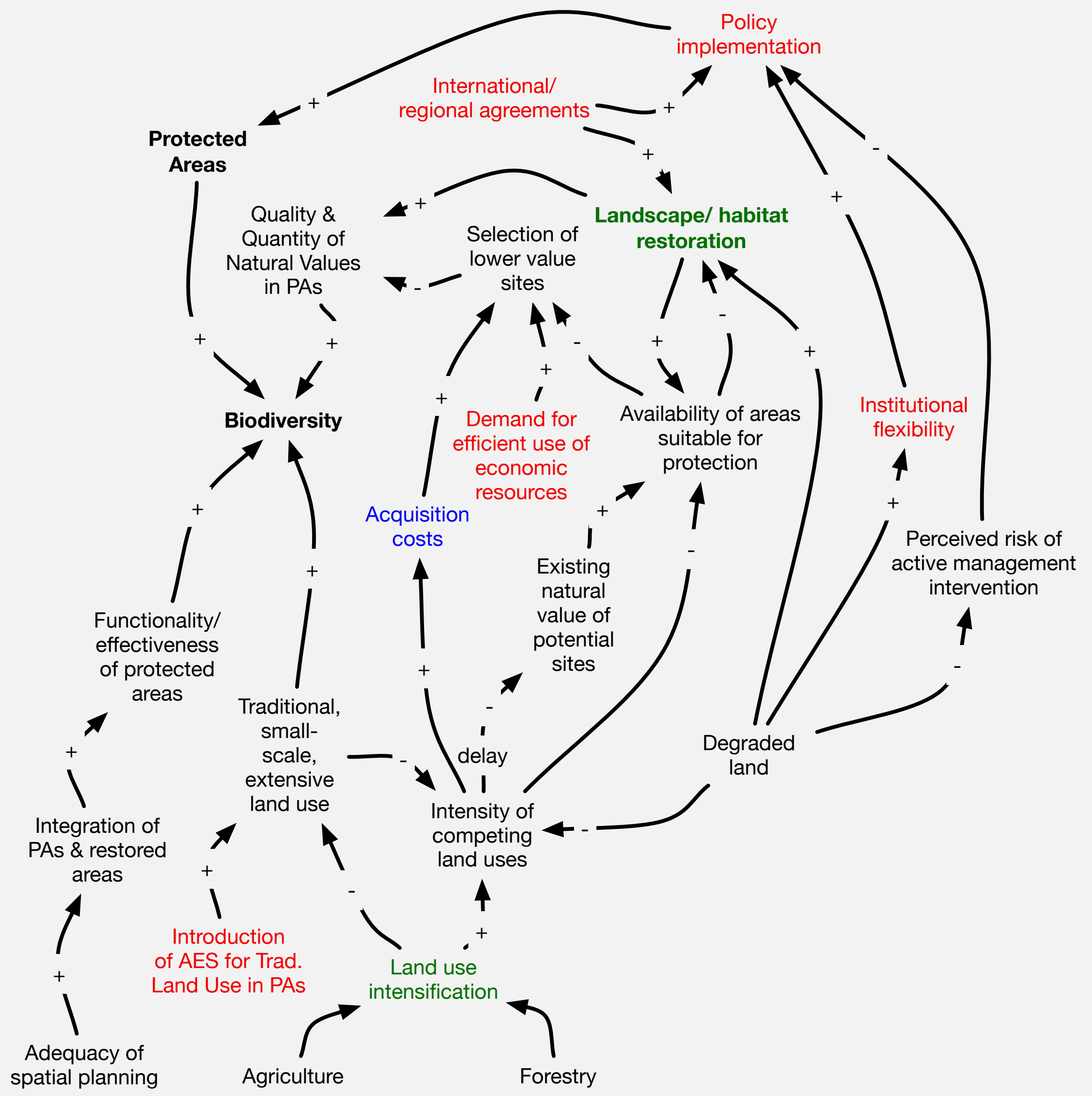
Landscape and habitat restoration offers opportunities for nature conservation and protected area development. For certain habitat types, restoration activities are prescribed to secure sufficient areas for protection and for meeting Aichi Biodiversity Target 11. High rates of land conversion, including loss of cultural landscape habitats dependent on traditional land use (Hartel & Plieninger, 2014) and the expansion of modern forestry into remnants of natural forests in the northern part of Western Europe (Naumov *et al.*, 2017), implies the continued loss of high-quality areas suitable for protection. Lack of suitable areas combined with demands for efficient use of limited resources for protection leads to the consideration of sites/areas of lower natural values in terms of biodiversity and nature's contributions to people. This includes, for example, expanding existing reserves with adjacent areas of lower conservation value, but providing long-term benefits by succession or active conservation (Mazziotta *et al.*, 2016; Polasky *et al.*, 2008) **(Figure 4.38)**.

The restoration of degraded land is a part of the Strategic Plan for Biodiversity 2011-2020 (specifically Aichi Biodiversity Target 15 – "ecosystems restored and resilience enhanced") and is included in the European Union's biodiversity strategy; both calling for restoration of at least 15% of degraded ecosystems. Degraded lands may offer multiple opportunities for restoration projects, including lower land prices, fewer current users and greater support for active management interventions, lower perceived risks, and greater institutional flexibility (Dawson *et al.*, 2017).

4.5.4.2.8 Tourism

Tourism opportunities can provide a political incentive for protected area establishment, due to the possibility of offsetting protection costs with sought-after rural socio-

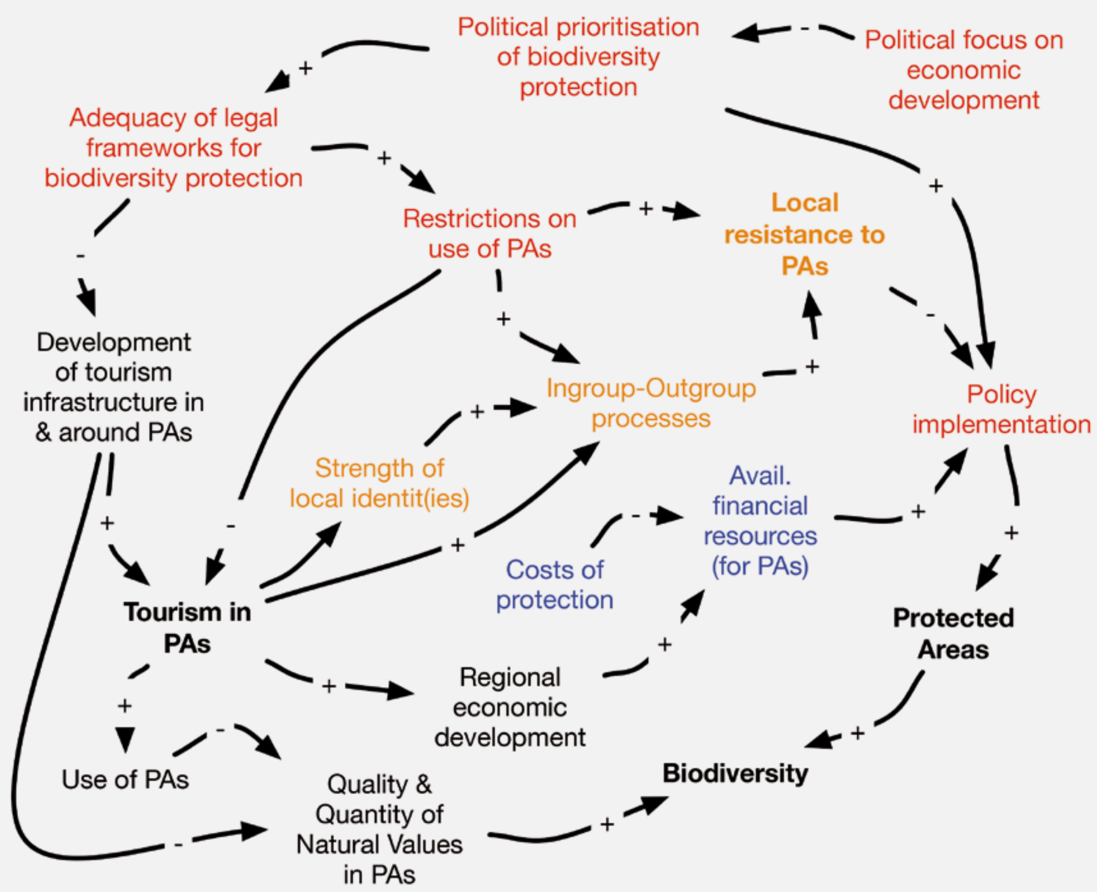
Figure 4 38 **The restoration of degraded land can be an important opportunity for nature protection in some regions, particularly where land prices are high or land uses are intensive. PAs: Protected areas. Source: Own representation.**



economic development (Sevastiyanov *et al.*, 2014; Svoronou & Holden, 2005; Zachrisson *et al.*, 2006). An example is the creation of new diving tourism opportunities associated with marine protected areas. However, the introduction of new user restrictions for local residents, while at the same time opening up the area for new users (tourists), may reinforce insider-outsider dynamics or otherwise engender local resistance and conflicts (Colchester, 1997; Cortes-Vazquez, 2014). For example, a number of studies note that urban populations tend to adopt a more dualistic perspective regarding human-nature relations, supporting calls for more protected areas with less human intervention in their management (Coleman & Aykroyd, 2009; Cortes-Vazquez, 2014; Linnell *et al.*, 2015). Additionally, the transition from a staple economy to jobs based on amenity values, outdoor recreation and tourism can also be challenging for many local rural communities (Westlund & Kobayashi, 2013). Recent legislative amendments in Russia (see above) have opened protected areas up for tourism, ostensibly as a means to improve their economic situation (Boreyko *et al.*, 2015; Chibilev, 2014; Shtilmark, 2014). The engagement of strict nature reserves, for example, in commercial activities (primarily tourism) has led to numerous attempts to violate the nature protection

Figure 4 39 **Tourism offers opportunities for regional economic development offsetting some of the costs of protected areas (PAs). Source: Own representation.**

However, tourism and related infrastructure have negative impacts on the natural values under protection, as well as encouraging the erosion of protection policies. Encouraging tourist use while imposing restrictions on local use can result in conflicts.



regimes in both federal and regional protected areas, and UNESCO World Heritage sites, including illegal construction of tourism-related infrastructure (Stepanytskyy & Kreyndlin, 2004) **(Figure 4.39)**.

4.5.5 Trends and indirect drivers of changes in traditional land use

4.5.5.1 Trends in traditional land use

Traditional land use encompasses multiple non-intensive, locally adapted land-use practices based on local and indigenous knowledge that have played a significant role in the development of diverse, productive and sustainable food and material production systems (Molnár & Berkes, 2017; Parrotta & Sunderland, 2015; Parrotta *et al.*, 2016; Plieninger *et al.*, 2006). In Europe and Central Asia, traditional land-use practices, including forest management, agricultural activities, and agroforestry, have influenced nature over millennia, leading to the development of diverse ecosystems and cultural landscapes favouring a range of semi-natural and natural habitats and associated plant and animal species (Aitpaeva *et al.*, 2007; Fedorova, 1986; Kile, 1997; Laletin, 1999; Saastamoinen, 1999; Saastamoinen *et al.*, 2000; Taksami & Kosarev, 1986; Turnhout *et al.*, 2012; Dmitriev, 1991) **(Figure 4.40)**.

Since the 1950s, agricultural practices across the region and traditional land use have undergone substantial changes (EEA, 2015a; Van Zanten *et al.*, 2014). There are two main trends in traditional land-use systems in Europe and Central Asia: (1) substantial decrease in land area with traditional land use and loss of traditional ecological knowledge; and (2) maintenance of traditional practices and adaptation of traditional ecological knowledge to new ecological and socio-economic conditions.

Figure 4 40 **The traditional village system found in Eastern Europe's forest and woodland landscapes is characterized by a centre-periphery zoning from houses, gardens, fields, mowed and grazed grasslands to forests (i.e. the ancient system with domus, hortus, ager, saltus and silva), as illustrated in this view of the village Volosyanka in the Skole district of Ukraine's west Carpathian Mountains.**

Beginning in the left part of the picture, the church in the very village centre is surrounded by houses that are located in the bottom of the shallow valley. The private gardens have many fruit trees and shrubs. Further to the right there is a fine-grained mixture of grasslands, some individual fields of which some have been mowed and have hay-stacks and some not yet, and fields, like the potato field in the foreground. Further, to the right there is forest, which is grazed by cattle moving in and out along specially designed fenced trails from the farm houses in the valley bottom. In addition, above the tree line on the top of the mountains, there are open grazed pasture commons. Photo: Per Angelstam.

Trend 1: Substantial decrease in land area with traditional land use and loss of traditional ecological knowledge

The land area, where traditional practices are still applied has substantially decreased in many regions of Europe and Central Asia (Rotherham, 2007) as a result of socio-economical changes and land-use intensification. However, many practices have survived on marginal lands, in protected areas, or as a result of socio-cultural preferences (Juler, 2014; Lieskovský *et al.*, 2014; Molnár *et al.*, 2016). For example, transhumant herding, once dominant practice in most mountainous areas in Western and Central Europe, has undergone a sharp decline but has still survived some regions due to cultural traditions (e.g. in Romania - Juler, 2014) or as a part of organic farming activities (Evans, 1940; Juler, 2014; Thompson *et al.*, 2006). Other, more sedentary forms of herded grazing have for example survived in the vast steppe areas of Hungary (Kis *et al.*, 2016; Molnár, 2014). Traditional agro-silvicultural systems, including wood-pastures and coppicing, have almost completely disappeared in Western and Central Europe, as well as management of forest commons according to ancient regulations (Kirby & Watkins, 2015; Rigueiro-Rodríguez *et al.*, 2009). Traditionally managed wood-pastures have partly been preserved in Romania (Hartel *et al.*, 2015), but are also in decline. For example, traditional multi-species fruit orchards with ancient varieties and a species-rich semi-natural grazed herb layer are also in decline, but have begun to revive over the past two decades in Romania (Antofie *et al.*, 2016). Semi-natural grassland ecosystems in Western, Central and Eastern Europe have been largely converted to agricultural fields, afforested or abandoned, depending on the region, though agri-environmental schemes of the European Union may help some to survive. For example, mountain meadows in the Carpathians (examples of the most species rich grasslands on Earth) are mostly abandoned (Babai *et al.*, 2015; Dengler *et al.*, 2014; Ivaşcu *et al.*, 2016) **(Box 4.5)**. In Estonia, traditionally managed semi-natural grassland habitats (wooded meadows, coastal grasslands, floodplain meadows, dry and mesic grasslands) covered about 1.5 million hectares (35% of the country) in 1950s (Kukk & Kull, 1997). Since then, some areas have been turned into cultivated land but most overgrew with forest following the abandonment. By 2010, only 60,000 hectares of semi-natural habitats (4% of their coverage in 1950s) remained, of which only 30,000 ha was under appropriate management. However, the area under management has been increasing in past decades with the help of targeted subsidies (Management Plan for Estonian Semi-natural habitats 2014-2020).

Trend 2: Maintenance of traditional practices and adaptation of traditional ecological knowledge to new ecological and socioeconomic conditions

The essence of traditional practices and traditional ecological knowledge has been preserved or adapted with new ecological and socioeconomic conditions in many marginal areas (e.g. mountains, dry areas, taiga-tundra) across Europe and Central Asia. For example, in Eastern Europe, land-use systems based on beliefs, customs, norms, bans, and rules of natural resource use are maintained by numerous indigenous and local communities (Kile, 1997; Taksami & Kosarev, 1986; Turaev *et al.*, 2005). In a survey of more than 500 respondents

Box 4 5 **Nature is becoming wild – local perceptions of loss of traditional land use and its drivers in European cultural landscapes.**

If traditionally managed hay meadows are abandoned, pioneer forests develop B. Forced abandonment in national parks is often a source of conflict between locals and conservationists. In the case of the eastern Carpathians, however, both of them prefer the managed cultural landscape which is "in order" A according to locals and rich in species according to conservationists. Photo: Ábel Molnár.

A

B

Traditional small-scale farmers developed fine-scale multifunctional cultural landscapes all over Europe (Agnoletti, 2006). With global changes, cultural landscapes are often abandoned or transformed into urban or more intensively managed agricultural areas. If abandoned, natural processes may accelerate, native shrubs and trees and invasive alien species may spread. Local farmers often perceive these changes as a landscape-in-order where "each corner had a role" is changing into a landscape-in-disorder. Independently whether succession is going through more and more natural or degraded stages, locals perceive the process as "getting wild" meaning the intensity of ecosystem service use decreases (Babai & Molnár, 2014; Molnár, 2014). Wild place is a specific folk habitat: under this expression local people understand an area with no or little human utilization. Wild places are e.g. narrow steep valleys where no livestock can graze and timber is difficult to get out, or marshes dominated by tall tussock sedges, which are difficult to cross, impossible to cut for hay and where livestock can drown (Babai & Molnár, 2014; Kis *et al.*, 2016; Molnár, 2014). Abandoned pastures with accumulating litter and encroaching shrubs also are areas that turn into wild. National parks manage their lands in many different ways to help protected species and natural regeneration. If cultural landscapes in national parks are managed in a way where agricultural use is abandoned, local people often argue: the park manages the landscape improperly by letting it turn wild (Bérard *et al.*, 2005). These differences in understandings of "proper" landscape management may cause conflicts between authorities and locals (Babai *et al.*, 2016; Kelemen *et al.*, 2013).

from Central Siberia Vladyshevskiy *et al.* (2000) have shown that in the last years of the twentieth century the use of wild mushrooms and Siberian pine nuts increased from two- to threefold; the use of wild onion three- to fivefold; and berries one and a half to two times. In forest depending communities, non-timber forest products are often the main source of food and income for village populations, representing as much as 30–40% of family income (Laletin *et al.*, 2002).

Pastoralists in mountainous regions of Central Asia practice so-called vertical and horizontal migrations (transhumant) of livestock (Alimaev *et al.*, 2008; Kanchaev *et al.*, 2003). Livestock mobility, which is a main feature of traditional pastoralist patterns, is key for the sustainability of pasture management (Galvin *et al.*, 2008; Robinson *et al.*, 2016). Traditional knowledge in Central Asia has been widely used to control desertification and soil erosion in mountain areas. In Tajikistan, where the use of stepped terraces has a 1,000-year history, planted forests are widely used for stabilization of hill slopes (Civil Initiatives Support Fund, 2006). Methods for slope terracing and cultivation of fruit and nut gardens, especially in the traditional system of land and water management known as boghara, has been known to inhabitants of mountains since ancient times. Throughout the region, traditional techniques including shelterbelts have been used to control windblown sands in the vicinity of settlements.

In the forest regions of the Caucasus, where pastures and haymaking resources are limited, local people use a traditional "pasture turnover" system for regulated forest grazing. The creation of cultural pastures in open areas within forests increases animal productivity while preventing damage to sprouts and seedlings of valuable species (i.e., oak, ash, maple, beech) due to grazing in young, naturally regenerating forest stands. Once regenerating trees attain heights sufficient to prevent their damage by livestock, these forests are used on a temporary basis for grazing, while previously used pastures are managed to encourage restoration of forest cover and growth of valued tree species through natural regeneration (Eganov, 1967).

Sacred sites are common throughout Europe and Central Asia where indigenous and local communities still thrive (Bocharnikov *et al.*, 2012). Such sites may range in size from small groves or even individual trees to extensive forested landscapes. Some areas are considered sacred because they provide major habitats for species with ritual or medicinal values. The protection of such sites is important for the health and spiritual well-being of local communities (Samakov & Berkes, 2016). Protection of forest resources based on religious beliefs is characteristic for Central Asia, where the sacralization of nature is expressed in cultural traditions and practices connected with particular species and sites (Aitpaeva *et al.*, 2007).

4.5.5.2 Drivers of trends in traditional land use

Multiple drivers have underpinned traditional land-use change across Europe and Central Asia. These drivers are mainly context specific and differ across the region **(Figure 4.41)**.

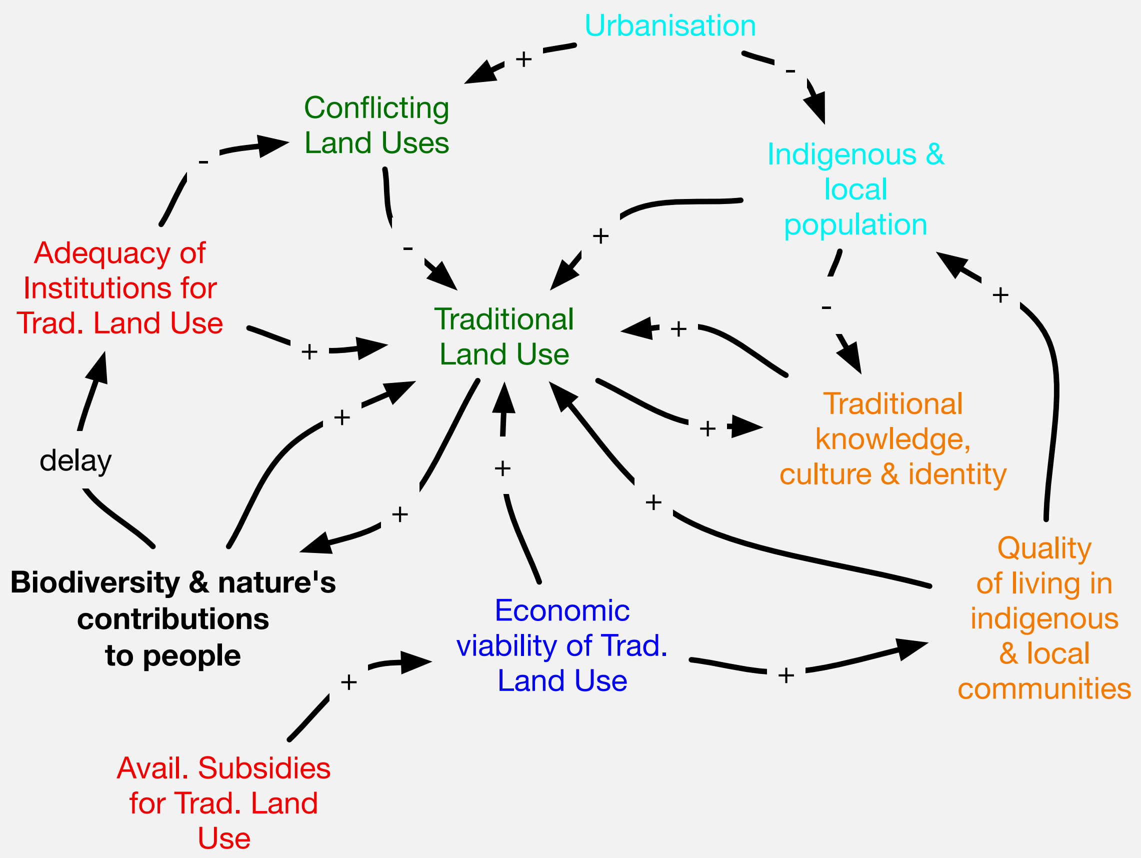
4.5.5.2.1 Institutional drivers of trends in traditional land use

In Central Europe, the European Union's agricultural subsidies have a positive effect on grassland management; many areas abandoned in the 1990s (after collapse/dis-integration of the Soviet Union) are now grazed, mown and cleared of shrubs. In marginalized villages of Central Europe agri-environmental payments are a vital source of income for farmer families. However, culturally and ecologically less adapted regulations for traditional management have diverse side effects – hay meadows are turned into sheep pastures (Csergo *et al.*, 2013), or old trees are cut on wood-pastures (Hartel & Plieninger, 2014). Revival of folk traditions among the youth in cities (e.g. folk singing, folk dancing) may provide a background for the maintenance of traditional practices in rural areas. Back-to-the-country movements are, however, hindered by ecologically and culturally inappropriate regulations (Babai *et al.*, 2015). Recognition of and respect for viable and useful traditional management practices is vital, otherwise farmers may be reluctant to maintain or reintroduce them in their everyday management (Sereke *et al.*, 2016) **(Figure 4.42)**.

In Eastern Europe and Central Asia traditional land use has been especially affected by radical changes in the political system. In recent years, the indigenous peoples of Russia have been trying to restore their traditional livelihoods through legal efforts. The Russian Constitution contains the concept of "indigenous minorities", whose rights are guaranteed by the Russian Federation in accordance with the generally acknowledged principles and norms of international rights and international agreements. The Russian legislation ensures a new status for indigenous peoples by providing enabling conditions for traditional nature resource use within the so-called Territories of Traditional Nature Resource Use for indigenous peoples. These territories are designated to ensure environmental protection and to support indigenous livelihoods, religion, and culture. The legal norms for these territories are related to the various natural resource uses, such as reindeer breeding, hunting, fishing, and non-timber forest product collection, within different territories (Sulyandziga & Bocharnikov, 2006). However, there are no norms ensuring the preservation and use of traditional knowledge, especially in the management of traditional natural resources. During the preparation of the Strategy and

Figure 4 41 **Institutional adequacy and economic viability are key drivers of traditional land use in Europe and Central Asia. Source: Own representation.**

Demographic trends, including urbanization, continue to diminish indigenous and local populations, with concomitant negative impacts on traditional knowledge, culture and identities. These inter-relationships are further unpacked in a series of sub-models below (**Figure 4.42** and **Figure 4.43**).



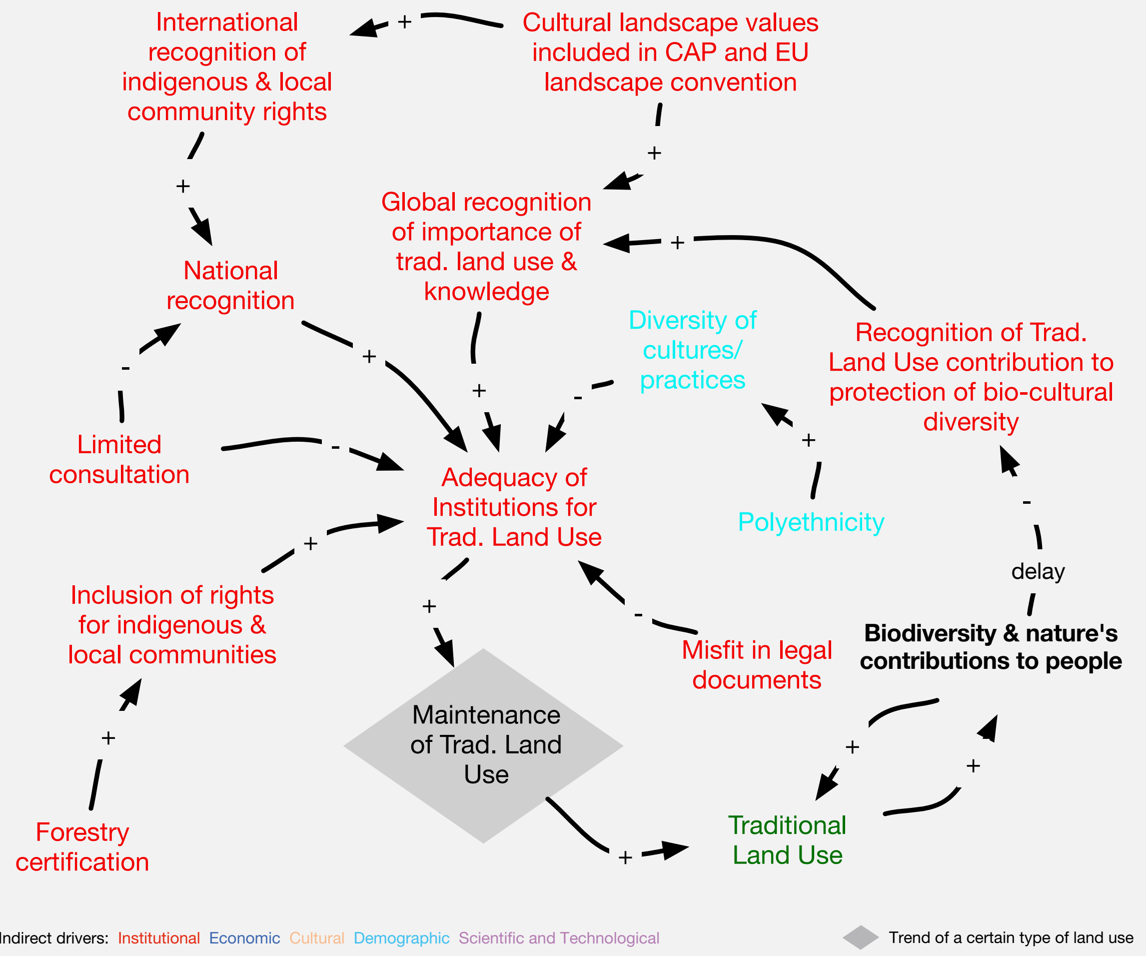
Executive Plan for the Conservation of Biodiversity within the Russian Federation the new goal was formulated to ensure the maintenance of traditional lifestyles and the sustainable use of biodiversity by indigenous peoples, including consideration of traditional knowledge in the planning and implementation of activities related to use of biological resources (Ministry of Natural Resources and Environment of the Russian Federation, 2014). In Central Asia, a shift from state command-and-control economy to market-based economy led to the concentration of a large number of livestock in few hands, which left the majority of households in possession of small numbers of animals (Robinson *et al.*, 2016; Vanselow *et al.*, 2012). To make the use of migratory routes economically viable, the households with a small number of animals revived the traditional models of pooling animals from many households and shepherding them on a rotational basis or hiring a shepherd among themselves (Robinson *et al.*, 2016). As livestock numbers have started to recover following the hardship of early independence years, pasture management issues are becoming more urgent. Having recognized the value of traditional migratory grazing patterns and importance of livestock mobility in sustainable use of pastures, for example, countries in Central Asia have designated pastures as common property, and management of common pastures is exercised by a locally elected pasture users committee.

4.5.5.2.2 Economic drivers of trends in traditional land use

In Western Europe, the traditional practice of collecting non-timber forest products for wild food and medicine has been declining due to emigration to urban areas to pursue economic opportunities, to mass production of food and to modern synthetically produced medicines (Łuczaj *et al.*, 2012; Quave *et al.*, 2012; Schulp *et al.*, 2014). In some places, however, there are markets for wild plants and mushrooms (Richards & Saastamoinen, 2010; Sitta & Floriani, 2008). For these products, a market demand

Figure 4 42 **Growing international recognition of the rights of indigenous and local communities, and of the contribution of traditional land-use practices in protecting bio-cultural diversity, have improved a number of institutions concerning traditional land use in Europe and Central Asia. Source: Own representation.**

Certification schemes have led to greater inclusion of indigenous and local rights in forest management systems. Poly-ethnic regions, with a broader diversity of cultures and practices to account for, face additional challenges in developing adequate institutions for traditional land use.

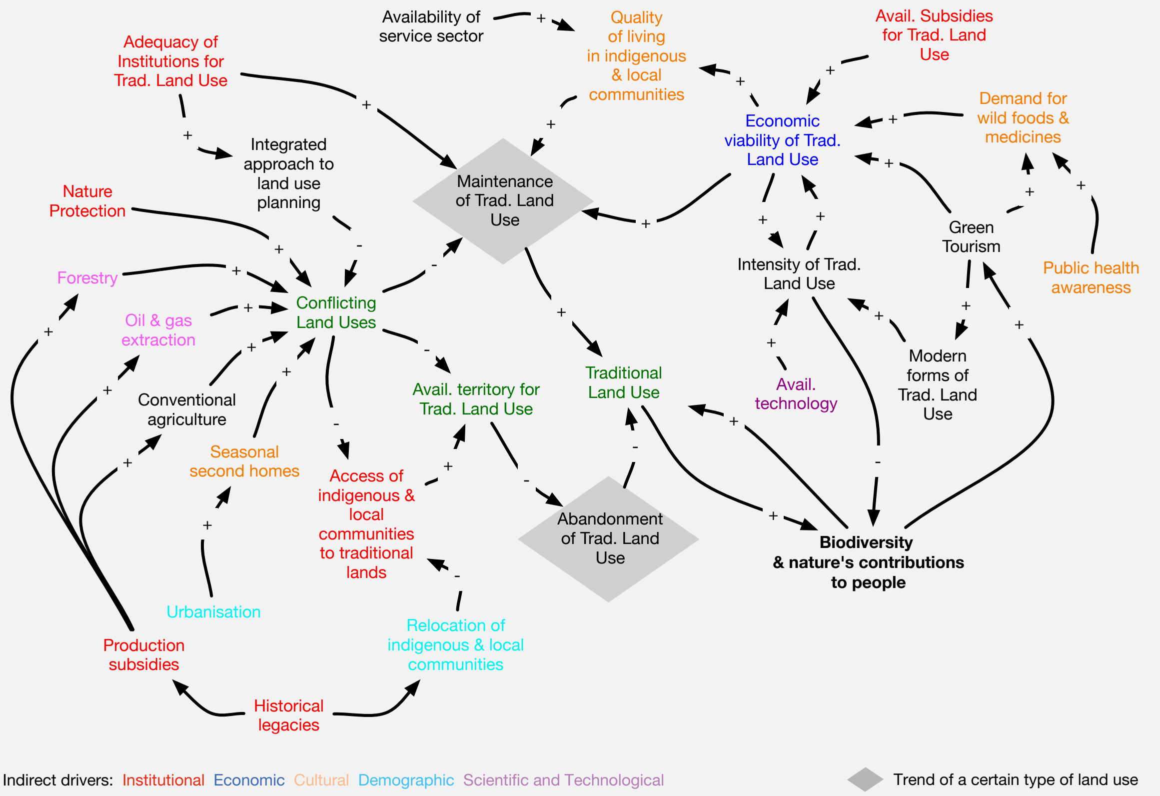


and viable industry exists, although affected by variation in harvests from year-to-year and sensitive to labour costs. Some of these markets are also dominated by imports (e.g. the Italian market of *Boletus*; Sitta & Floriani, 2008). Estimates of the value of non-timber forest products indicate that these may be in the same order of magnitude as traditional timber products. For instance, if forest management would take bilberry production into account in Finnish forests the economic gain during the rotation period could, theoretically, more than double (Miina *et al.*, 2016). It has also been shown that urban citizens demand a market for non-timber forest products and there can be a considerable demand for such products among urban consumers. This especially concerns food where quality and environmental friendliness is seen as important attributes (Kilchling *et al.*, 2009) **(Figure 4.43)**.

In the Russian Federation among the economic drivers that negatively affect the traditional land use of indigenous people is reduction of areas of traditional indigenous settlements due to industrial development. The Committee on the Affairs of the Indigenous Peoples of the Russian Federation in the materials for the Parliamentary hearings on Legal provision of technological expertise (2007) stated “From the 1930s the structure of nature resource use and the concept of development of the North gave priority to industrial development instead of the traditional land use, which resulted in severe pollution and degradation of the natural environment that led to the disruption and retirement of the most valuable agriculture land. First of all, significant damage was done to reindeer pastures. One factor that destabilizes the ecological situation in the area of traditional land use is stressful influence of industrial

Figure 4 43 **Production-based subsidies driving growth in agricultural, forestry and natural resource extraction sectors tend to exacerbate conflicting land-use issues, often impinging on available territory for traditional users. Source: Own representation.**

Maintenance of traditional land use is dependent on the quality of living that traditional lifestyles afford to indigenous and local communities, in turn dependent on the economic viability of traditional land-use practices and the availability of services. The growth of green tourism and demand for products derived from traditional practices, the modernization of practices, and the availability of subsidies for traditional land-use practices are important factors in ensuring the economic viability of traditional practices.



facilities on deer pastures and hunting grounds, covering up to 40% of the area of "traditional land use". Due to industrial development and pollution by industrial emissions of the traditional land-use area, the rural population lost not only pastures and hunting grounds, but also traditional fishing areas and areas for gathering wild plants" (Ayzan *et al.*, 2011).

4.5.5.2.3 Social drivers of trends in traditional land use

Often, people leave rural areas for higher education and higher salaries in cities. Even people living in villages pursue an urban lifestyle. In Western Europe, the last few decades' health industry development and alarm about unhealthy additives in mass-produced food have resulted in a renewed interest in wild food and medicine (Mabey, 2001; Reynolds Whyte *et al.*, 2002). Wild food is considered pure, naturally healthy and rich in vitamins and antioxidants (Łuczaj *et al.*, 2013). Moreover, wild plants and mushrooms play an important role as spices and accompaniments in traditional cuisines in the region (Łuczaj *et al.*, 2013; Sõukand *et al.*, 2013; Stryamets *et al.*, 2015; Svanberg, 2012). There is also a growing interest in folk medicine in different parts of the region (DuBois & Lang, 2013; Ghirardini *et al.*, 2007; González-Tejero *et al.*, 2008; Łuczaj *et al.*, 2013; Vitalini *et al.*, 2009), even where collecting plants for medicinal purposes is no longer a widespread practice (Łuczaj *et al.*, 2012; Molina *et al.*, 2009; Quave *et al.*, 2012; Rigat *et al.*, 2007).

4.5.6 Trends in urban development

Urban populations are foreseen to increase considerably across Europe and Central Asia (United Nations, 2014), which may cause further urban sprawl, depending on urban planning policies. In Europe, urban sprawl has increased considerably over the past decades. Between 2006 and 2012, semi-natural and natural areas were converted into artificial surfaces at a rate of 107,000 ha/year in 39 European countries (EEA, 2016d). Urban land expansion has mostly taken previous arable areas and, to a lesser extent, semi-natural habitats and forests (EEA, 2016d). In Central Asia, the rate of urban sprawl was reduced following independence of its constituent States. This was because of economic reasons, but also because migration from rural areas to urban areas increased the density of urban populations rather than the expansion of urban areas (Osepashvili, 2006). Unusually, Kazakhstan experienced a decline in urban populations coupled with increases in the rural population between 1990 and 2014 (United Nations, 2014). A further example of urban sprawl is growing migration to coastal areas, especially in the Mediterranean in Western and Central Europe **(Box 4.6)**.

4.6 DRIVERS AND EFFECTS OF POLLUTION

By extracting resources and returning them to the environment as waste, humans alter the biogeochemical cycles that have evolved for millennia. Pollution arises when humans introduce new substances that are toxic to species, or when the rate at which humans generate and deposit waste is faster than nature's own rate of re-absorbing and effectively neutralizing these resources.

Pollution is often categorized according to its effect in a certain medium i.e., air, water or soil/land. In this chapter, we categorize pollution according to Òollutant or problem/effect **(Table 4.6)** and focus on five categories: nutrient pollution, organic pollution, acidification, xenochemical and heavy metal pollution and "other pollution" (i.e. ground-level (tropospheric) ozone, light and plastic pollution). Gene

Box 4 6 **Urban sprawl on the Mediterranean coast.**

Human pressures on the Mediterranean coast are further exacerbated by urbanization, resulting in the decline of rural areas (Giacanelli *et al.*, 2015; Kelly *et al.*, 2015). The general result is a spatial dichotomy between strong, heavily populated coastal areas and thinly populated inland areas, with lower urban density and a less dynamic economy (Parcerisas *et al.*, 2012). The Mediterranean coasts also host a large seasonal tourist population and, even if the fortunes of Mediterranean destinations have fluctuated in recent years, the whole region remains among the most popular destinations of the global tourist market (UNWTO, 2015). Tourism is the main source of foreignincome in the Mediterranean region, representing as much as 25% of GDP in some countries (WTTC, 2015). Projected tourist arrivals in the Mediterranean basin for 2030 are estimated as 350 million (WWF, 2004). The environmental impacts of tourism are far-ranging and include land-use changes, pollution and waste production. Both resident and seasonal human populations are dependent on the availability of resources, infrastructures and services. These economic and demographic shifts also brought radical changes in agricultural, industrial and commercial sectors, all with their own share of environmental implications, ranging from soil degradation (Guerra *et al.*, 2015), land abandonment (Reino *et al.*, 2010), habitat loss (Monteiro *et al.*, 2011), waste production and disposal (Tatsi & Zouboulis, 2002), land-use changes (Celio *et al.*, 2014; Serra *et al.*, 2008) and pollution of water resources, both freshwater and marine (Zalidis *et al.*, 2002). With the help of new technologies enabling the harvest of higher yields, many initially traditional livelihood activities, like subsistence fishing, turned into new, capital-driven economic sectors. Mediterranean fisheries are also the subject of political controversies due to territorial disputes and degradation of marine habitats (Hofrichter, 2003).

The impacts of people moving to the coast are both direct and indirect, with direct impacts including emissions of effluents and pollutants, and indirect impacts including locational factors, where urbanization and industrial areas often serve as hubs for further urban sprawl (Salvati, 2013). Maritime transport also presents a key environmental pressure, with several major commercial routes crossing the Mediterranean Sea. On average, there are about 60 maritime accidents in the Mediterranean annually, of which about 15 involve fuel or chemical spills (EEA, 1999).

Water is also becoming a scarce and valuable commodity in the Mediterranean region, either because of decreasing quantities or inadequate quality. Today it is evident that damming cannot be considered a long-term and large-scale solution to water shortage, while desalination with reverse osmosis technology requires vast amounts of energy (Teixeira *et al.*, 2014). The water conflict in the Middle East and North Africa already provided ample examples of the volatile nature of negotiations over water resources, particularly across national boundaries (Poff *et al.*, 2003).

Climate change will also play a major role in the future evolution of the Mediterranean Basin. Potential impacts related to climate change include drought, floods, sea level rise, changes in the marine currents, and increased storm frequency. All of these changes will affect most coastal regions, with likely repercussions on national economies, particularly where those are directly dependent on natural resources and tourism. The critical factor for implementing future strategies in the Mediterranean region is cooperation, as environmental threats are not constrained by national boundaries.

pollution, noise pollution, thermal pollution and radioactive pollution were also identified as relevant, but generally to a lesser extent, and are therefore not included in this assessment. Greenhouse gas emissions causing climate change and the introduction of invasive alien species can also be considered as pollution (Spangenberg, 2007; Weale, 1992) and have therefore been included in **Table 4.6**, which provides an overview of pollutants, problems/effects, and their drivers.

Pollution is influenced by natural resource extraction. In turn, it also influences some forms of resource extraction. For example, local fishing communities on the Faroe Islands, Denmark, who are pressed by international opinions to stop killing pilot whales, are more worried that the whales are too polluted to consume and that the whales will become extinct due to pollution (Nieminen *et al.*, 2004).

4.6.1 Nutrient pollution

Nutrient pollution arises when the concentrations of nutrients that are naturally found in low concentrations, such as phosphorus (P) and nitrogen (N), increase to excessive levels. This also causes eutrophication in freshwater and marine ecosystems. In Europe and Central Asia phosphorus is often the main problem (nutrient which constrains eutrophication) in freshwater while nitrogen is most often the limiting nutrient in terrestrial and marine environments.

4.6.1.1 Effects of nutrient pollution on biodiversity and nature's contributions to people

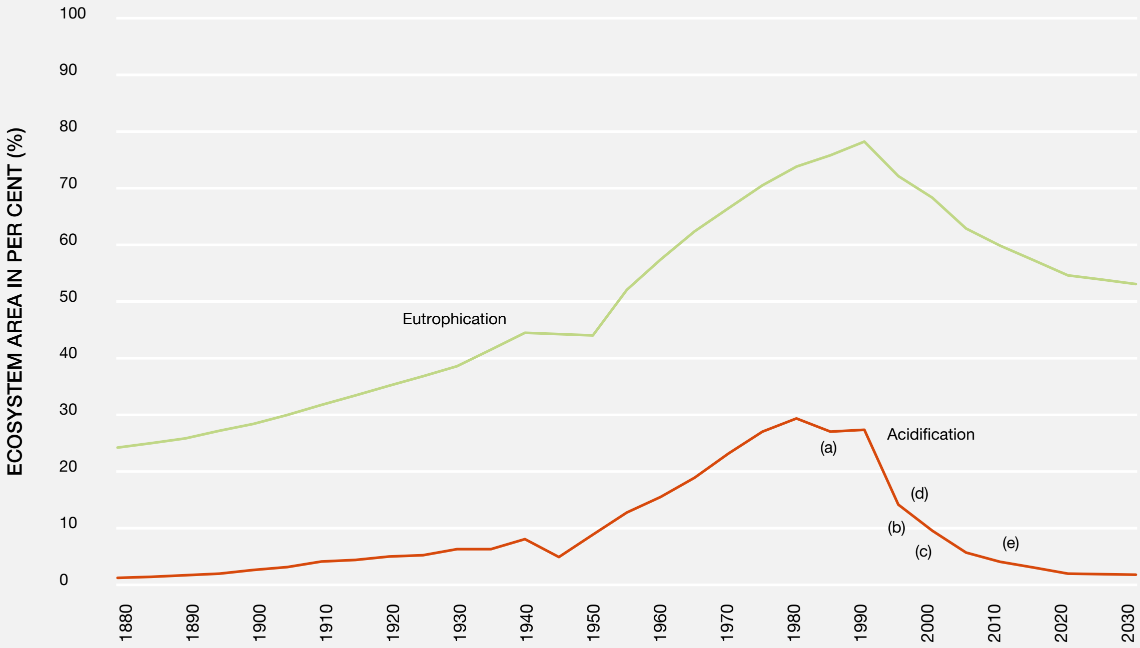
Increased nitrogen concentrations enhance productivity through fertilization and they decrease biodiversity through eutrophication and acidification **(Figure 4.44)**. The deposition of reactive nitrogen (nitrogen oxides (NO_x) and ammonia (NH_3) reduces biodiversity in terrestrial ecosystems by favouring plant species well adapted to nitrogenous or acidic conditions at the cost of less tolerant species (Bobbink *et al.*, 2010). Susceptibility to stress, such as frost damage or disease, may also be enhanced (Dise *et al.*, 2011). An annual deposition of 5–10 kg nitrogen per hectare has been estimated as a general threshold for such adverse effects (Bobbink *et al.*, 2010). The species richness of understory vegetation of Western and Central European forests also decreased with increasing nitrogen deposition rates and oligotrophic species were replaced by eutrophic ones (Dirnböck *et al.*, 2014).

Eutrophication of marine ecosystems is perhaps more worrying than freshwater eutrophication since, although

Table 4 6 Categorization of pollutants, problems/effects and main drivers. Source: Own compilation.

Pollutants	Problem/Effect	Main drivers
Bio-accessible nitrogen and phosphorus in terrestrial, freshwater and marine ecosystems	Eutrophication (hypertrophication)	Agriculture, industrial air pollution, wastewater
Organic pollutants	Oxygen-depleted systems, eutrophication, soil erosion, brownification	Wastewater, land-use change
Sulphur dioxide and nitrogen oxides from high temperature energy release, ammonia	Acidification	Electricity production, agriculture, incineration and industrial processes, transportation
PBT, POPs, pesticides, PCBs, dioxins, furans, PAHs, heavy metals	Xenochemical and heavy metal pollution	As above plus mining, chemical production
Nitrogen oxides, volatile organic compounds including methane, carbon monoxide	Ground-level ozone	Electricity production, industry, transportation
Light pollution	Disruption of species reproduction and survival	Material intensity of GDP, low variable cost of LED
Plastic debris	Life of marine organisms	Polymer production
Carbon dioxide, nitrous oxide, methane, etc. (Section 4.7)	Climate change	Energy use and agriculture
Invasive alien species (Section 4.8)	Biological invasion, biodiversity loss	Globalization

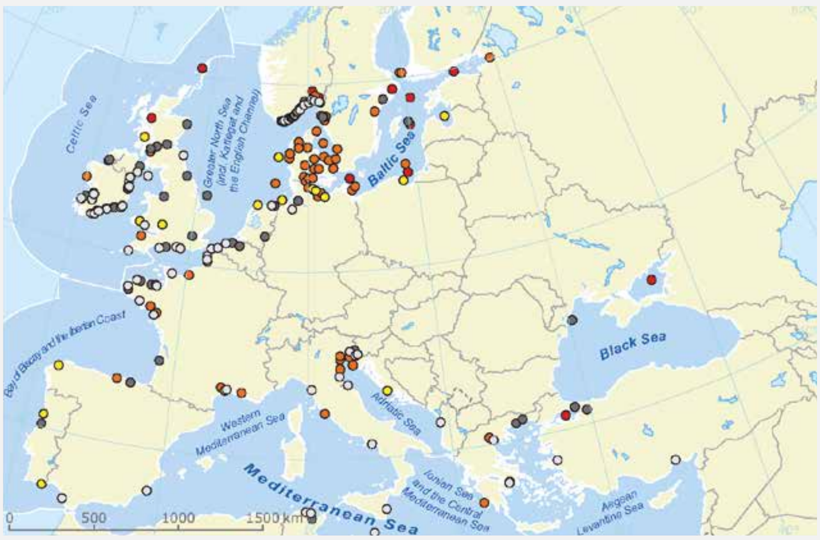
Figure 4 44 **Acidification and eutrophication of terrestrial ecosystem in Western and Central Europe peaked in the 1980s and early 1990s and have been reduced in extent (area) since then. Source: EEA (2014a, 2014b).**



(a) First Sulphur Protocol (1985);
(b) Second Sulphur Protocol (1994);
(c) Gothenburg Protocol (1999);
(d) NEC Directive (2001);
(e) Amended Gothenburg Protocol (2012).

The (a) to (e) show the point in time when protocols under the LRTAP Convention or the EU's NEC Directive were signed or adopted. The area covered is the so-called EMEP domain, here the geographic area between 30°N-82°N latitude and 30°W–90°E longitude. This includes all EU-28 countries as well as the EEA member and cooperating countries, other non-EU eastern European countries, parts of the Russian Federation and parts of Turkey (EMEP, 2014a and 2014b). The percentage (%) results are based on emission trends since 1880 (Schöpp *et al.*, 2003), with deposition patterns following different versions of the EMEP model (e.g. Hettelingh *et al.*, 2013), and the most recent critical load database (Posch *et al.*, 2012) in combination with the current legislation (CLE) scenario developed for the Gothenburg Protocol amendment for the period 2010 to 2030 (Amann *et al.*, 2011).

Figure 4 45 **Eutrophication and hypoxia are very frequent in coastal areas in Europe and Central Asia. Source: EEA (2014d).**



DISTRIBUTION OF LOCATIONS WITH OBSERVED HYPOXIA

Classification

- Eutrophic
- Hypoxia (not specified)
- Hypoxia (episodic)
- Hypoxia (seasonal)
- Hypoxia (persistent)
- Regional seas

recent studies have shown a decrease in marine and coastal eutrophication, the number of marine dead zones due to hypoxia (oxygen depletion due to organic pollutants) fuelled by eutrophication has increased markedly (EEA, 2014a, 20142014b) **(Figure 4.45)**.

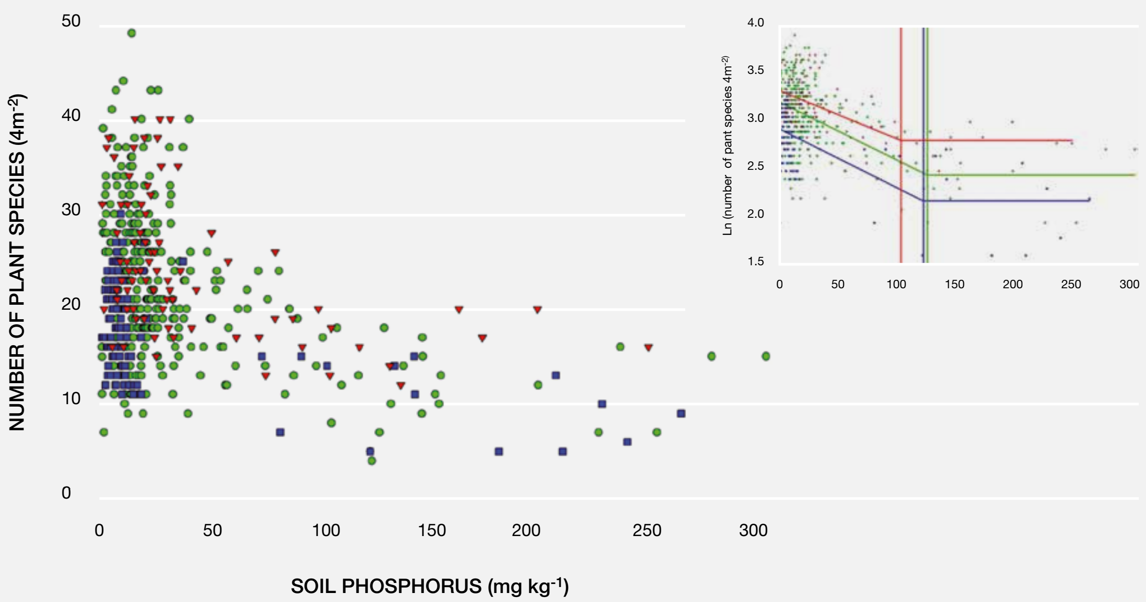
Emissions of nitrogen have contrasting implications on nature's contributions to people. There are clear and well-established negative impacts of nitrogen, derived from anthropogenic reactive nitrogen (NO_x and NH_3) on eutrophication, soil acidification, drinking water quality (Villanueva *et al.*, 2014) and human health (WHO, 2013). Besides, nitrous oxide (N_2O), a potent greenhouse gas, produced in soils with excess nitrogen, is increasingly emitted into the atmosphere, where it contributes to climate warming and, in the stratosphere, to the decomposition of ozone (Ravishankara *et al.*, 2009).

Increased nitrogen deposition, however, can positively influence other contributions of nature to people like crop, timber and livestock production (Wang *et al.*, 2015). Carbon sequestration is higher in nitrogen-limited systems if nitrogen deposition increases (Erisman *et al.*, 2014). In an evaluation of these opposing effects on nature's contributions to people, a reduction in nitrogen deposition was estimated to have net benefits to society by reducing the need for greenhouse gas regulation measures and by increasing non-material contributions, such as recreation. These benefits exceeded the total cost of material contributions (Jones *et al.*, 2014).

Phosphorous has long been regarded as the main driver of eutrophication in freshwater ecosystems. Excessive levels of phosphorous and soil erosion (organic P) cause an overgrowth of plants and algae that in turn increases the level of activity of decomposers and decreases the dissolved oxygen levels (hypoxia). This affects biodiversity negatively, mainly invertebrates and higher plants (Lepori & Keck, 2012; Lyons *et al.*, 2014; Noges *et al.*, 2016). The internal loading of phosphorous from sediments in lakes can keep them in a state of eutrophication even when external inputs are reduced, a process that is further promoted by increased temperatures (Moss *et al.*, 2011). Such legacy effects, i.e. phosphorous accumulation in sediments, have recently been observed in the River Thames (UK) where algal blooms still occur in most years, controlled by light and water temperature (Bowes *et al.*, 2016).

A meta-analysis found that phosphorous limitation of primary production is as strong as nitrogen limitation and is not confined to freshwater ecosystems and tropical forests as previously believed (Elser *et al.*, 2007). A study of more than 500 unfertilized grasslands in five countries in Western Europe found a significant negative effect of soil phosphorous on plant species richness, mainly in acidic grasslands (Ceulemans *et al.*, 2014). Species richness decreased until a threshold value (104-130 mg P/kg soil depending on grassland type), indicating that species loss is fastest at low phosphorous concentrations **(Figure 4.46)**.

Figure 4 46 **High soil (plant-available) phosphorous concentration negatively affects terrestrial plant species diversity. Source: Ceulemans *et al.* (2014).**



4.6.1.2 Trends in nutrient pollution

Between 1980 and 2011, NO_x and NH_3 emissions in the European Union declined by 49% and 18%, respectively (EEA, 2014b). 94% of NH_3 emissions come from agriculture (EEA, 2016a). However, while NO_x continues to decrease, NH_3 emissions in Western Europe have stabilized with even slight increases in recent years (EEA, 2016a) (see also **Figure 4.49** under Acidification). For Western and Central Europe (EEA-39), NO_x emissions are projected to further decrease in future years while NH_3 emissions will stay approximately constant until 2020 (EEA, 2016a). Some uncertainty prevails, for example Turkey reported a doubling of NH_3 emissions between 2012 and 2013; the level was kept for 2014 (EEA, 2016a).

The average nitrogen deposition rate in the region is about 5 kg/ha/yr, in contrast to a background rate of 0.5 kg/ha/yr or less (BIP, 2016).

The anthropogenic input of phosphorous increased from <0.3 Tg/yr before the industrial revolution to 16 Tg/yr currently (Peñuelas *et al.*, 2012). Over 50% of the soils studied in Belgium, Netherlands and Sweden had higher phosphorous levels than recommended (Ceulemans *et al.*, 2014). In contrast, the levels of total-phosphorous decreased markedly in rivers and lakes, mainly due to advances in wastewater treatment **(Figure 4.47)**.

There is little information on changes expected until 2050. However, phosphorous-limited terrestrial ecosystems have lately increased in extent and will continue to do so due to climate change (Peñuelas *et al.*, 2012).

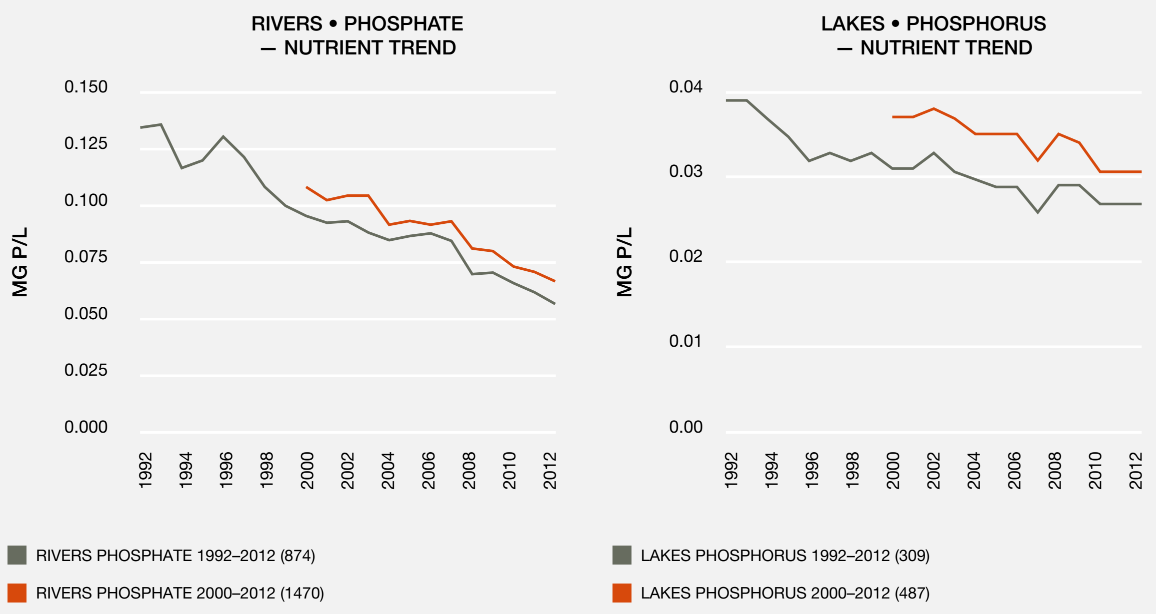
4.6.1.3 Drivers of nutrient pollution

In Western and Central Europe, nutrient pollution is driven by agricultural land-use change (intensification by increasing manure, fertilization and soil erosion), wastewater (sewage and septic systems), storm water, fossil fuel combustion in transportation and energy production (increasing NO_x), and households (gardens, detergents) (EEA, 2015c).

Regulations and technological innovation have been effective in reducing NO_x and, except in recent years, NH_3. These decreases are mainly due to policies that enforced measures in transportation (catalytic converters and fuel switching), plant improvement (e.g., flue-gas abatement techniques) in the energy and production industries, and the Nitrates Directive in agriculture reducing the use of fertilizer. The emissions of N_2O decreased by 38% mainly due to the measures of the European Union Nitrates Directive, the Common Agriculture Policy (CAP), and the Land-fill Waste Directive (EEA, 2014c).

Vegetarianism is a cultural driver with a high potential: a 50% reduction in the consumption of animal products would lead to at least a 10%-reduction in nitrogen pollution in the EU-27 (Van Grinsven *et al.*, 2015).

Figure 4 47 **Changes in phosphorous concentrations in Western and Central Europe. Source: EEA (2015c).**



Climate change is expected to have adverse effects by increasing erosion and nutrient run-off in agricultural areas, frequency of wastewater overflow, water temperature, and the duration of the growing season (Dokulil & Teubner, 2010).

4.6.2 Organic pollution

Organic pollution refers to large emissions to water of organic compounds that can be oxidized by naturally occurring micro-organisms. Organic pollution is most often point-source, i.e., released directly into the water, although diffuse loss from catchments can also yield large amounts of organic compounds. The most important sink of organic pollutants is decomposition by bacteria and fungi by enzymatic catalysis. These decomposers grow rapidly and use a great deal of oxygen during their growth. When they die, they are broken down by other decomposers, which causes further depletion of the oxygen levels (hypoxia and eventually anoxia).

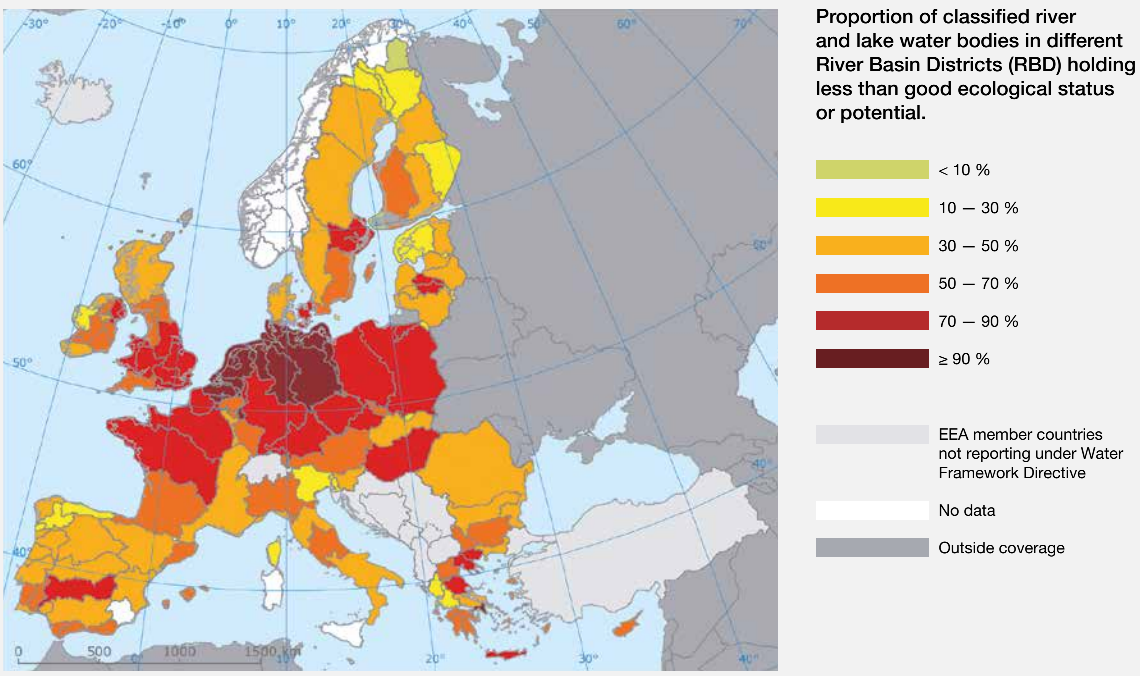
4.6.2.1 Effects of organic pollution on biodiversity and nature's contributions to people

In freshwater, increased levels of easily degradable organic compounds reduce primary production and degrade habitats for aquatic life (Couture *et al.*, 2015). Easily degradable organic compounds have a well-documented, strong negative impact on riverine biodiversity by depleting oxygen to critically low levels for benthic macroinvertebrates and fish (Connolly *et al.*, 2004; Hering *et al.*, 2006; Sand-Jensen & Pedersen, 2005). Organic compounds also increase light attenuation in the water column ("browning" if the source is humic compounds) and the epiphytic growth of biofilm (Burns & Ryder, 2001; Richardson *et al.*, 1983).

Organic compounds strongly bind various toxins, thereby somewhat reducing their bioavailability (Ravichandran, 2004). They also serve as transport vectors for heavy metals and organic pollutants (Kopáček *et al.*, 2003), which are toxic for aquatic life (Ravichandran, 2004; Teien *et al.*, 2006).

The ecological status of Western and Central European rivers and lakes is strongly linked to pollution by nitrogen, phosphorous and organic compounds (EEA, 2015c). Rivers with high concentrations of nitrogen, phosphorous and organic compounds are more likely to be in a poorer ecological state. Lakes with high nutrient loads will have high chlorophyll concentration and low water clarity due to abundant phytoplankton growth. As a result, a large proportion of lakes and rivers in Western and Central Europe do not reach a satisfying ecological status **(Figure 4.48)**.

Figure 4 48 **Proportion of rivers and lakes of less than "good" ecological status or potential in the European Union. Source: EEA (2012e).**



4.6.2.2 Trends in organic pollution

Emissions of easily degradable organic compounds is decreasing in Western and Central Europe thanks to improved sewage treatment and better storage of animal manure in agriculture, for example, as a result of effective regulations during the past 30 years (European Commission, 2012). However, several monitoring programmes have detected significant increases in the concentration of dissolved organic carbon since 1990 in Western Europe (Monteith *et al.*, 2007). Water colour, an easily observable consequence of organic matter in the water, has changed markedly in lakes and rivers across the boreal zone in the past decades and this trend is likely to continue (De Wit *et al.*, 2016). Currently, surface waters in northern waters are browning as a result of reduced acid deposition (Garmo *et al.*, 2014; Monteith *et al.*, 2007) and increased precipitation (De Wit *et al.*, 2016).

Although the causal relationships are not straightforward, a combination of climate change induced increases in run-off and temperature, and indirect changes in terrestrial vegetation (Meyer-Jacob *et al.*, 2015) are projected to increase organic matter loads in future (Hejzlar *et al.*, 2003). These increases will be strongest in the boreal zone of the region and in the Arctic, where thawing of permafrost is a further source of organic matter (Abbott *et al.*, 2014).

4.6.2.3 Drivers of organic pollution

Demographic and economic drivers have increased organic pollution from sewage, agriculture (livestock manure), aquaculture (fishponds and farms), and certain types of industries (such as dairy, or sugar refinery). Except for land-use change, the source of organic pollution is mainly point sources and therefore regulations and technological innovations have managed to reduce emissions (EEA, 2012c). Sewage overflows in connection with high precipitation events, however, remains a problem (Rauch & Harremoës, 1996).

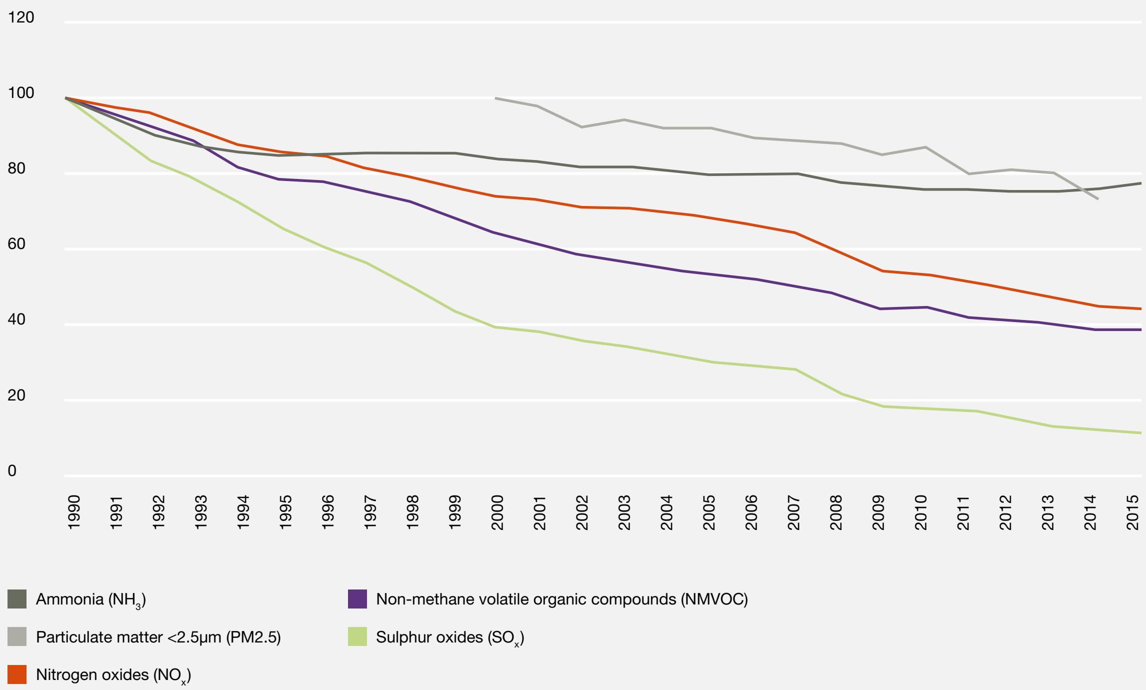
4.6.3 Acidification

Acidifying substances such as sulphur dioxide (SO_2), ammonia (NH_3) and nitrogen oxides (NO_x) undergo chemical transformation into acids as they are dispersed in the atmosphere. Their subsequent downwind deposition leads to acidification of the soil and surface water.

4.6.3.1 Effects of acidification on biodiversity and nature's contributions to people

Historically, SO_2 was the dominant pollutant causing acidification, but today NO_x are increasingly important.

Figure 4 49 **Emissions of air pollutants, EU-28, 1990–2015, Index 1990=100. Note: PM2.5 time series start in 2000. Source: Eurostat (2016).**



Effects of terrestrial acidification from nitrogen were briefly assessed in Section 4.6.1.1. Anthropogenic acidification has profound, well-documented ecological impacts, including the loss of many acid-sensitive species from all trophic levels (e.g. Hildrew & Ormerod, 1995; Likens & Bormann, 1974; Schindler, 1988). In catchments with an insufficient supply of base cations to buffer acidity, runoff to freshwater ecosystems becomes strongly acidic and at a pH of 5.5, alkalinity falls to zero and inorganic aluminium concentration rises to become toxic to many forms of life, including almost all fish (Sutcliffe & Hildrew, 1989).

Despite reduced emissions there is still a legacy effect on biodiversity. Evidence for biological recovery from anthropogenic acidification has therefore been much less obvious than changes in, for example, water chemistry (Battarbee *et al.*, 2014). Soil and surface water acidification remains an issue in the most sensitive areas of Nordic countries, the United Kingdom and Central Europe (EEA, 2017). Kernan *et al.* (2010) found that invertebrate assemblages showed signs of partial recovery at around half of sites in the UK acid water monitoring network that had recovered in terms of water chemistry and even less showed any evidence of recovery of salmonid populations (Malcolm *et al.*, 2014; Murphy *et al.*, 2014).

4.6.3.2 Trends in acidification

In Western and Central Europe (EEA-33) emissions of SO_2 decreased by 74% between 1990 and 2011 (EEA, 2016a). **Figure 4.49** illustrates this trend, which is projected to continue **(Figure 4.50)**. Within the European Union, NO_x emissions decreased by 49% between 1980 and 2011 (EEA, 2014b), or by 40% between 2000 and 2010 (EEA, 2016a). Data is limited from other regions and contingent on economic activity; as an example, NO_x emissions in Montenegro dropped after 1990 but increased to the same level in 2009 (EEA, 2015b).

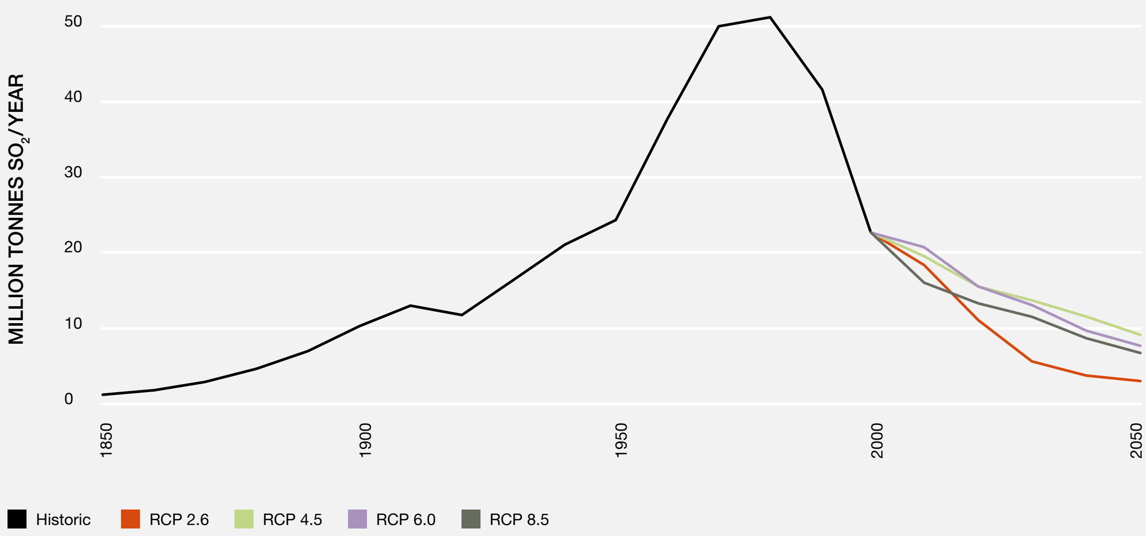
4.6.3.3 Drivers of acidification

Anthopogenic NO_x and SO_2 are mainly caused by fossil fuel combustion. The basic drivers are economic, which Montenegro and Serbia may illustrate: During the period of sanctions on the former Yugoslavia (1990-1995), there was a significant drop in SO_2 and NO_x emissions, due to the overall reduction in economic activities. After 1995, emissions increased steadily with GDP (EEA, 2015b). However, institutional drivers are key to push for technological change which, in the case of acidification, has been relatively simple. Regulations like the Sulphur Protocols (Section 4.6.1.1) have been effective in reducing acidification.

4.6.4 Xenochemical and heavy metal pollution

Xenochemical pollution is the introduction or release of chemical substances into ecosystems where they are not naturally found.

Figure 4 50 **The emission of Western and Central Europe and this trend is projected to continue in all IPCC scenarios. Source: EEA (2014a). Representative concentration pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth assessment report (IPCC, 2013b).**



4.6.4.1 Effects of xenochemicals and heavy metals on biodiversity and nature's contributions to people

The polluting impact of many chemicals and heavy metals (e.g. polychlorinated biphenyl [PCB] and lead) are well-known, and their use and emission strictly regulated in most parts of Europe and Central Asia. There are, however, emerging threats to biodiversity and nature's contributions to people, which relate not only to recently introduced compounds but also to inappropriate use of listed toxic compounds, unknown effects of toxic mixtures, unknown effects of chemicals that have not undergone toxicological testing (e.g. hygiene products) and potentially aggravating effects of climate change (Malaj *et al.*, 2014).

Xenochemicals primarily influence ecosystems and biodiversity in close proximity to urban areas, industry and agriculture although a number of studies have shown long range pollution of xenochemicals in air, water and biota. Toxicity of most of the emerging pollutants is unknown, as is knowledge on their persistence in the environment and ability to bioaccumulate. A large amount of literature has documented toxic effects of xenochemicals on both terrestrial and aquatic biota (Beketov *et al.*, 2013; Pereira *et al.*, 2009; Sabater *et al.*, 2007). Impacts of toxic compounds on freshwater macroinvertebrates have been shown for heavy metals and pesticides (Heckmann & Friberg, 2005; Liess & Von Der Ohe, 2005; Rasmussen *et al.*, 2008; Schäfer *et al.*, 2007).

Studies have shown increases of Priority Hazardous Substances like mercury in the aquatic food web, especially fish (Åkerblom *et al.*, 2014), to levels that exceed advised limits for humans and can have negative impacts on wildlife (Scheulhammer *et al.*, 2007). Various synthetic compounds acting as hormone distruptors (e.g. BPA and other bisphenols, phtalates, etc.) have direct negative effects on nature's contributions to people (EEA, 2012c).

Multiple chemicals interact in the environment, producing combined ecotoxic effects that exceed the sum of individual impacts (Kortenkamp *et al.*, 2009). As a result, a substance present in concentrations below the threshold level may still contribute to combined and possibly synergistic effects. In particular, robust evidence exists of combination effects for hormone disrupting chemicals (EEA, 2012c).

4.6.4.2 Trends in xenochemical and heavy metal pollution

In Western and Central Europe more than 100,000 commercially available chemical substances are registered in the European Inventory of Existing Commercial Chemical Substances (EINECS). Global sales from the chemical industry sector doubled between 2000 and 2009, with increases in all world regions (OECD, 2012), which is a development that is predicted to continue. The total sales of pesticides across the European Union increased from 2011 to 2014 by 4% to just under 400,000 tonnes of active substances, despite the adoption of the Directive on the Sustainable Use of Pesticides in 2009. However, the aim of this Directive was not only to reduce the use of pesticides but to "promote the use of less harmful pesticides and provide incentives to industry to develop pesticides with less hazardous properties" (EEA, 2016c).

4.6.4.3 Drivers of xenochemical and heavy metal pollution

Xenochemical pollution is integrated in all sectors of industrialized countries, driven by market forces in general and globalization in particular. Public awareness has modified institutional drivers, e.g. the European Union "Reach" legislation. However, the globalized characteristics of xenochemicals combined with uncertainty concerning the effects of new substances inhibit effective regulations (OECD, 2011).

4.6.5 Other pollution

4.6.5.1 Ground-level ozone

Ground-level ozone may have significant effects on biodiversity (Wedlich *et al.*, 2012). These effects include changes in species composition of semi-natural vegetation communities (e.g. Ashmore, 2005), reductions in forest net primary productivity (Matyssek *et al.*, 2003), also in combination with nitrogen (Bobbink *et al.*, 2010). Ozone pollution has been linked to the prevalence of damage in mountain forests: the acute effects of O_3 involve visible injuries to leaves and shoots and changes in physiological processes and metabolism.

The emission of O_3 or ozone precursor gases has recently decreased considerably in Western and Central Europe (EEA, 2015c). However, the ground-level concentrations of O_3 have remained stable or even increased due to long-range transport from outside Western and Central Europe (EEA, 2015c). As a result, most types of vegetation and almost all crops (88% of Western and Central Europe's agricultural area, mainly its southern and eastern parts) are exposed to levels above the critical load, especially near roads with heavy traffic. Drivers of nitrogen concentration and ozone formation interact, which calls for integrated policy responses (e.g. see Table 6.1 in Chapter 6).

4.6.5.2 Light pollution

Light pollution is generated by the use of artificial light at night and affects terrestrial, aquatic and marine ecosystems (Davies *et al.*, 2014; Longcore & Rich, 2004). It is related to material affluence and concerns 23% of global land surface and 88% in Western and Central Europe (Davies *et al.*, 2014). Temperate and Mediterranean ecosystems have experienced the greatest increase in exposure to artificial lighting (Bennie *et al.*, 2015b) and a significant increase in average nighttime lighting has been reported in 32% of Western and Central European terrestrial protected areas since 1995 (Gaston *et al.*, 2015). This rate is expected to increase in the coming decades because of the replacement of existing lighting infrastructure by broad-spectrum white lighting technologies (such as LEDs), which is expected to double the perceived night sky brightness.

Light pollution also dramatically influences movements and distributions of nocturnal species, which represent 30% of mammals and 60% of invertebrates worldwide (Hölker *et al.*, 2010). Nocturnal insects present a "flight-to-light behaviour" (Altermatt *et al.*, 2009), which generates insect biomass accumulation in illuminated patches and depletion in surrounding dark areas. Unnatural polarized light sources, e.g. from building materials, can also trigger maladaptive behaviours in polarization-sensitive taxa and alter ecological interactions (Horváth *et al.*, 2009).

Light pollution induces major shifts in biological communities by disrupting the interspecific balance of trophic and competition interactions (Bennie *et al.*, 2015a; Davies *et al.*, 2013; Knop *et al.*, 2017; Rydell *et al.*, 1996). This can have profound impacts on ecosystem functions such as pest control, pollination, and seed dispersal. For example, moths carry less pollen in light-polluted areas than in dark areas (Macgregor *et al.,* 2017), which in turn may impact the fitness of insect-pollinated plant species (Macgregor *et al.*, 2015). Additionally, light pollution induced large-scale phenology changes in UK deciduous tree budburst (Ffrench-Constant *et al.*, 2016). The large spatial scale impacts of light pollution likely interact and accentuates the adverse impacts of both land use and climate changes on biodiversity.

4.6.5.3 Marine and beach plastic debris

Polymers are part of our everyday life. Annual production rates continue to grow and have risen from 1.7 million tonnes in 1960 to 322 million tonnes in 2015, with a current mean annual increase of 4% (Plastics Europe, 2016). Plastic debris and microplastics can affect a wide array of marine organisms, from plankton (Collignon *et al.*, 2012) to filter feeding marine organisms (Fossi *et al.*, 2014; von Moos *et al.*, 2012) and large pelagic fish (Romeo *et al.*, 2015). Size, shape and abundance of plastic debris influence uptake; microfibres are considered most harmful (Wright *et al.*, 2013). Plastics inhibit digestion and can transfer attached chemical pollutants into the animal tissues (Browne *et al.*, 2013). As a result of increasing awareness, developing new polymeric materials today often includes assessment of its durability and its degradation time when exhausted (Hottle *et al.*, 2013).

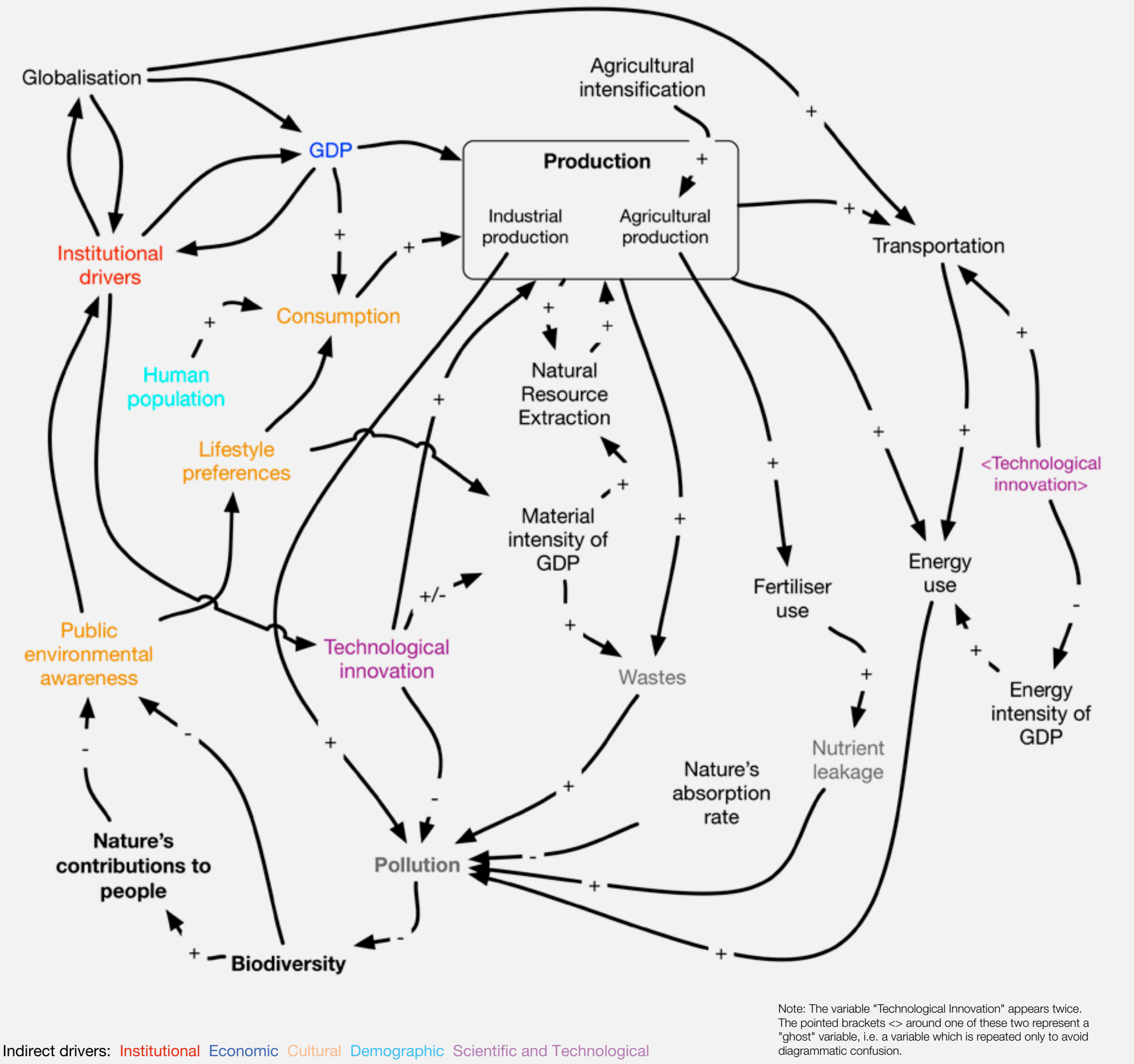
4.6.6 Synthesizing drivers of pollution

The passage of matter through our economy and society, from resource extraction to waste, is the premise for pollution. All factors affecting the size and the quality of the material throughput of our societies (Boulding, 1966) are drivers of pollution. In the 1990s, particularly in Europe, the need for a shift from end-of-the-pipe policies to prevention became evident. Several studies highlighted this (Adriaanse *et al.*, 1997; Matthews *et al.*, 2000; Von Weizsäcker *et al.*, 1997) so that material flow data eventually entered the official statistics of the European Union.

For the above reasons, pollution is driven by the same drivers that are highlighted for natural resource extraction, land-use change, and invasion of alien species, and climate change (which can be seen as a form of pollution). This is also evident from **Table 4.6** (introduction to Section 4.6) that summarizes the main pollution problems and their drivers. As synthesized by **Figure 4.51** below these drivers are mainly economic, i.e. effects of industrialization and globalization and its subsequent increase in transportation. Pollution also increases by population growth, institutional drivers that foster adverse technological development, and the cultural belief that a prosperous life must entail more material consumption (Jackson, 2009). Technological innovation usually increases production and transportation but may also change the material intensity of GDP and production technology to reduce waste and pollution. Recent institutional drivers have succeeded in developing technologies for reducing some pollutants in Europe, especially point sources like air pollutants from industrial effluents (including SO_2, NO_X, lead) and municipal waste water. However, the drivers of xenochemicals and nutrient leakage (NH_3) from agriculture have not successively been reversed.

Figure 4.51 depicts the main causal loops for pollution, emphasising industrial and agricultural production and transportation. There are two feedback loops in **Figure 4.51**. First, the public awareness of pollution influences regulations via political pressure. Second, awareness influences cultural beliefs and consumption patterns, which may alter the material intensity of GDP.

Figure 4 51 **Causal loop diagram of drivers of pollution. Source: Own representation.**



4.7 DRIVERS AND EFFECTS OF CLIMATE CHANGE

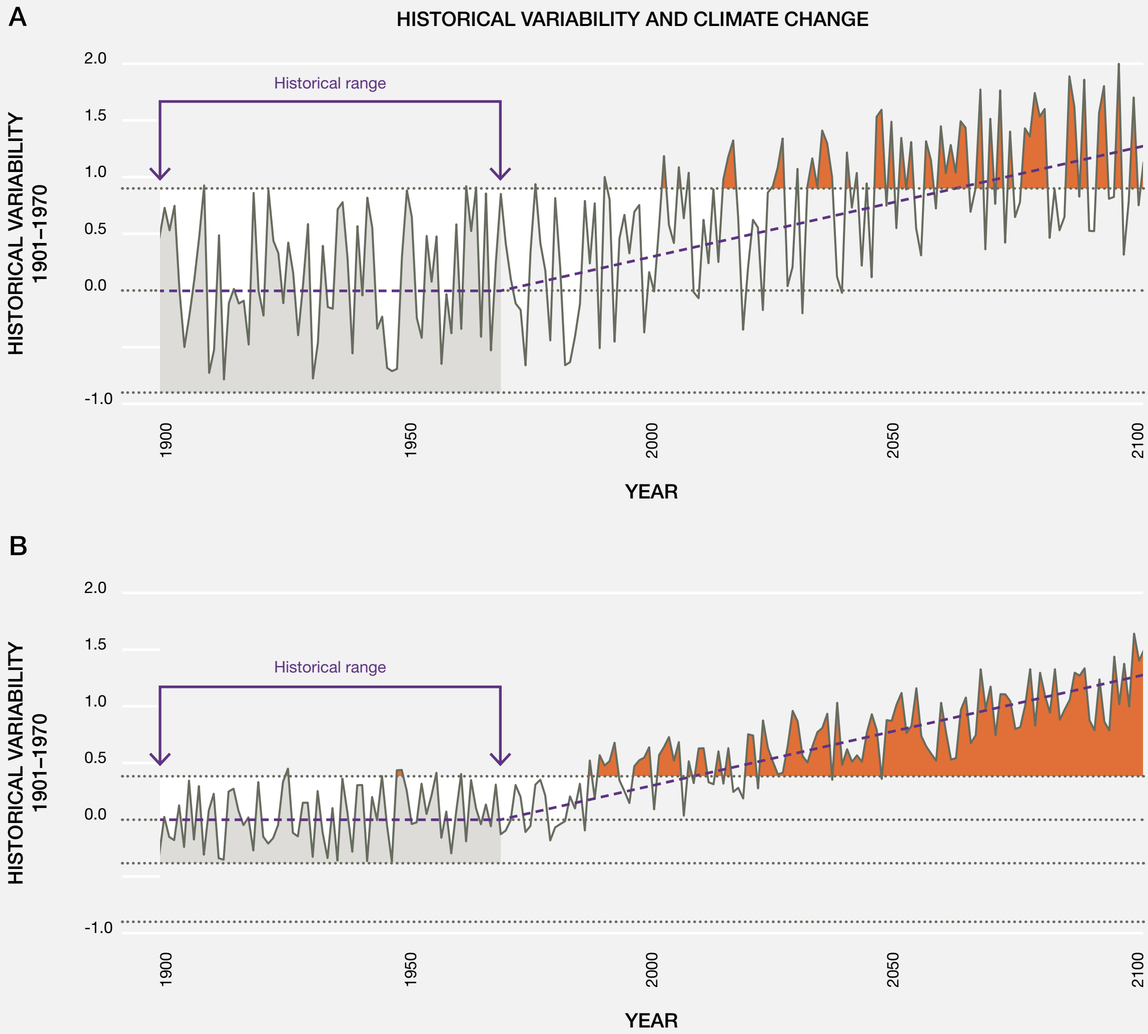
4.7.1 Effects of climate change on biodiversity

Climate change is a complex driver of ecosystem change, consisting of changes in precipitation and temperature patterns which lead to changes in drought, flood, and fire risk, ocean-atmosphere interchange, marine circulation and stratification, and the concentrations and distribution of O_2 and CO_2 in the atmosphere and in the ocean (IPCC, 2014a). These impacts affect species and influence and modulate important ecosystem functions and processes that underpin human livelihoods and nature's contributions to people, such as water regulation, food production, and carbon sequestration (CBD, 2016; Gallardo *et al.*, 2015; IPBES, 2016a; IPCC, 2014a; MEA, 2005a).

There is strong evidence that climate change affects the biodiversity of Europe and Central Asia through shifts in the timing of species' life-history events, growth, reproduction and population dynamics, and in their ranges and habitat occupancy. The evidence for impacts on the ecological processes underlying range shifts, such as species interactions, is rapidly accumulating. Knowledge gaps remain with respect to changes in physiological processes and evolutionary adaptations to new climatic conditions (Bellard *et al.*, 2012; Merilä & Hendry, 2014).

Figure 4 52 **Illustration of the link between climate variability and mean trend.**

The simulated historical range of climate variability is high in panel A and low in panel B. No trend in climate mean is simulated between 1900–1970 and shows the increasing mean trend from 1070–2100 in A and B. The red zone denotes years in which the historical range of variability is exceeded, which is observed much more rapidly in panel B (compared to A). Source: Illustration follows Beaumont *et al.* (2011).



Climate change impacts are not as strong as we would expect given recent changes in climate. In particular, many species-level responses lag behind the rate of change in climate drivers. These lags are caused in part by dispersal and establishment constraints and by biotic interactions that stabilize extant populations and communities, and in part by the fact that the rates and nature of climate are regionally variable and may only slowly be exceeding the historical range of variability (see **Figure 4.52**; see also Section 4.7.1.2). In Europe and Central Asia, northern areas are projected to experience fast spatial displacement of climate. Therefore, dispersal-related responses may be particularly important, mountainous regions will be subject to local divergences between temperature and precipitation drivers, and novel climates are more likely to appear in the Mediterranean area (Ordonez *et al.*, 2016). Climates outside the current range of variability are a particular threat as populations are unlikely to contain adapted individuals or genes. For a given rate of underlying climate change, novel conditions may be experienced sooner in highly variable systems, though such systems will also occasionally experience historically "normal" years further in the future **(Figure 4.52)**.

Complex responses and interplay between direct and indirect effects of multiple climate change drivers challenge our ability to project future trends in nature's contribution to people. Additional interactions with other anthropogenic drivers, such as reinforcement of ocean acidification and land-use change (Cloern & Jassby, 2012; Mantyka-Pringle *et al.*, 2012; Riebesell & Gattuso, 2014) further exacerbate the complexity. As gradual changes in mean climatic conditions can have dramatically different consequences for biodiversity, including ecosystems, compared with changes in the variability of short-term weather, the two are treated separately. Then, important secondary effects of climate change on ecosystems are briefly assessed.

4.7.1.1 Effects of gradual climate change

4.7.1.1.1 Effects on phenology, growth and fitness

It is well documented that recent climate change has affected phenology, but there is considerable variation across regions, biomes, and taxa (Cleland *et al.*, 2012; Cook *et al.*, 2012; Ma & Zhou, 2012; Parmesan, 2006, 2007; Wolkovich *et al.*, 2012). In Western Europe, standardized assessments have confirmed phenological advancement in terrestrial, freshwater and marine plants and animals (Menzel *et al.*, 2006; Thackeray *et al.*, 2010). Phenological changes are often linked to changes in the onset and duration of the growing season, potentially affecting species and ecosystems. These effects can be both direct, on the survival and population dynamics of individual species (e.g., “developmental traps”: prolonged seasons that allow multiple generations of insects but leave the autumnal cohort vulnerable - Van Dyck *et al.*, 2015), and indirect from e.g., phenological mismatches between plants and pollinators (Hegland & Totland, 2008); between predators and prey (Petitgas *et al.*, 2010; Raab *et al.*, 2013; Visser *et al.*, 2006); and between multiple trophic levels (Edwards & Richardson, 2004; Luczak *et al.*, 2012; Möllmann & Diekmann, 2012).

In animals, there are indications of climate change impacts on growth and body size, for example in otters (Yom-Tov *et al.*, 2010; Yom-Tov *et al.*, 2006b) and birds (Yom-Tov *et al.*, 2006a; Yom-Tov, 2001). The strength and direction of the linkage to climate change is not very clear, as effects are mostly indirect through changes in net primary production and thus food availability (Yom-Tov & Geffen, 2011). Body size decreases consistently across freshwater taxa under warming (Daufresne *et al.*, 2009). In marine systems, high temperatures are particularly stressful for vulnerable life stages of coastal zooplankton, especially larvae (Przeslawski *et al.*, 2015). For plants, warming will increase growth and size until reaching a point where other factors limit growth. For example, the largest warming experiment in the region found that climate warming increased alpine plant growth, but only in the first few years, possibly due to onset of nutrient or water limitation later on (Arft *et al.*, 1999).

Climatic factors can also act as forces of selection, driving adaptive differentiation between and within populations at fine spatial scales despite potentially high levels of gene flow (Anderson *et al.*, 2012). Plant populations may adapt *in situ* via selection on standing genetic variation in response to climate change (Jump *et al.*, 2009). Genetic differentiation in response to temperature or moisture gradients has been observed in plants at both fine spatial scales (e.g. Kelly *et al.*, 2003) and across landscapes (e.g. Jump *et al.*, 2006). Such patterns of genetic structuring are highly indicative of adaptive differentiation in response to environmental selection, which has been confirmed by direct experimental tests of genetic responses to climate change in plant species within intact ecosystems (e.g. Jump *et al.*, 2008; Ravenscroft *et al.*, 2015). However, despite this potential for genetic responses, a number of recent reviews of both terrestrial and marine systems find little direct evidence for adaptive genetic responses to current climate change (Boutin & Lane, 2014; Donnelly *et al.*, 2012; Reusch, 2014; Teplitsky & Millien, 2014). In cases where genetic changes are documented, it is still unclear whether these reflect adaptive responses, whether they are directly caused by climate change, and whether they are sufficient to keep up with future climatic changes (Franks *et al.*, 2014). Even in species with the highest adaptive potential, widespread species with large populations and high fecundity, adaptational lags are likely under future climatic changes (Aitken *et al.*, 2008).

4.7.1.1.2 Effects on biodiversity and community dynamics

Shifts in species ranges in response to climate change are relatively well documented for Europe and Central Asia. Latitudinal and altitudinal shifts in species distributions have been found for many taxa, e.g. 80% of studied taxa in a global meta-analysis by Root *et al.* (2003); for marine systems see Perry *et al.* (2005) and Beaugrand *et al.* (2014). Northwards migrations of warm-adapted species and associated loss of cold-adapted species have been documented for the Barents Sea and North East Atlantic (Beaugrand *et al.*, 2002, 2009; Brander *et al.*, 2003; Fossheim *et al.*, 2015), resulting in increased species richness of zooplankton (Beaugrand *et al.*, 2010) and fish (Hiddink & ter Hofstede, 2008). Northward range shifts (12.5-19 km per decade) are also prevalent among terrestrial species, including arthropods, birds and mammals (Hickling *et al.*, 2006). Similar range shifts are found along altitudinal gradients, but are not ubiquitous across a broad range of taxonomic groups (Benito *et al.*, 2011; Grytnes *et al.*, 2014; Nogués-Bravo *et al.*, 2008), while downslope or no shifts also occur (Lenoir *et al.*, 2010). While evidence for range shifts is mounting, the unequivocal attribution to climatic warming is not always clear, as the magnitude of shifts cannot always be predicted from observed climatic changes (Grytnes *et al.*, 2014).

Climate change does not affect species ranges and biodiversity equally in all regions or for all taxa (e.g. Garrabou *et al.*, 2009; Pairaud *et al.*, 2014; Tunin-Ley *et al.*, 2009). Negative impacts are likely strongest where species' latitudinal and altitudinal shifts are physically limited, for example in the case of mountaintops, northernmost or southernmost areas. The ranges of birds inhabiting northern Fennoscandia are strongly controlled by temperature, and will likely no longer overlap with terrestrial land areas in the future (Virkkala *et al.*, 2008). Strongly negative impacts can also be expected in taxonomic groups with high species turnover along climate gradients and with small range sizes, as for birds in Central Asia (La Sorte *et al.*, 2014), and in biodiversity hotspots, as for the highly diverse reptile fauna of the Central Asian Mountains (Ficetola *et al.*, 2013). Despite individual responses, an overall homogenization of biodiversity has been projected from model experiments for birds in Western and Central Europe (Thuiller *et al.*, 2014), indicating that taxonomic, phylogenetic and functional turnover decrease between regions. Relatively low and slow responses in range dynamics may not imply that climate change does not matter. Rather, it may reflect lagged responses, also known as climatic extinction debts (Devictor *et al.*, 2012; Dullinger *et al.*, 2012), and homogenization of regional species pools (Thuiller *et al.*, 2014).

Species shift their ranges at individual rates and directions (see above), which will result in novel assemblages (Alexander *et al.*, 2015), and may change the intensity of species interactions, such as increased interspecific competition (Olsen *et al.*, 2016), dampened herbivore cycles (Cornulier *et al.*, 2013), and changes in predator-prey dynamics (Schmidt *et al.*, 2012; Terraube *et al.*, 2011; Winder & Schindler, 2004). Such indirect impacts may be particularly important at the warmer-climate distributional edge of species ranges, where the intensity of interactions may be higher, and could lead to loss of specialized interactions (pollination, predator-prey, dispersal, consumer, trophic, etc.) to be replaced by generalists (Lurgi *et al.*, 2012).

Some of this context-dependency in species' ability to withstand climatic change can be predicted by species traits. For example, a global analysis indicates that thick leaves, high below-ground biomass, and tall growth are key traits for montane grassland species' ability to withstand climatic warming (Willis *et al.*, 2017). This is empirically confirmed for the Norwegian mountain flora (Guittar *et al.*, 2016) and plants in the Caucasus Mountains (Soudzilovskaia *et al.*, 2013), where the losers under climate change are plants lacking these traits.

A warmer climate will not only have negative impacts on species richness. As can be observed for many taxa, the biodiversity of algae in the south-Tajik depression (Barinova *et al.*, 2015), and zoobenthos in the Onega Bay of the White Sea (Denisenko, 2010) both increase towards warmer regions. Functional shifts have also been observed. In Georgia, a shift towards a higher species richness of ants is expected, at the expense of a decreased species richness of spiders (Chaladze, 2012; Chaladze *et al.*, 2014). However, the predictive ability of climate change responses based on such spatial gradients will be modified by nonlinearities (Nagorskaya & Keyser, 2005).

4.7.1.1.3 Effects on ecological processes and ecosystem functioning

It is well documented that climate change impacts vegetation and ecosystem functioning in Europe and Central Asia, but strength and direction depend on region, unit of analysis, and on the nature of the climatic changes. The relative importance of climate change and other concurrent drivers on ecosystem functioning are hard to disentangle.

Under increased temperatures, soil respiration, microbial activity (Sowerby *et al.*, 2005) and decomposition of lignified materials (Zell *et al.*, 2009) increase, but only if there is adequate moisture (Poll *et al.*, 2013). In the Mediterranean, temperatures are already close to the optimum for photosynthesis, so warming mainly increases plant water loss, whereas in temperate areas a warming of 1°C can increase biomass production by as much as 15% (Peñuelas *et al.*, 2004). In the UK, experimentally-increased temperatures led to a decrease in soil nitrogen leaching, probably due to increased nitrogen uptake because of increased plant growth (Ineson *et al.*, 1998a, 1998b). Warming also has a negative effect on soil biota abundance at all trophic levels, especially in cold dry regions, affecting their ecosystem functions (Blankinship *et al.*, 2011; Briones *et al.*, 2007).

Changing precipitation jointly impacts plants and biogeochemical cycles, a phenomenon well studied in Western and Central Europe with >70 experimental sites manipulating precipitation. Global meta-analyses reveal that plant biomass, productivity, respiration, ecosystem photosynthesis, and net carbon uptake are generally stimulated by increased precipitation and supressed by decreased precipitation (Vicca & Bahn, 2014; Wu *et al.*, 2011). Ecosystems are generally more sensitive to increased, than to reduced precipitation. Precipitation also affects decomposition, with coarse woody debris decay rate peaking at around 1,250 mm annual precipitation in temperate Western Europe (Zell *et al.*, 2009). Microbial soil communities in the northern parts of Western Europe may be more sensitive to changes in rainfall patterns than more moisture-limited soils in the southern parts of Western European (Sowerby *et al.*, 2005). Winter precipitation change also affect ecosystems, and snow depth manipulation experiments find that decreasing snow depth may reduce soil CO_2 efflux, increase N_2O efflux, and increase mobile nitrogen concentration (Blankinship & Hart, 2012).

Gradual warming favours harmful cyanobacterial blooms in freshwater systems, particularly in combination with eutrophication (O'Neil *et al.*, 2012). Warming will increase the spread of invasive fish in freshwater ecosystems, as cold seasons currently limit the spread of many freshwater invasive species (Rahel & Olden, 2008). Anadromous fish important for recreational fishing (salmonids) will shift their ranges northwards and suffer negative effects of warming in dry areas due to reduced river flows (Jonsson & Jonsson, 2009). Reduced precipitation will directly reduce water supply but considerable uncertainties remain regarding the impact of changing temperature and precipitation regimes on water quality. A review focussed on the UK found that there is insufficient evidence to link observed decreases in water quality to climate change (Watts *et al.*, 2015).

In oceans, recent temperature-driven changes in species ranges have strongly affected the trophodynamics of North East Atlantic ecosystems (Goberville *et al.*, 2014; Luczak *et al.*, 2011) as well as benthic-pelagic coupling (Albouy *et al.*, 2013; Kirby *et al.*, 2007). Increased vertical stability (strengthening of water stratification) leads to decreasing nutrient replenishment, which leads to changes in phytoplankton bloom phenology (Herrmann *et al.*, 2014), biomass and community structure (Bosc *et al.*, 2004; Goffart *et al.*, 2002; Tunin-Ley *et al.*, 2009). Reduced nutrient availability and phytoplankton biomass strengthens the microbial pathway in the plankton ecosystem (Bosc *et al.*, 2004; Goffart *et al.*, 2002; Tunin-Ley *et al.*, 2009). A reduction in primary production and reduced upwelling intensity will also have negative impacts on fisheries (Chassot *et al.*, 2010). In Mediterranean systems, warming leads to a shift in plankton communities towards smaller species, and a decrease in diatoms (Durrieu de Madron *et al.*, 2011). Temperature increase will, however, increase the metabolic activity of the surviving species, and modelling suggests that this could compensate for the species loss, resulting in similar net primary production by 2100 (Lazzari *et al.*, 2014).

4.7.1.2 Effects of extreme events on biodiversity

Climate change leads to more extreme and less predictable weather events (heat waves, droughts, floods, heavy precipitation, windstorms) that impact biodiversity across ecosystems. Ecosystem response to climate extremes depend upon the ecosystem itself, in particular on whether productivity is precipitation-, radiation- or temperature-limited (Seddon *et al.*, 2016). The spatial distribution of Central European forest trees is partly explained by climatic extremes, in addition to average climate, suggesting such extreme events have long-term distribution-wide impacts (Zimmermann *et al.*, 2009).

Observations of extreme weather events are important sources of information on ecosystem responses. For example, the unusually hot and dry summer of 2003 in Western and Central Europe resulted in decreased primary productivity and increased net carbon flux to the atmosphere (Ciais *et al.*, 2005; Reichstein *et al.*, 2007). Trees growing at high elevations in the Alps benefitted due to release from snow cover while there was decreased growth of lower-elevation trees due to increased evapotranspiration (Jolly *et al.*, 2005). The decrease was greatest in grasslands and croplands (Reichstein *et al.*, 2007), while among forests beech and Mediterranean broadleaved forests were the most susceptible (Granier *et al.*, 2007). Species richness also decreased in several heathlands across Western and Central Europe except for cool, damp heathlands in the UK (Peñuelas *et al.*, 2007). Similarly, other droughts have been shown to reduce carbon flux from roots to the soil compartment in north-western Europe (Gorissen *et al.*, 2004), to reduce the number of flowering shoots (Peñuelas *et al.*, 2004), and to cause forest dieback in the Arkangelsk region (Aakala & Kuuluvainen, 2011) and southern Siberia (Kharuk *et al.*, 2013), altering forest vulnerability to damaging agents and pathogens (Jactel *et al.*, 2012; Morley & Lewis, 2014). Across Central Asia, drought had affected grasslands, shrublands and areas of sparse vegetation, and the desertification risk in the Kakheti Region, the most drought-sensitive part of Georgia, is driven by increased drought frequency (Basialashvili *et al.*, 2015). Experimental evidence is now emerging to complement the observational evidence on extreme events. However, published studies largely focus on Western and Central European grasslands, for which there is a broad range of experimental evidence that growth and biomass accumulation recover rapidly from drought (Geels *et al.*, 2015).

The impact of an extreme event on biodiversity and nature's contributions to people is highly contingent on the timing of the event. In Arctic and alpine regions, short-term heat waves in winter have the greatest negative impact on productivity in the following summer (Bokhorst *et al.*, 2011; Bokhorst *et al.*, 2009). Ice forming on vegetation, when winter precipitation falls as rain instead of snow, decreases the availability of vegetation to herbivores and in turn has negative consequences for top predators (Hansen *et al.*, 2013, 2014).

Freshwater systems are highly sensitive to temperature extremes, leading to habitat and species loss under drought events (Matthews & Marsh-Matthews, 2003; Woodward *et al.*, 2016). Heatwaves lead to the proliferation of toxic algal blooms, reducing both biodiversity and the provisioning of drinking water (Gallina *et al.*, 2011; Jöhnk *et al.*, 2008; Paerl & Paul, 2012). Floods, on the other hand, directly impact fresh water provisioning by increasing water turbidity and eutrophication (Khan *et al.*, 2015). The protection from flooding and erosion provided by coastal and intertidal vegetation is reduced by increased storm activity (Cardoso *et al.*, 2008; Gedan *et al.*, 2011; Kinsella & Crowe, 2015). Drought has affected nutrient leaching into lakes, with knock-on effects on aquatic communities, with rotifers and cladocerans dominating during dry periods and copepods dominating during wet periods (Krylov *et al.*, 2013). In coastal systems, benthic macroinvertebrates suffered high mortality in the middle of the 2003 heat wave, exacerbated by nutrient stress (Garrabou *et al.*, 2009).

Variability has always been part of natural systems. Climate extremes denote events that depart clearly from the past range of variability of a given unit of analysis or region. Systems with low natural variability are usually at risk of rapidly exceeding their natural range, while systems of high variability may depart from this range frequently, but return to historical conditions for longer into the future than systems with low variability **(Figure 4.52)**. High latitude units of analysis are much less prone to completely depart from the historical range of variability than more equatorial units, due to the higher variability in the former and lower variability in the latter systems (Beaumont *et al.*, 2011). On the other hand, the absolute departure from the historical range of variability is higher in systems with high variability, and strong extremes (strong departures) may build more rapidly in such highly variable systems, with devastating effects from single events.

4.7.1.3 Secondary climate effects

While air temperature and precipitation changes may be seen as primary climate changes, other warming effects are also important for biodiversity and ecosystem function. Here we consider permafrost melting, atmospheric CO_2, ocean acidification and stratification, and sea level rise. Decreased precipitation and increased temperature also lead to an increased risk of fire (see Section 4.7.2).

As permafrost is the second largest terrestrial carbon pool (after soil), there is the potential for release of large amounts of carbon and methane when it thaws, thereby intensifying global warming and its earlier-mentioned effects on biodiversity; including ecosystems (Zhang *et al.*, 2017). Thawing permafrost has been shown to result in shrinking lakes due to drainage (Smith *et al.*, 2005), rapidly eroding river banks, the disappearance of wildlife including fish and migratory birds, altered migration routes, and shifted distributions of birds, reindeer, and caribou, and has been suggested to increase the danger of forest fires. Further, it may change plant species composition and productivity, as a result of warmer temperatures and associated changes in soil hydrology (Schuur *et al.*, 2007; Turetsky *et al.*, 2007).

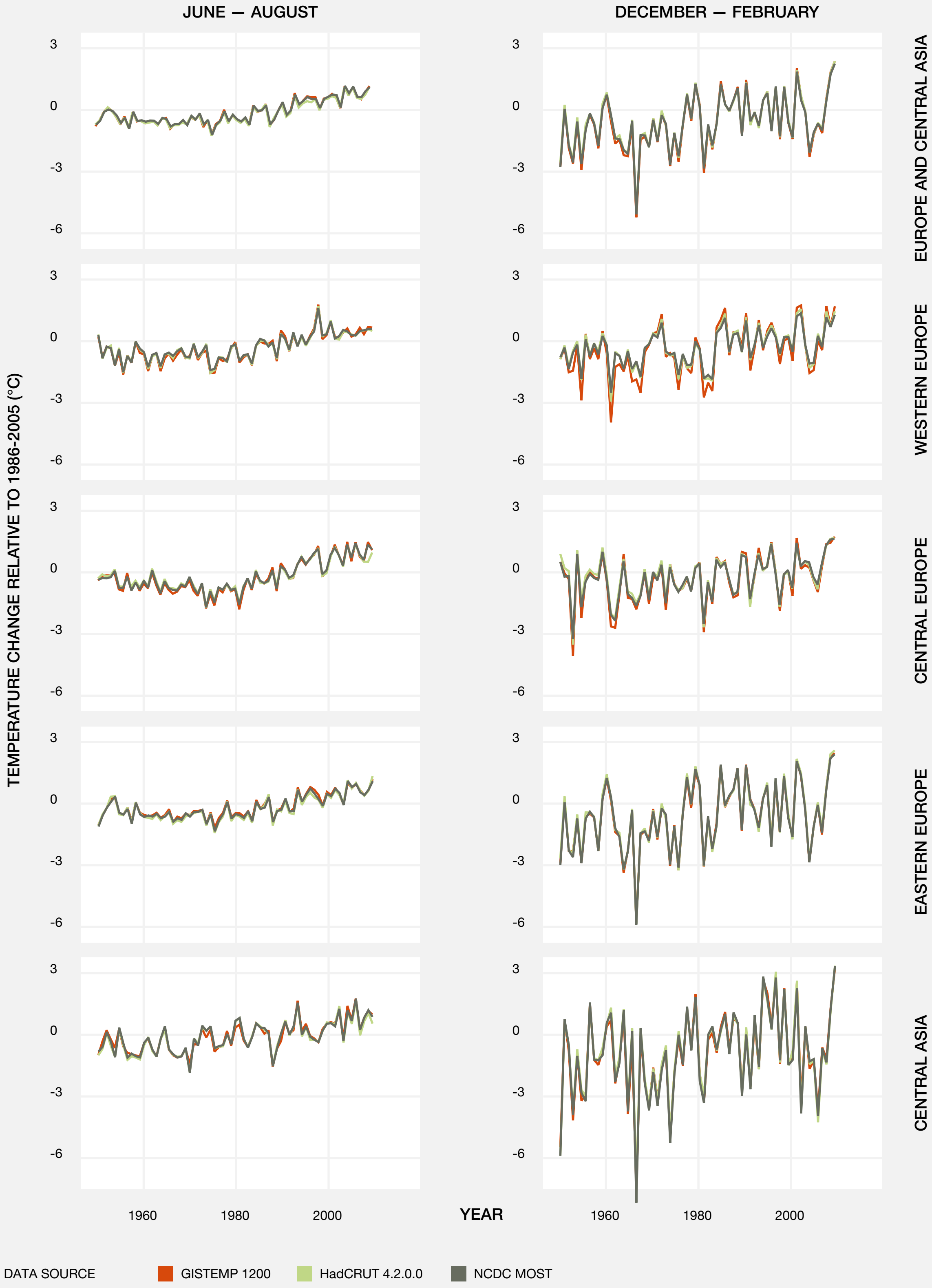
An increase in atmospheric CO_2 concentration, a major cause of climate change, directly impacts plant functioning. The increase in total plant biomass under elevated CO_2 is contingent on adequate other resources such as water and nutrients (Zheng & Peng, 2001). A recent global analysis combining remotely sensed leaf area index time-series with biogeochemical modelling revealed a significant increase in leaf biomass of land vegetation (termed "greening") in many regions of the world, and thus a significantly altered biogeochemistry (Zhu *et al.*, 2016). This was primarily driven by CO_2 fertilization effects, which accounted for 70% of the greening – the remainder by climate change, nitrogen deposition and land-cover change. The greening also varied regionally. It was statistically significant in many parts of Western and Central Europe, and prominent in Eastern Europe, but not observed in Central Asia. Elevated CO_2 can increase root activity, the abundance of microflora and microfauna, and particularly detritivores (Blankinship *et al.*, 2011). These effects result in changes in ecosystem biogeochemistry and altered vegetation-atmosphere feedbacks.

Ocean acidification results from increased atmospheric CO_2 and affects organism physiology (e.g. calcification, dissolution), biology (e.g. reproduction, skeletogenesis) with potential consequences for ecosystem structure and functioning (e.g. resistance to disease, unbalance of predator-prey interaction) and global carbon cycle (Hofmann *et al.*, 2010; Kroeker *et al.*, 2010). In the Atlantic and Arctic oceans, all calcifying plankton organisms exhibited simultaneously abrupt shifts in abundance during the mid- to the late-1990s (Beaugrand *et al.*, 2015). However, these large-scale ecological shifts appeared more correlated to changes in northern hemisphere temperature than to ocean acidification.

Changes in the UV-B radiation in oceans, caused by changes in the mixed-layer depth, impair photosynthesis, growth and reproduction (Llabrés *et al.*, 2013; Helbling *et al.*, 2003). Increased stratification is expected in the Mediterranean Sea during the 21st century (Somot *et al.*, 2006), and this may modify the exposure of organisms and organic compounds to solar radiation and favour photochemical oxidation reactions. The extratropical North Atlantic Ocean and its adjacent seas may be an important carbon sink (Sarmiento *et al.*, 2004). The carbon sink may become less efficient in a warmer world because of changes in phytoplanktonic types (floristic turnover) but also because upward mixing of nutrients will diminish due to increased stratification of the oceans (Bopp *et al.*, 2005; Thomas *et al.*, 2004). Deepening of the nutrient gradient would favour coccolithophorids against the diatoms, which are the major sink agents of carbon (Cermeño *et al.*, 2008). Indeed, coccolithophorids have increased in the North Sea during recent decades (Beaugrand *et al.*, 2013).

A sea-level rise of 1 m, a realistic maximum projected by 2100, will affect primarily the heavily populated regions in

Figure 4 53 **Observed annual mean temperature (°C) trends from 1950 to 2016, relative to mean temperatures for 1986–2005, for summer (June to August) and winter (December to February) across Europe and Central Asia, plotted for three datasets: GISTEMP 1200, HadCRUT 4.2.0.0 and NCDC MOST (see Section 4.2.6). Source: Own representation.**



Western Europe (mostly The Netherlands, but also Germany, Denmark and UK). Such drastic shifts will have a strong effect on coastal ecosystems, on sessile and migrating animals (birds - Iwamura *et al.*, 2013), and on the structuring of the coastal biomes. A population of 21.7 million is calculated to be at risk in the inundation area (Rowley *et al.*, 2007).

4.7.2 Trends in climate change

4.7.2.1 Temperature change

There is strong agreement that temperature has increased in Europe and Central Asia over the last sixty years **(Figure 4.53)**, especially after 1980, both for summer and winter average temperatures. The increase for 1950-2016 is significant for almost all of Europe and Central Asia, and was generally higher in winter (specifically in the Arctic Ocean and in Eastern Europe) than in summer, but was higher in summer in the south of Western Europe and Central Asia (see **Figure 4.54**).

The increase in temperatures was significant for all units across Europe and Central Asia, with positive trends of 0.15-0.30°C per decade for summer, and 0.10-0.45°C per decade for winter (see **Figure 4.55**). Increases in temperature were larger in winter than in summer for most units of analysis, except for southern biomes (Mediterranean, subtropical forests, temperate grasslands and deserts in Western Europe and Central Europe). All increases were significant except for winter temperatures of southern units in Western Europe, Central Europe and Eastern Europe.

Figure 4 54 **Map of observed (linear) temperature (°C / 100 years) trends between 1950 and 2016, for summer (June to August) and winter (December to February) throughout Europe and Central Asia.**

Only the GISTEMP dataset is presented here (see 4.2.6.1). The hatching represents areas where the estimated trend is less than one standard deviation away from zero (see Hartmann *et al.,* 2013). Source: Own representation.

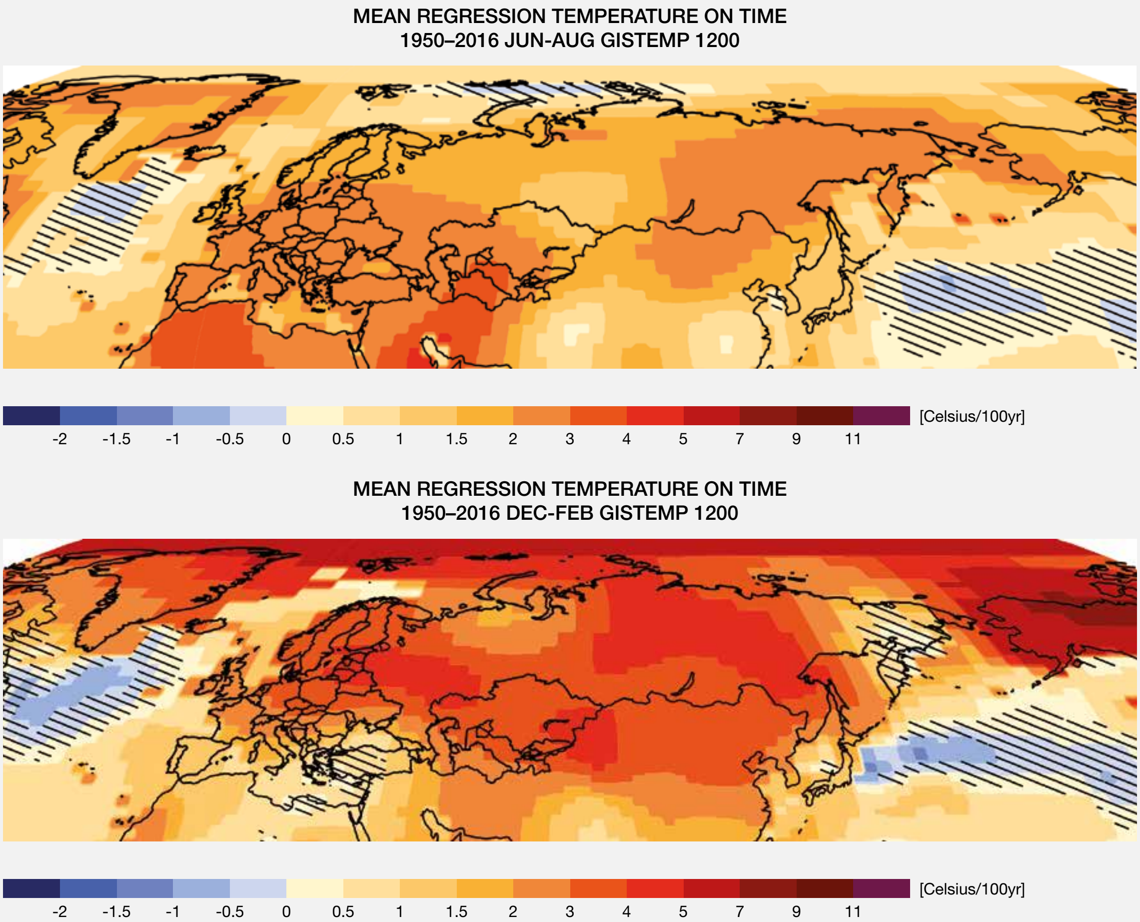
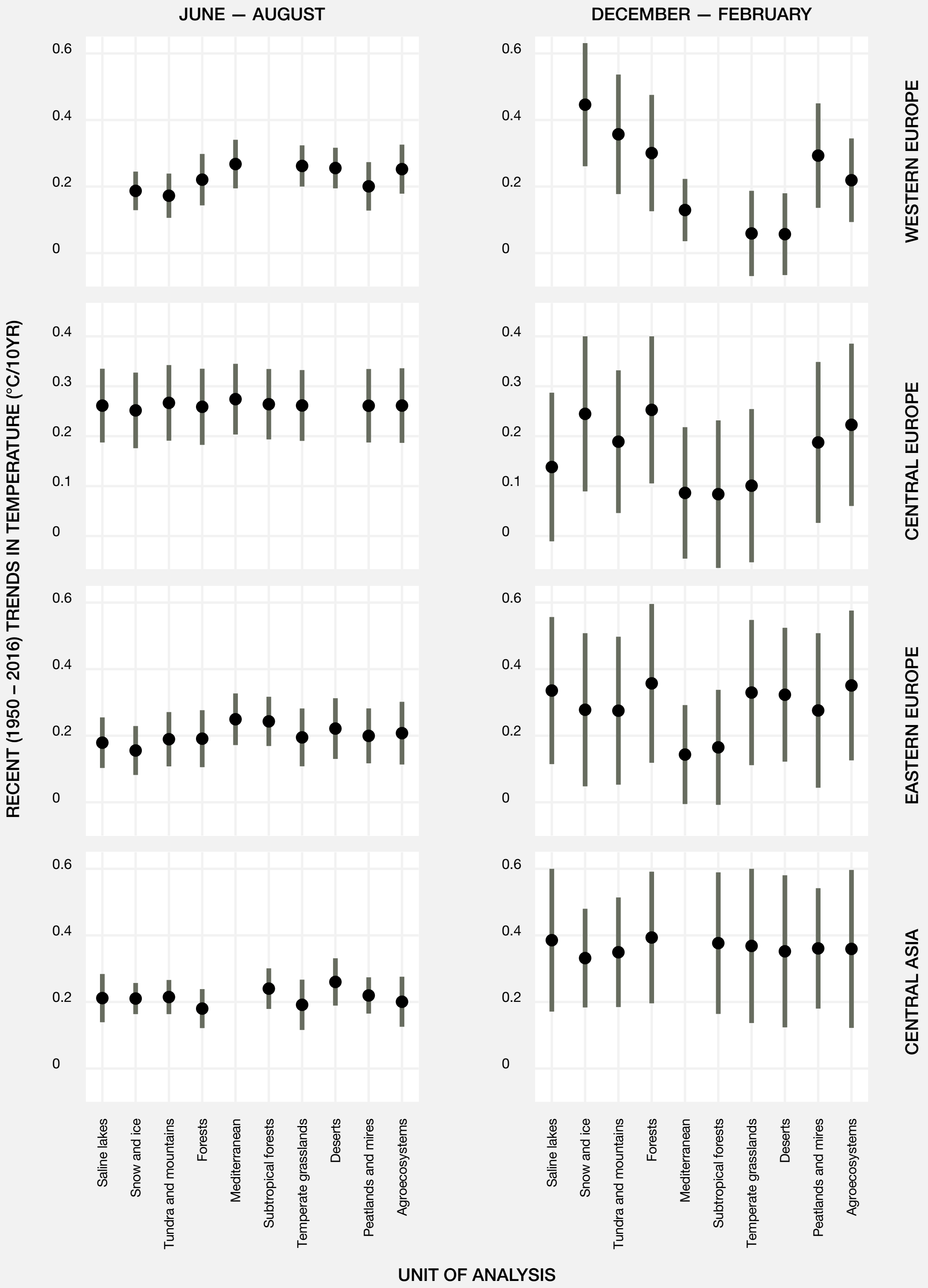


Figure 4 55 **Historical temperature trends (1950–2016) for units of analysis in Europe and Central Asia.**

The calculated linear trend is expressed in °C change/decade (see Hartmann *et al.*, 2013). Colour bars represent 90% confidence intervals around trend estimates. If 90% confidence intervals cross the dashed line of zero, the estimated trend is considered statistically insignificant. Units of analysis are: saline lakes; snow and ice (snow and ice-dominated systems - everything north of or higher than alpine); tundra and mountains (tundra and mountain grasslands - only high elevation grasslands); forests (broad-leaved, mixed and coniferous forests); Mediterranean (Mediterranean forests, woodlands and scrub); subtropical forests (tropical and subtropical dry and humid forests); temperate grasslands; deserts; peatlands and mires; agroecosystems. Source: Own representation.



Temperature is projected to increase across Europe and Central Asia in all RCP scenarios **(Figure 4.56)**, with 5 to 95% ranges of projected anomalies for 2041-2060 (relative to 1986-2005) for summer ranging from 0.38 to 3.17°C for RCP 2.6 and from 1.28 to 3.72°C for RCP 8.5 **(Figure 4.56)**, and for winter ranging from 0.18 to 3.92°C for RCP 2.6 and from 2.01 to 5.35°C for RCP 8.5 **(Figure 4.56)**. Increases in temperatures are projected to continue throughout the 2016-2060 period for RCPs 4.5, 6.0, and 8.5, while a plateau is projected for RCP 2.6 after 2040. Summer temperature increases are projected to be higher for southern parts of Western Europe and Central Europe (see **Figure 4.56**, **Figure 4.57**) than for other subregions. Winter temperature increases are projected to be largest for Central Asia and Eastern Europe, especially at higher latitudes **(Figure 4.56, Figure 4.57)**.

Temperatures are projected to increase for all units of analysis throughout subregions of Europe and Central Asia **(Figure 4.58)**, with increases in summer being projected similarly among all units according to the CMIP5 ensemble ranging from 1 to 3°C depending on representative concentration pathway scenario, and with increases in winter being projected to differ among biomes. Specifically, snow and ice, and tundra and mountain grasslands have larger projected winter temperature increases (2.5 to 5°C) than the other units if analysis (1 to 3.5°C) in both Western and Eastern Europe.

4.7.2.2 Precipitation change

Precipitation has increased only insignificantly over the last sixty years across most of Europe and Central Asia (see **Figure 4.59**) (Hartmann *et al.*, 2013), with considerable subregional variation **(Figure 4.59)**. Significant increases and decreases were only detected for some parts within subregions **(Figure 4.60)**. Winter precipitation has decreased for southern Western Europe and Central Europe. In Eastern Europe, summer precipitation has in- and decreased in some areas throughout the subregion, whereas winter precipitation has decreased in eastern, but increased in the western parts of Eastern Europe. In Central Asia summer precipitation has generally decreased but winter precipitation has increased.

Precipitation trends were generally insignificant for the different units across Europe and Central Asia **(Figure 4.61)**, and only a few significant changes were detected for tundra and mountain grasslands (winter increase in Western Europe), and saline lakes, temperate grasslands and agroecosystems (winter increase in Central Asia) **(Figure 4.61)**.

Precipitation is projected to increase in future across Europe and Central Asia according to all RCP scenarios (see **Figure 4.62**), yet with important uncertainties. Increases are projected to be larger for winter than for summer. Summer precipitation anomalies for 2041-2060 relative to 1986-2005 for RCP 2.6 range from –0.06 to 0.24 mm/day and for RCP 8.5 range from –0.07 to 0.21 mm/day (5 to 95%) (see **Figure 4.62**). Projected winter precipitation anomalies for 2041-2060 relative to 1986-2005 for RCP 2.6 range from 0 to 0.21 mm/day and for RCP 8.5 range from 0.05 to 0.23 mm/day (5 to 95%) (see **Figure 4.62**).

At a subregional scale, most projected precipitation changes fall within one standard deviation of the natural variability over much of Europe and Central Asia (see **Figure 4.63**). For summer, significant increases in precipitation are projected for northern areas of Western Europe and Eastern Europe, and decreases in southern parts of Western Europe (see **Figure 4.63**), in accordance with Kirtman *et al.* (2013). For winter, increases in precipitation are projected over Eastern Europe, Central Asia, and in northern parts of Western Europe (see **Figure 4.63**).

Changes in summer precipitation are projected for most units of analysis throughout Europe and Central Asia except for deserts **(Figure 4.64)**. Changes in winter precipitation are projected for almost all units in Western Europe, Eastern Europe and Central Asia, whereas projected changes for Central Europe are less clear with values projected within natural variability range depending on scenarios **(Figure 4.64)**. Specifically, in Western Europe, changes (increases and decreases, depending on units) are projected for both summer and winter precipitation. In Central Europe, decreases are projected for all units for summer precipitation, whereas projected changes are variable among units for winter. In Eastern Europe, increases are projected for most units for both summer and winter precipitation, except for summer precipitation in Mediterranean and subtropical forest units, which is projected to decrease. In Central Asia, increases are projected for all biomes for winter precipitation only.

In summary, precipitation will very likely change throughout Europe and Central Asia, will likely increase for most units of analysis in Eastern Europe and Central Asia and for northern units in Western Europe, and likely decrease for southern units in Western Europe and Central Europe.

4.7.2.3 Sea-level change

The sea-level has risen ca. 150 mm in the past century. Recent trends in sea-level rise are uniform across the globe. Eastern Europe and Central Asia are exceptional because of the Caspian Sea, where sea-level change is decoupled from global sea-level rise and trends are uncertain. The Caspian Sea level decreased throughout the first half of the previous century, and subsequently increased to almost re-reach its historical level (Arpe & Leroy, 2007; Leroy *et al.*, 2006 and references therein).

Figure 4 56 **Time series of temperature trends relative to 1986–2005 averaged over land grid points for (from top to bottom) Europe and Central Asia, Western Europe, Central Europe, Eastern Europe, and Central Asia in summer (June to August, left panel) and winter (December to February, right panel).**

Thin lines denote one ensemble member per model and thick lines the CMIP5 multi-model mean (see **Figure 4.3** for details). On the right-hand side of each graph the 5th, 25th, 50th (median), 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2041–2060 under the four IPCC RCP scenarios. Source: Own representation.

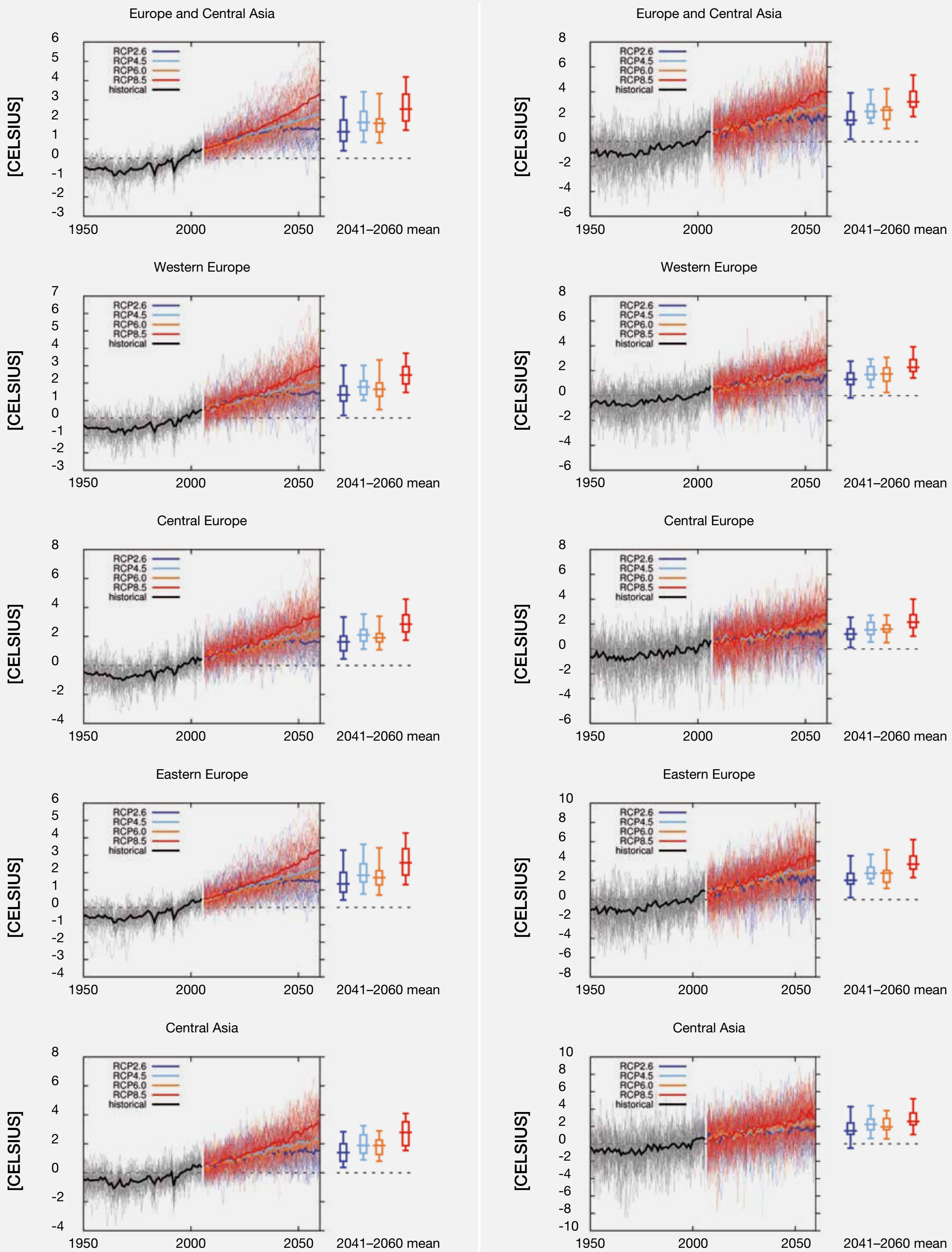


Figure 4 57 **Maps of projected (linear) temperature trends by 2041–2060 relative to 1986–2005 under the RCP4.5 (top two panels) and the RCP 8.5 scenario (bottom two panels) for summer (June to August) and winter (December to February).**

Ensemble means from CMIP5 are presented here, extracted from data of IPCC (2013b). Source: Own representation.

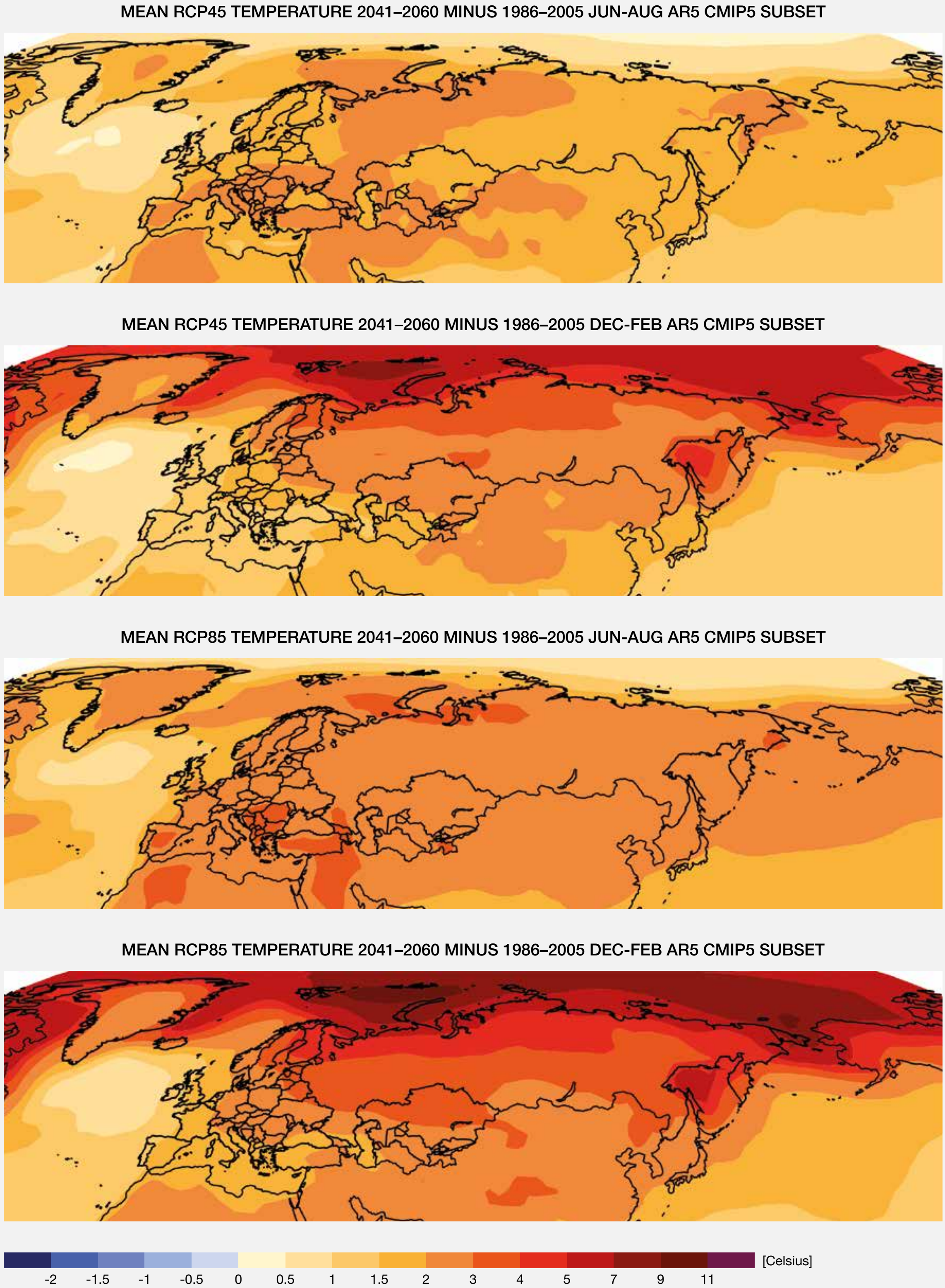


Figure 4 58 **Projected temperature changes (2041–2060) relative to 1986–2005 averaged over land grid points for units of analysis of Western Europe, Central Europe, Eastern Europe, and Central Asia.**

Points represent model ensemble means from CMIP5 for each representative concentration pathway (RCP) scenario. Bars represent one standard deviation of natural variability around 1986–2005 means. Units of analysis are: saline lakes; snow and ice (snow and ice-dominated systems - everything north of or higher than alpine); tundra and mountains (tundra and mountain grasslands - only high elevation grasslands); forests (broad-leaved, mixed and coniferous forests); Mediterranean (Mediterranean forests, woodlands and scrub); subtropical forests (tropical and subtropical dry and humid forests); temperate grasslands; deserts; peatlands and mires; agroecosystems. Source: Own representation.

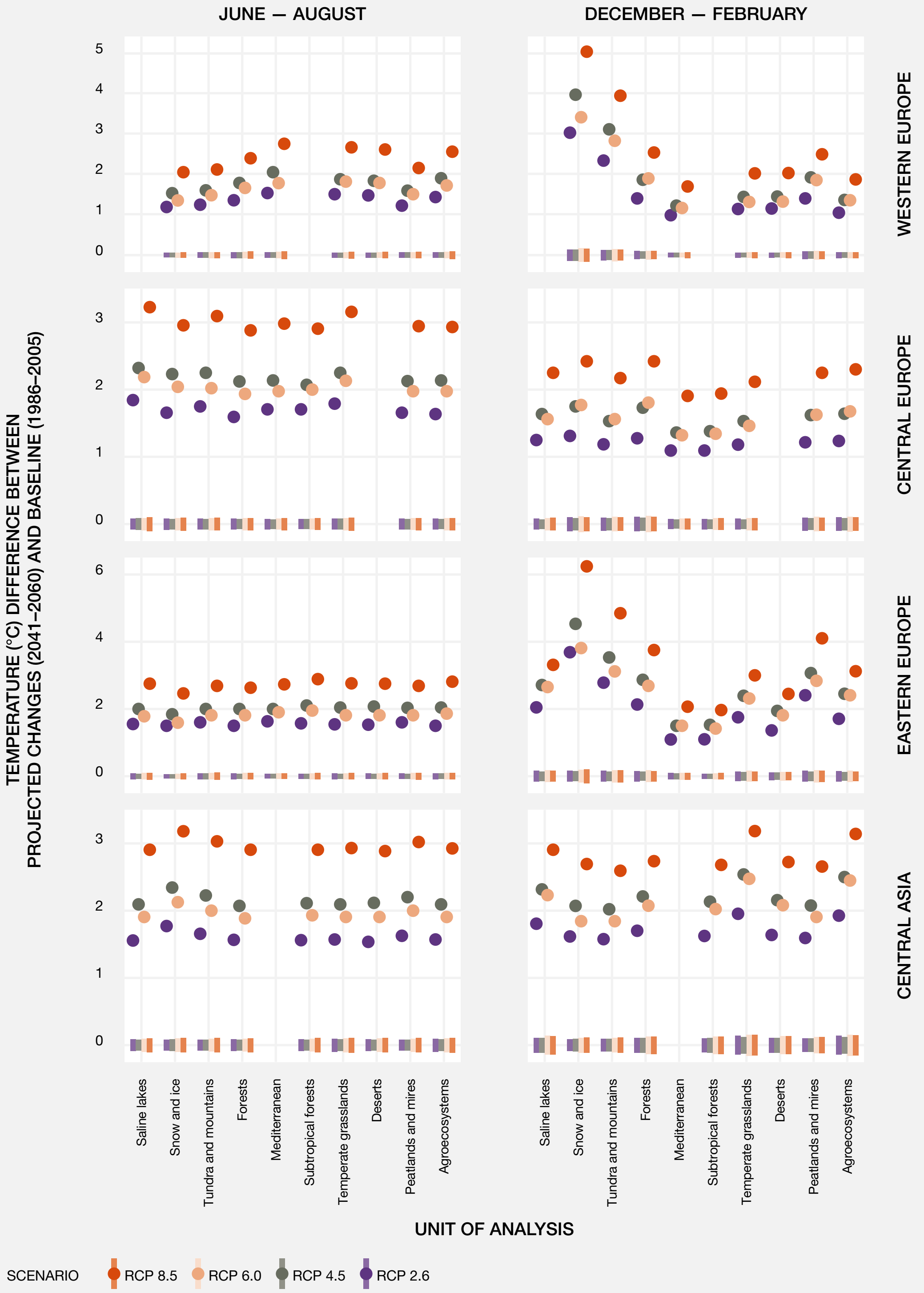


Figure 4 59 **Observed precipitation (mm/day) trends from 1950 to 2016, relative to mean precipitation for 1986–2005, for summer (June to August) and winter (December to February) across Europe and Central Asia, plotted for three datasets: CRU TS 4.00, GPCC V7 and NCDC anomalies. Source: Own representation.**

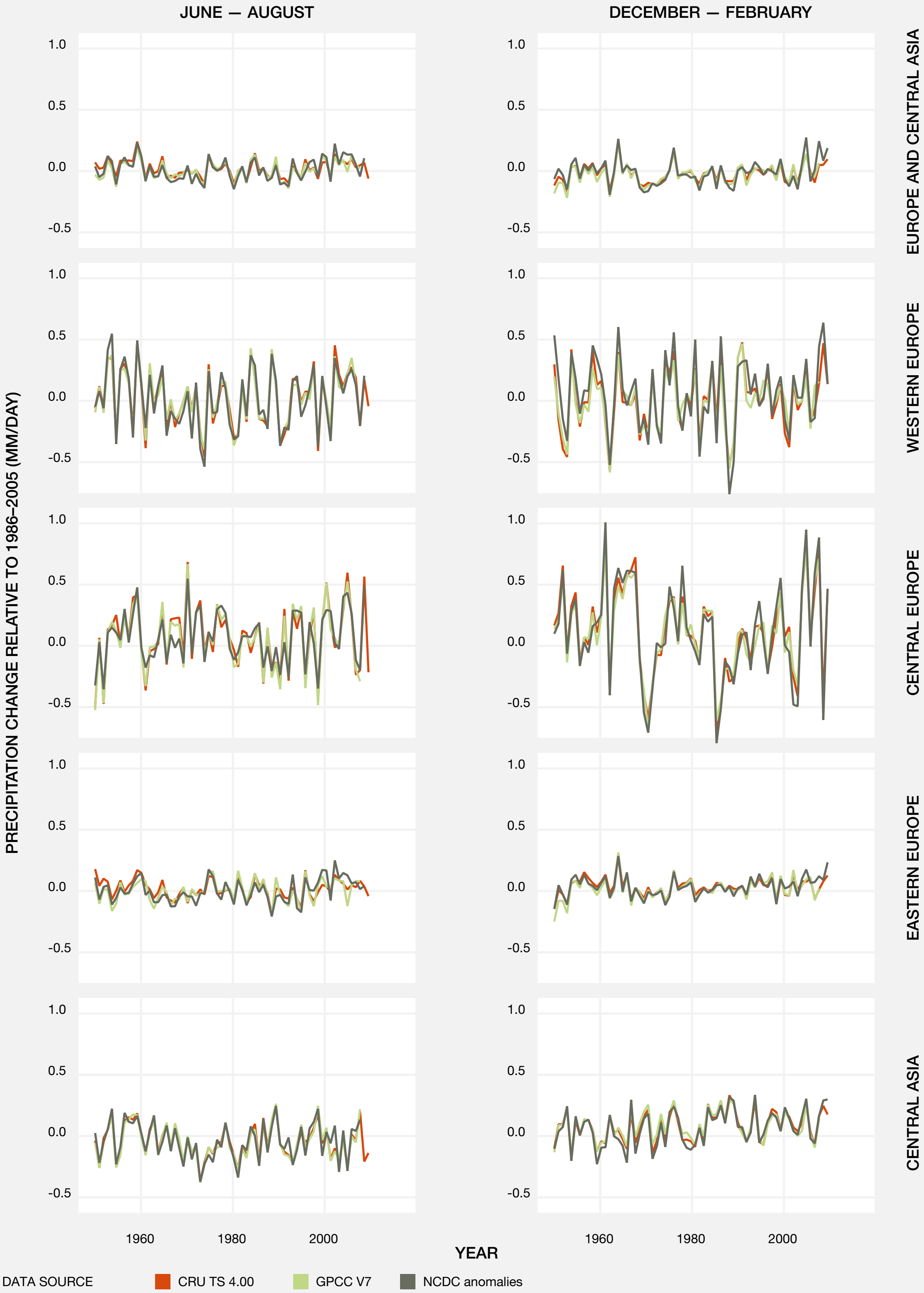
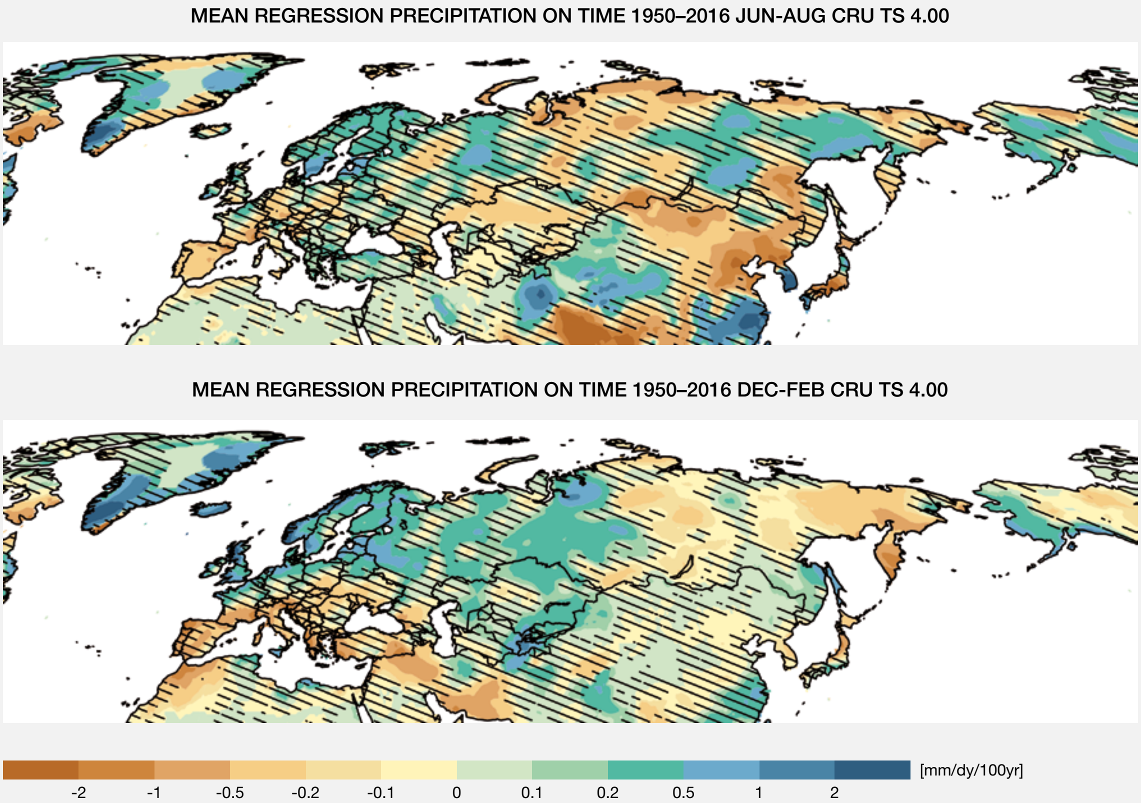


Figure 4 60 **Map of observed (linear) precipitation trends (mm/day per 100 year) between 1950 and 2016, for summer (June to August) and winter (December to February) throughout Europe and Central Asia.**

The CRU TS 4.00 dataset is presented here. The hatching represents areas where the estimated trend is less than one standard deviation away from zero (see Hartmann *et al.* (2013) for details). Source: Own representation.



In the future sea-level is projected to continuously increase globally **(Figure 4.65)** due to various reasons, including temperature induced swelling and melting land ice, to reach a total increase by 2100 of 0.3-1 m (IPCC, 2013b). Sea level changes in the Caspian Sea will most likely depend on the projected precipitation regimes of its watershed (Arpe & Leroy, 2007), which are least certain but potentially increase, while fluctuations may be extreme (Roshan *et al.*, 2012).

While coastal habitats and estuaries experience strong effects from rise in sea-level, benthic habitats are less concerned (only near-shore) and pelagic habitats are least affected. Within the region, a sea-level rise of at least 1 m would affect primarily the heavily populated regions in Western Europe (mostly The Netherlands, but also Germany, Denmark and UK), where a rise of 1-5 m **(Figure 4.66)** would affect up to 22 million inhabitants. A realistic sea level rise of just 1 m would affect almost the same amount of land, biomes and people as a 5 m rise. Such drastic shifts will have a strong effect on coastal ecosystems, on sessile and migrating animals (birds), and on the structuring of the coastal biomes.

4.7.2.4 Trends in glaciers and permafrost

4.7.2.4.1 Glacier melting

There is high general confidence that current glacier extents are out of balance due to increased recent temperatures, indicating that glaciers will continue to shrink in the future even without further temperature increase (Hagen *et al.*, 1993; IPCC, 2013b). The average rate of ice loss from glaciers around the world (including both Alpine and Arctic glaciers), excluding glaciers on the periphery of the ice sheets, was very likely 226 [91 to 361] Gt yr^{-1} over the period 1971 to 2009, 275 [140 to 410] Gt yr^{-1} over the period 1993 to 2009 and 301 [166 to 436] Gt yr^{-1} between 2005 and 2009 (IPCC, 2013b). Most glaciers around the globe have been shrinking since the end of the Little Ice Age (ca. 1300-1850), with increasing rates of ice loss since the early 1980s.

Figure 4 61 **Historical precipitation trends (1950–2016) for units of analysis of Europe and Central Asia.**

The calculated linear trend is expressed in mm/day/decade (Hartmann *et al.,* 2013). Colour bars represent 90% confidence intervals around trend estimates. If 90% confidence intervals cross the dashed line of zero, the estimated trend is considered statistically insignificant. Units of analysis are: saline lakes; snow and ice (snow and ice-dominated systems - everything north of or higher than alpine); tundra and mountains (tundra and mountain grasslands - only high elevation grasslands); forests (broad-leaved, mixed and coniferous forests); Mediterranean (Mediterranean forests, woodlands and scrub); subtropical forests (tropical and subtropical dry and humid forests); temperate grasslands; deserts; peatlands and mires; agroecosystems. Source: Own representation.

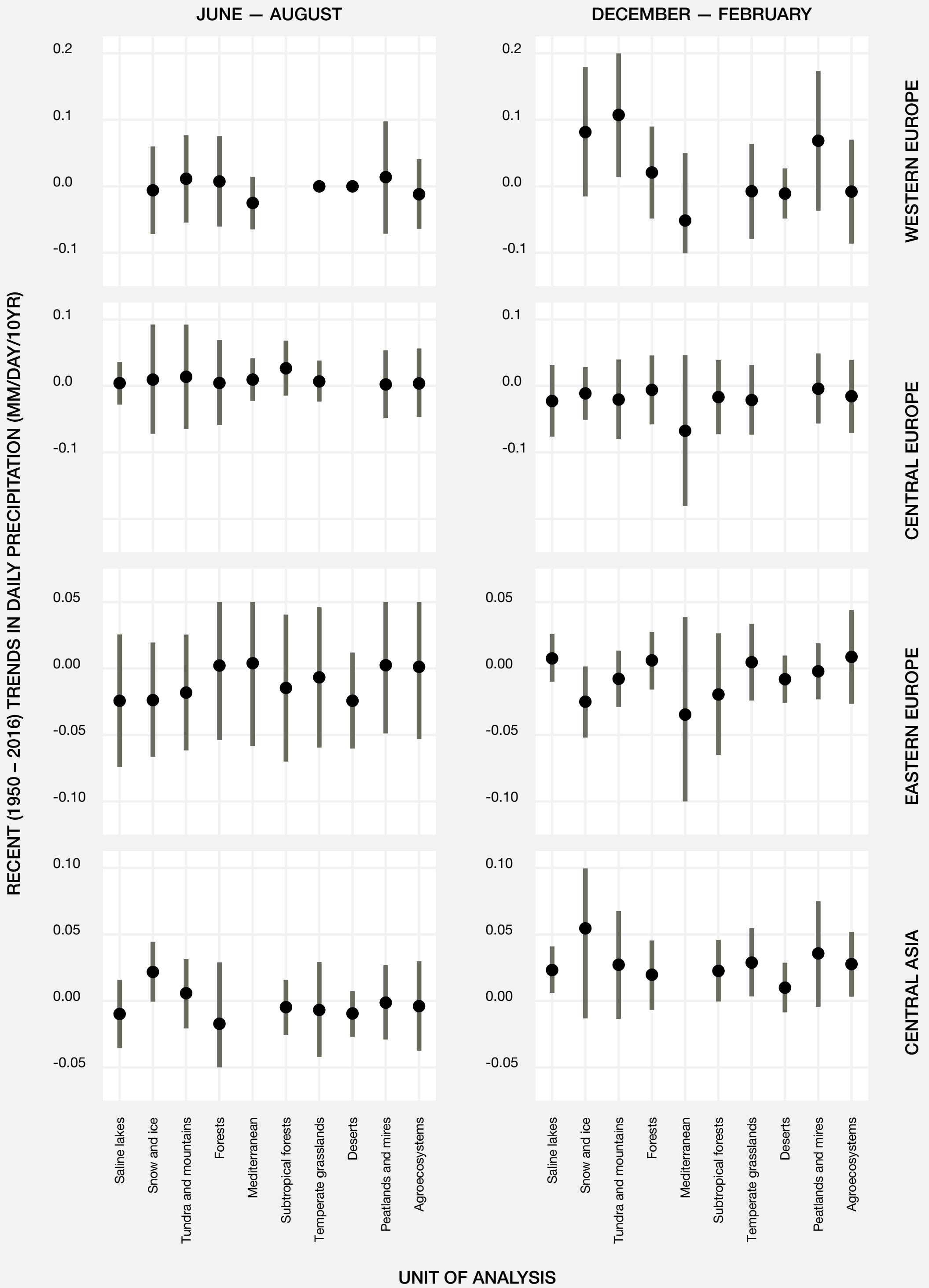


Figure 4 62 **Time series of precipitation trends relative to 1986–2005 averaged over land grid points for (from top to bottom) Europe and Central Asia, Western Europe, Central Europe, Eastern Europe, Central Asia in summer (June to August, left panel) and winter (December to February, right panel).**

Thin lines denote one ensemble member per model and thick lines the CMIP5 multi-model mean (see **Figure 4.3** for details). On the right-hand side of each graph the 5th, 25th, 50th (median), 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2041–2060 under the four IPCC representative concentration pathway (RCP) scenarios. Source: Own representation.

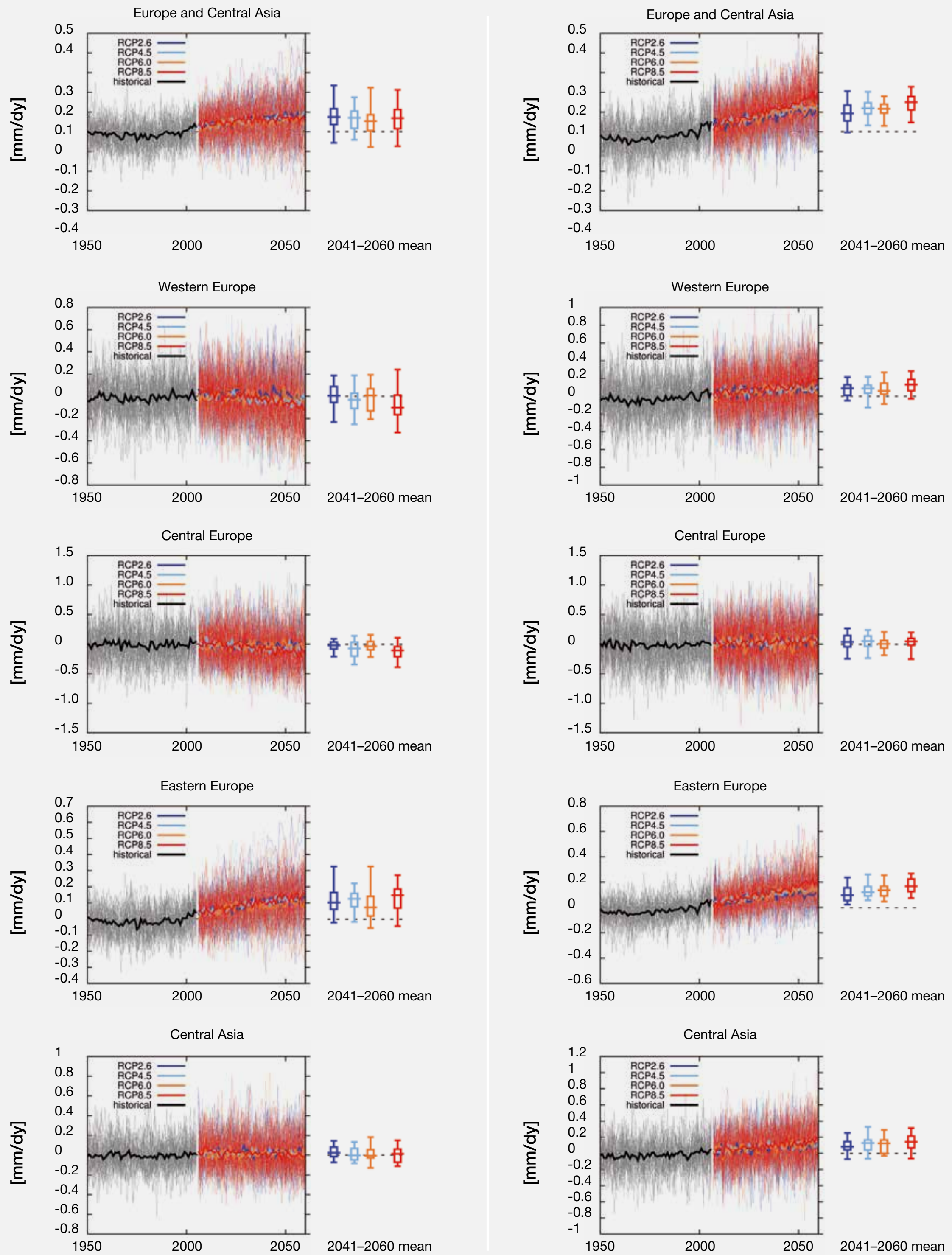


Figure 4 63 **Maps of projected (linear) precipitation trends by 2041–2060 relative to 1986–2005 under the RCP4.5 (top two panels) and the RCP 8.5 scenario (bottom two panels) for summer (June to August) and winter (December to February).**

Ensemble means from CMIP5 are presented here, extracted from data of IPCC (2013b). Source: Own representation.

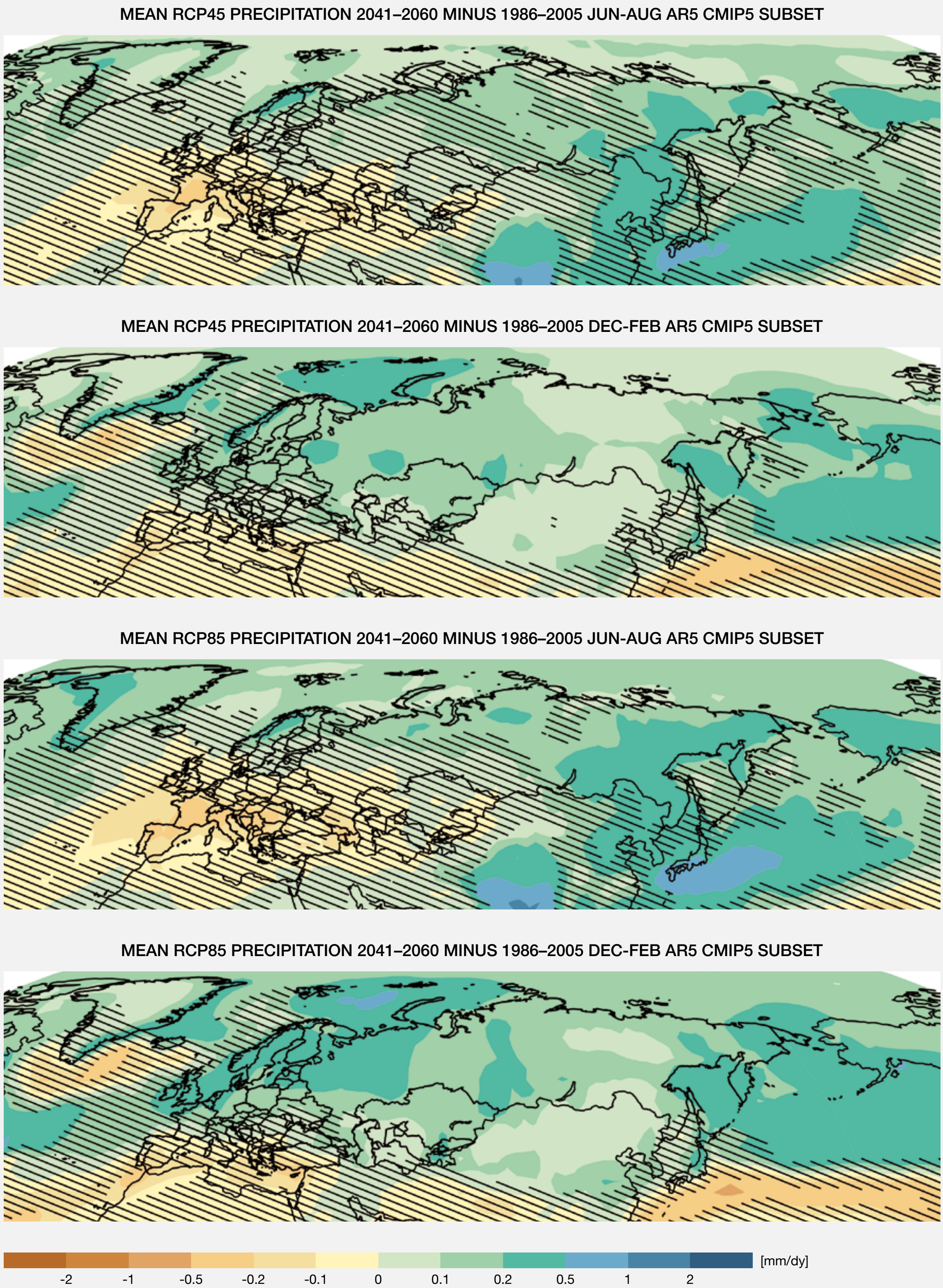


Figure 4 64 **Projected precipitation changes (2041–2060) relative to 1986–2005 averaged over land grid points for units of analysis of Europe and Central Asia, Western Europe, Central Europe, Eastern Europe, Central Asia.**

Points represent model ensemble means from CMIP5 for each representative concentration pathway (RCP) scenario. Bars represent one standard deviation of natural variability around 1986–2005 means. Units of analysis are: saline lakes; snow and ice (snow and ice-dominated systems - everything north of or higher than alpine); tundra and mountains (tundra and mountain grasslands - only high elevation grasslands); forests (broad-leaved, mixed and coniferous forests); Mediterranean (Mediterranean forests, woodlands and scrub); subtropical forests (tropical and subtropical dry and humid forests); temperate grasslands; deserts; peatlands and mires; agroecosystems. Source: Own representation.

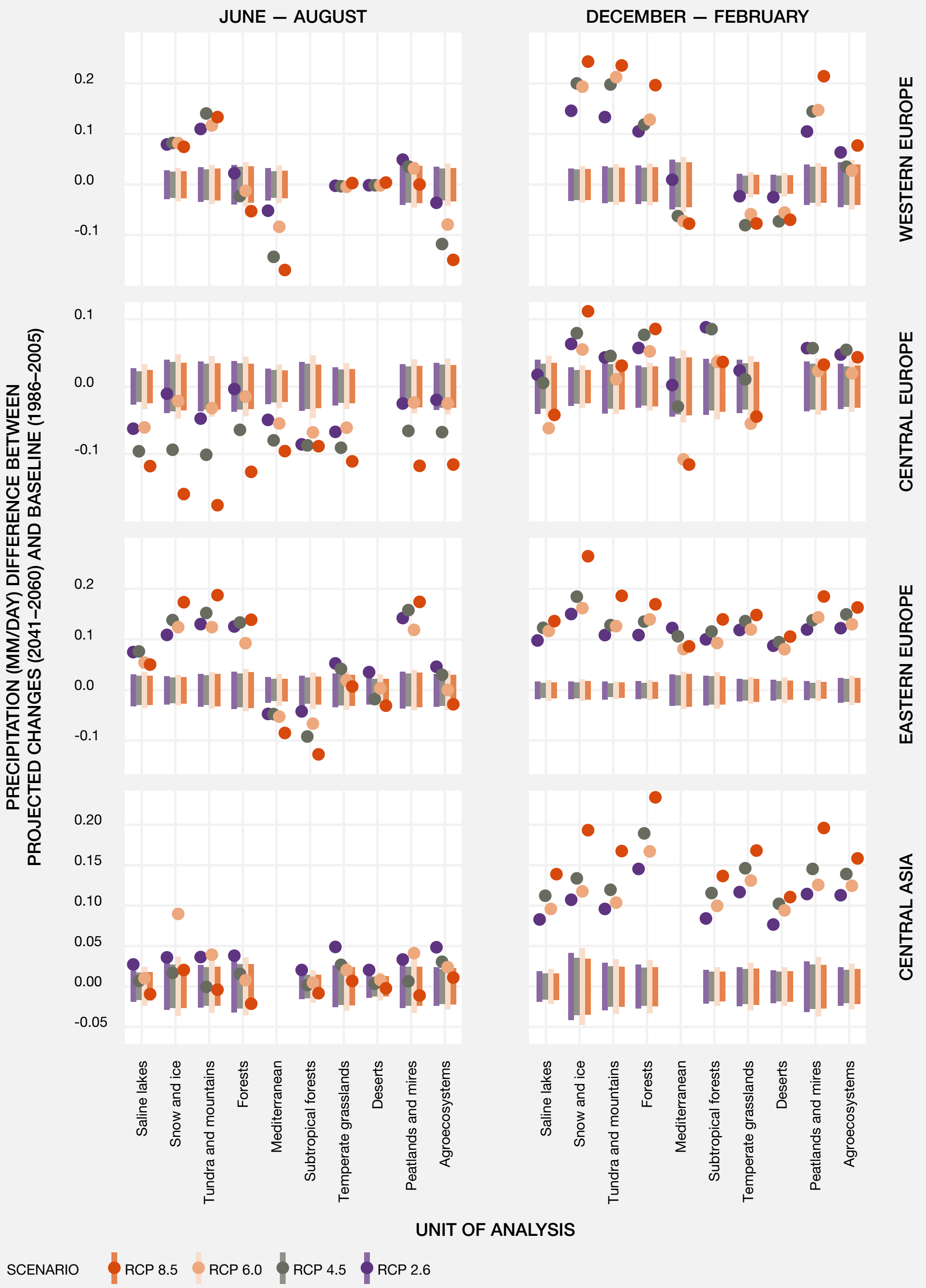
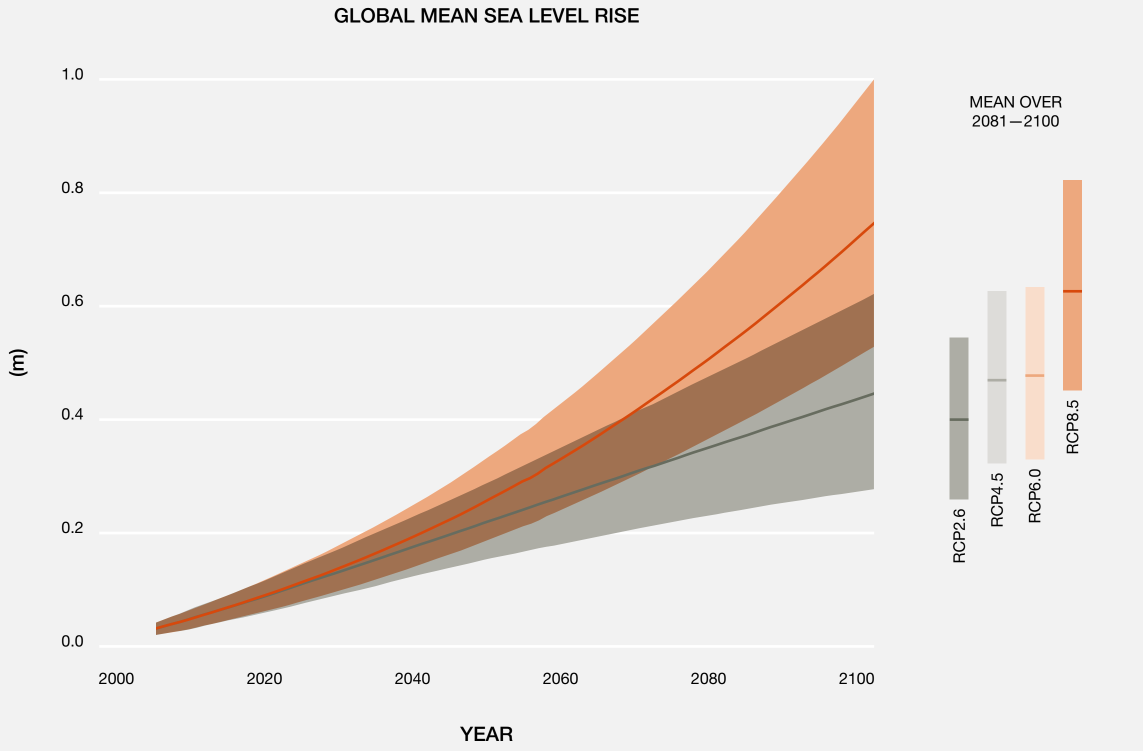


Figure 4 65 **Projected sea level rise according to the different representative concentration pathways (RCP) used in the 5th assessment report of the Intergovernmental Panel on Climate Change. Source: Figure SPM.9 from IPCC (2013b).**

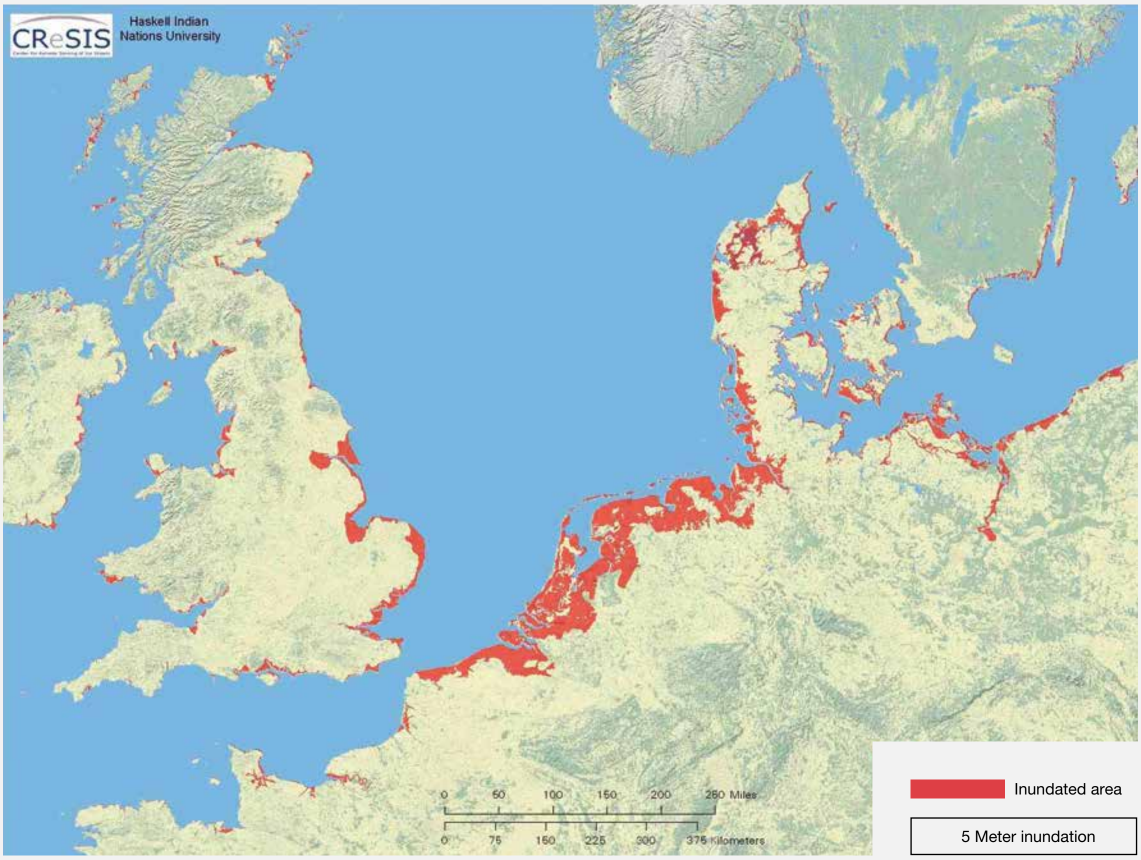


There is, however, regional variation and also wide variation within regions related to precipitation patterns, altitudinal range, area distribution and dynamic responses. For instance, in the Jotunheimen region, the highest mountain massif in Norway, the general trend (based on Landsat TM/ ETM+ data from 2003) is glacier recession, while some glaciers in that region increased their size or remained nearly unchanged over these decades (Andreassen *et al.*, 2008). Another example is the Svartisen region in Norway, where the overall glacier area changed from 1968 to 1999 was close to zero, but where there was a stronger relative area loss towards the wetter coast (Paul & Andreassen, 2009). Generally, the investigated glaciers in the Jotunheimen region shrank since the 1930s, with an overall area reduction of about 23% for 38 glaciers. Since the 1960s the area reduction for 164 glaciers in that region was 12% (*c.* 3.2% per decade) and since 1980 3% per decade. The 3.2% per decade reduction in glacier area since 1965 and 3% since 1980 in Jotunheim is comparable to other parts of the region with mountain and valley glaciers. In the Swiss Alps, the area change was –2.2% per decade for the period 1850-1973 and -6.4% per decade for the period 1973-1999 (Paul *et al.*, 2004). In the Jostedalsbreen region, Norway, there was an area loss of 2.3% per decade in the period 1966-2006 (Paul *et al.*, 2011). Inventory results from the Austrian Alps show a net reduction of glacier area of 17% between 1969 and 1998 (Lambrecht & Kuhn, 2007), or –6% per decade. In southern Spitsbergen, most glaciers - whether tidewater or land-terminating, large or small, debris-covered or comparatively clean ice types – have undergone retreat, both over the period 1936-1990 (832.5 km^2) and 1990-2008 (243.1 km^2). In the latter period, the glacier area change was on average around –3% per decade (König *et al.*, 2014). Also in other parts of Svalbard, glacier area has been decreasing substantially during the past 50 years (Hagen *et al.*, 1993). In the Russian High Arctic, the archipelagos have lost ice at a rate of –9.1 ± 2.0 Gt per year, which corresponds to a sea level contribution of 0.025 mm per year. Approximately 80% of the ice loss came from Novaya Zemlya with the remaining 20% coming from Franz Josef Land and Severnaya Zemlya (Moholdt *et al.*, 2012). In the Tien Shan (in the border region of Kazakhstan, Kyrgyzstan and north-western China) the area reduction was 32% between 1955 and 1999 (Bolch, 2007), or – 9% per decade.

4.7.2.4.2 Permafrost thawing

There is agreement that near-surface permafrost extent at high northern latitudes will be reduced as global mean

Figure 4 66 **Projected impact from a sea level rise (5 m) for north-western Europe. A population of 21.7 million is calculated to be at risk in the inundation area (Rowley *et al.* 2007).**



surface temperature increases. By the end of the 21st century, the area of permafrost near the surface (upper 3.5 m) is projected to decrease by between 37% (RCP2.6) and 81% (RCP8.5) for the model average (IPCC, 2013b). Permafrost temperatures have increased, and the depth of seasonally frozen ground has become reduced, in most regions since the early 1980s, although the rate of increase has varied regionally. Also, the temperature increase for colder permafrost was generally greater than for warmer permafrost. Significant permafrost degradation has occurred in the Russian European north, where observed warming was up to 2°C in the period 1971 - 2010 (Malkova, 2008; Oberman, 2008, 2012; Romanovsky *et al.*, 2010). In the latter region, a considerable reduction in permafrost thickness (up to 15 m) and areal extent (poleward shift up to 80 km for discontinuous and up to 50 m for continuous permafrost extent) has been observed over the period 1975 to 2005 (IPCC, 2013b).

In northern Yakutia (Russia), permafrost temperatures have warmed by 0.5-1.5°C between the early 1950s and 2009 (Romanovsky *et al.*, 2010), and in the Trans-Baykal region (Russia) by 0.5-0.8°C between the late 1980s and 2009 (Romanovsky *et al.*, 2010). In Tian Shan, permafrost temperature has increased by 0.3-0.9°C during 1974-2009 (Marchenko *et al.*, 2007; Zhao *et al.*, 2010). In the Alps, permafrost temperatures have increased by 0.0 – 0.4°C in the period 1990-2010 (Christiansen *et al.*, 2012; Haeberli *et al.*, 2010; Noetzli & Mühll, 2010), and in the Nordic countries by 0.0-1.0°C during 1999-2009 (Christiansen *et al.*, 2010; Isaksen *et al.*, 2011). The thickness of the seasonally frozen ground in some non-permafrost parts of the Eurasian continent likely decreased, in places by more than 30 cm from 1930 to 2000.

4.7.2.5 Trends in extreme events

4.7.2.5.1 Drought and temperature extremes

In recent decades, drought and heat waves have increased in Western and Central Europe, while showing a north-south gradient in both subregions (drier in the south, no change or moister in the north, Alexander *et al.*, 2006; Kiktev *et al.*, 2003; Sheffield & Wood, 2008a). These recent trends for Western, Central, and Eastern Europe are considered likely, while trends in Central Asia are as likely as not (IPCC, 2012). Drought is often associated with extreme heat waves, which can stretch over large regions, and which may result in punctuated drought events **(Figure 4.67)**.

Projected trends in drought are considered very likely in Western and Central Europe since projections are in high agreement (drier in the south, no change or moister in the north, Alexander *et al.*, 2006; Kiktev *et al.*, 2003; Sheffield & Wood, 2008b), while for Eastern Europe and Central Asia the projected trends are about as likely as not. Generally, the largest increase in the duration and intensity of drought periods is projected for Mediterranean climate zones (Beniston *et al.*, 2007; May, 2008), while for northern parts of Western Europe only moderate or no increase in drought is expected (IPCC, 2012), so this trend is as likely as not. Future trends for Eastern Europe vary between projections, but also spatially, with potentially less drought in northern parts of Eastern Europe (Dai, 2011; Sillmann & Roeckner, 2008). Seasonality in drought events is also expected to change throughout Europe and Central Asia (Orlowsky & Seneviratne, 2012).

4.7.2.5.2 Floods

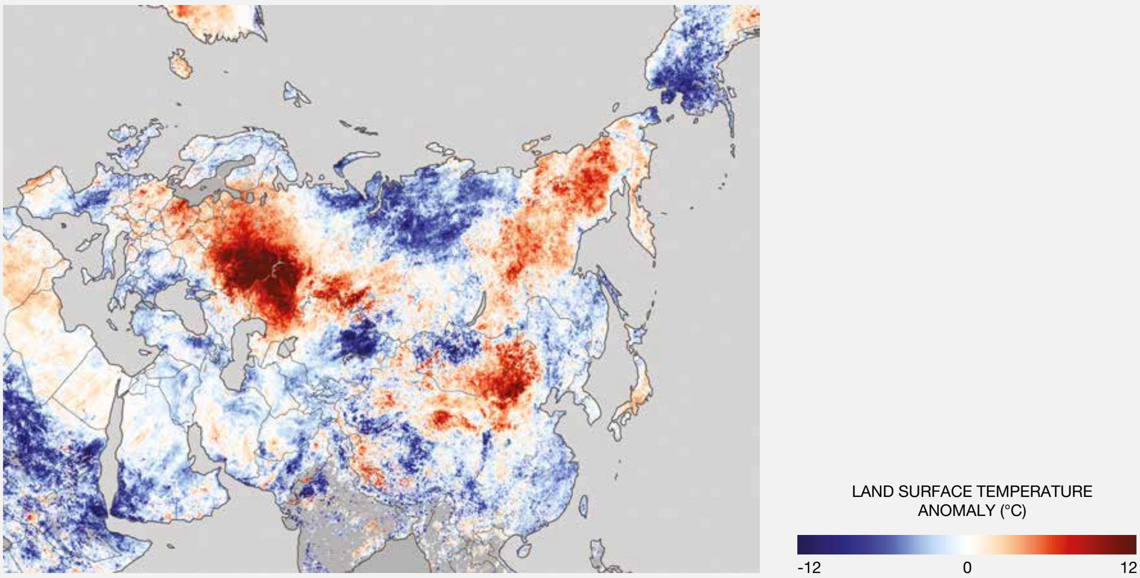
Recent trends in floods are very difficult to assess because of a lack of long time-series of gauge-stations and because floods are rare. Therefore, flood assessments of the recent past are least certain and without a directional trend throughout Europe and Central Asia (IPCC, 2012).

Projections of floods are to a large degree based on projections of heavy precipitation events which, in turn, are based on physical reasoning, but changes in snow accumulation and the timing of snow-melt potentially also contribute to flood-risk projections. However, the magnitude of this contribution is uncertain (IPCC, 2012). Heavy precipitation is expected to increase in Western and Central Europe, with highest certainty and magnitude in the north while Mediterranean Europe may not experience the associated increase in flood risk (Beniston *et al.*, 2007; Frei *et al.*, 2006; Kendon *et al.*, 2008). While the trend is consistent between summer and winter, the magnitude may vary between seasons, but also spatially (Frei *et al.*, 2006; Kendon *et al.*, 2008). Coastal regions of Western Europe may be exposed to north-shifted extra-tropical cyclones (IPCC, 2012) and thus be under increased flooding risk. Increased frequency of heavy precipitation events is highly certain in Eastern Europe (IPCC, 2012)[1], while for Central Asia projections are partly contradictory resulting overall in no projected increase of heavy precipitation, but with least certainty (IPCC, 2012).

1. See table 3-3 therein

Figure 4 67 **Russian heat wave in 2010, which has stretched over large parts of Eastern Europe and affected also Central Europe and Central Asia.**

Image derived from NASA. Colours indicate the degree of positive (red, hotter) or negative (blue, colder) deviations from July 20-27, 2010 compared to the average temperature of the same dates over the measurement period 2000–2008, as obtained by the MODIS Earth Observation Satellite.
Source: https://earthobservatory.nasa.gov/images/45069.



4.7.2.5.3 Fire

An observed global increase in fire frequency and burnt area is most likely driven by climate (Marlon *et al.*, 2008). Fires have generally increased in recent decades in the Mediterranean area (EEA, 2012a; Pausas, 2004). Forest fires have also generally increased in Europe and Central Asia (Schelhaas *et al.*, 2003), with highest increases in the southern parts of Western, Central and Eastern Europe (EEA, 2012a), while the boreal forest in the north of the Europe and Central Asia region does not show increased fire frequency (EEA, 2012a; Lehtonen *et al.*, 2014). Trends in frequency of fires in Central Asia are less certain, but fires have also generally increased (Goldammer *et al.*, 2004). Risk and spread of fire is often a direct consequence of multiple other direct drivers, notably of drought, heat, and tree mortality due to insect disturbance (Bigler *et al.*, 2005; Clark *et al.*, 2016; Gouveia *et al.*, 2016).

Fire danger is projected to increase, especially for the Mediterranean areas of Western and Central Europe (Karali *et al.*, 2014; Khabarov *et al.*, 2014), and potentially for large parts of the Alpine Arc (EEA, 2012a) and boreal forests of Western Europe (EEA, 2012a; Lehtonen *et al.*, 2014). Fire danger projections for Eastern Europe and Central Asia are less certain, but increase in fire risk is potentially low in the north and moderate in the south of Eastern Europe (Mokhov *et al.*, 2006; Tchebakova *et al.*, 2009), and generally increased in Central Asia (Goldammer *et al.*, 2004).

4.7.2.5.4 Windthrow

Trends in windthrow are difficult to assess because they are rare, thus confidence in emerging trends is low. Studies consistently report an increase in storms or storminess from 1960 to 1990, yet no long-term trend reaching further back in time is available (Allan *et al.*, 2009; Bärring & von Storch, 2004; Matulla *et al.*, 2008; Schelhaas *et al.*, 2003; Wang *et al.*, 2009). The number of available studies and the certainty of trend assessments are highest for Western Europe and lower for Central Europe, Eastern Europe, and Central Asia.

Future projections of extreme winds are highly uncertain (IPCC, 2012). A north-south gradient with more extreme winds in the north and less extreme winds in the south is projected for Western and Central Europe (Beniston *et al.*, 2007; Mcinnes *et al.*, 2011), but the expected poleward shift of extra-tropical storm tracks (IPCC, 2012) indicates increased extreme winds for Western Europe in general, and therefore an increase is very likely for coastal habitats. Eastern Europe is projected to be under increased wind throw risk across most of its range, while Central Asia will likely experience less extreme winds (Beniston *et al.*, 2007; Mcinnes *et al.*, 2011).

4.7.2.5.5 Trends in marine circulation and deoxygenation

Among all marine waters in Europe and Central Asia, the Mediterranean Sea could be particularly vulnerable to climate variations (Turley, 1999) and was identified as a hot spot for climate change (Giorgi, 2006). It is indeed characterized by very short ventilation and water residence times (70 years) compared to other oceanic zones (Durrieu de Madron *et al.*, 2011). This specificity makes it a marine area where climate variations may strongly and rapidly impact hydrodynamics and marine ecosystems.

4.7.2.5.6 Ocean warming

From the 1980s to the late 2000s, the surface temperature of the North Atlantic has warmed faster than the overall northern hemisphere, as is depicted in the Atlantic multi-decadal oscillation index (www.esrl.noaa.gov/psd/data/timeseries/AMO/). This is also seen in an enhanced warming of the upper ocean integrated to 700 m, with particularly large changes in the eastern Atlantic inter-gyre region, as well as on the outskirts of the North Atlantic sub-polar gyre (but not in the Nordic Seas). Hydrological observations showed that the temperature and salinity of the western Mediterranean deep-water masses have increased by 0.0034°C/year and 0.0011 psu/year between 1959 and 1997 (Bethoux *et al.*, 1998). Numerical studies confirmed that the increase of net atmospheric heat flux to the sea surface associated to climate change could induce a warming and a salinization of Mediterranean water masses, in particular at the surface, as well as an intensification of the water column stratification and a weakening of the thermohaline circulation and winter deep convection (Adloff *et al.*, 2015; Bozec, 2006; Herrmann *et al.*, 2008; Somot *et al.*, 2006; Thorpe & Bigg, 2000).

4.7.2.5.7 Water masses and horizontal circulation

Climate change has also been identified as cause of weakening and shrinking the North Atlantic sub-polar gyre and a shift of the sub-polar front (Hatun, 2005). This westward shift of the sub-polar front implies that the waters in the eastern North Atlantic part of the inter-gyre gyre seem to originate in recent decades from further south (and get warmer and saltier) than in the 1950-60s. This represents a shift to more subtropical origin and implies an increased northward flow along Western Europe (Lozier & Stewart, 2008).

In addition, there is clear evidence from upper temperature and salinity measures of a near decadal variability in the North Atlantic sub-polar gyre, propagating in a few years all the way through the Nordic Seas towards the Barents Sea (Yashayaev & Seidov, 2015). Atmospheric forcing or input of cold and fresh water from the Arctic could contribute to these signals that have been observed since regular observations began at least 60 years ago. The origin of this ocean variability is debated, and could be in part natural but also anthropogenically enhanced (for example more North Atlantic oscillation-related atmospheric variability, or variable fresh water exports from the Arctic Ocean). It is also possible that some of these changes in the warming and vertical structure will reverse, as the Atlantic multidecadal oscillations (AMO) shifts to another phase, as has been witnessed twice in the past 120 years.

4.7.2.5.8 Vertical circulation and mixing

There is debate as to whether the meridional circulation component of the ocean circulation (Atlantic Meridional Overturning Circulation) has or has not become stronger during the last century. There is accumulating evidence that a slow-down of this circulation is outruled by its large interannual to decadal variability, for example induced by wind variability (Rahmstorf *et al.*, 2015). This seems logical, based on the expectation that Atlantic Meridional Overturning Circulation intensity is influenced by changes in surface water density. Thus, an observed reduction in surface density could result in a decrease in Atlantic Meridional Overturning Circulation. A decrease in surface density seems to have happened in those areas since 1996 until the early 2010s, as the change due to surface warming was not fully compensated by the change due to salinity increase. This is, however, difficult to accurately estimate from observations over the relevant time scales.

It is likely that some of these observations and regional patterns of variability might be dependent on natural multi-decennial variability such as the North Atlantic oscillation, but there are fewer observations to support this. However, these long time-scale trends can be interrupted as the result of intense vertical mixing in individual years, such as in 2005 in the Bay of Biscay (Somavilla *et al.*, 2016). Clearly, there is also a very large year-to-year variability as the result of surface forcing in the eastern Atlantic north of 35-40°N.

4.7.2.5.9 Ocean acidification

The uptake of increased anthropogenic CO_2 is causing profound changes in seawater chemistry resulting from increased hydrogen ion concentration (decrease in pH) referred to as ocean acidification (IPCC, 2013b). Repeated hydrographic sections provide an understanding of these changes in the basin-wide seawater CO_2 chemistry over multi-decadal timescales. The formation of "North Atlantic deep water" makes the Atlantic unique with regards to the depths to which anthropogenic CO_2 can penetrate over these time scales, reaching the bottom at about 3,000 m in the far north of the North Atlantic (Wanninkhof *et al.*, 2010). Here, the ocean acidification signal adds to that of temperature. As a consequence, the lysocline, i.e. the depth in the ocean below which the rate of dissolution of calcite increases dramatically, could be shallower in polar regions while the decreased rate of pH is expected to be similar to the other latitudes.

A recent estimate suggests that all water masses in the Mediterranean Sea are also already acidified (-0.14 to -0.05 pH units; Touratier & Goyet, 2011). Considering the highest values of this range, the Mediterranean Sea appears to be one of the most acidified marine basins in the world. Yet, as far as we know, no estimates of future acidification rates in the Mediterranean Sea have been carried out.

4.7.2.6 Trends in atmospheric CO_2 concentration

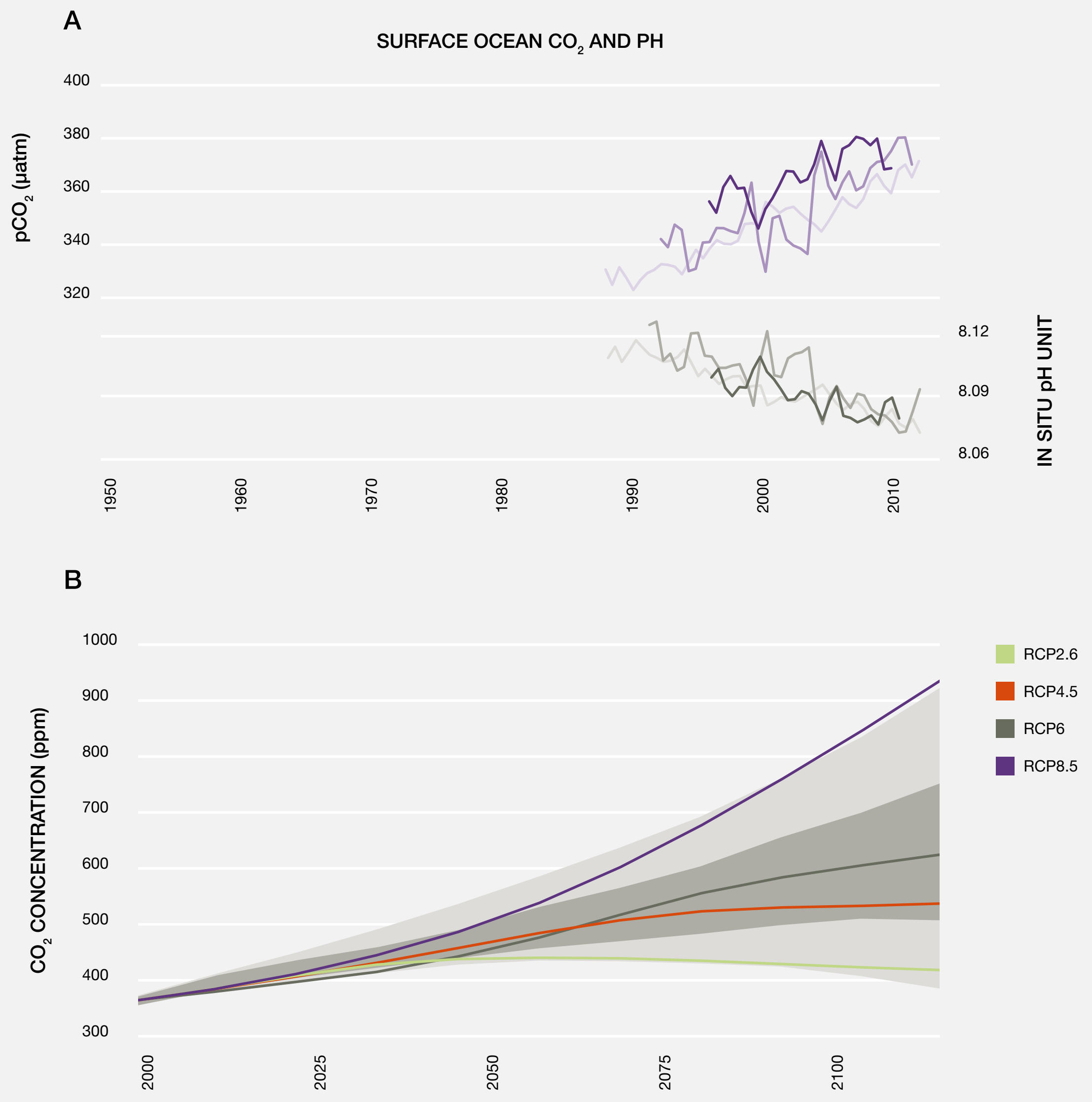
The atmospheric concentration of CO_2 is rising with the well-known seasonal pattern, and this trend is accelerating steadily (IPCC, 2013b). While from 1965-1974 the atmospheric CO_2 concentration increased by 1.06 ppm/yr, this increase has reached 2.11 ppm/yr for the decade 2005-2014, and in 2013 the level of 400 ppm of atmospheric CO_2 concentration was reached (IPCC, 2013b) for the first time since about 23 million years ago (Pearson & Palmer, 2000). This steady increase in atmospheric CO_2 affects the ocean surface partial CO_2 pressure, and the increase of this partial pressure reduces the ocean pH, leading to steady acidification **(Figure 4.68)**, and the trend is expected to continue over the 21st century **(Figure 4.68)**.

The steady increase in atmospheric CO_2 concentrations originates from spatially variable emission patterns, and these emissions are projected to depend on socio-economic determinants reflecting human decisions (indirect drivers) regarding greenhouse gas emissions. **Figure 4.69** illustrates the CH_4 (methane) emission patterns for 2100 according to the four representative concentration pathway (RCP) scenarios that represent different levels of radiative forcing.

4.7.3 Indirect drivers influencing climate change

Drivers of climate change are the same regardless of whether we are ultimately interested in effects on biodiversity, nature's contributions to people, or other effects. Drivers of emissions from land-use change have been discussed in Section 4.5. Drivers of greenhouse gas emissions have been assessed in the fifth assessment report of the Intergovernmental Panel on Climate Change (Blanco *et al.*, 2014) and will not be repeated here. However, in contrast to the global level, both primary energy and CO_2 emissions in Europe and Central Asia have been reduced since 1990 **(Figure 4.70)**.

Figure 4 68 **A Partial pressure of dissolved CO_2 at the ocean surface (violet, upper curves) and in situ pH (grey curves), a measure of the acidity of ocean water recorded in three different locations in the Atlantic and Pacific Ocean. Source: Figure SPM.4 from IPCC (2013b). B Trends in concentrations of greenhouse gases. Grey area indicates the 98th and 90th percentiles (light/dark grey) of the recent EMF-22 study (Clarke *et al.*, 2009). Source: van Vuuren *et al.* (2011).**



To analyse the reasons for this decreasing mission, we use the "Kaya identity" (Kaya, 1990) for territorial CO_2 emissions:

$$CO_2 \text{ emissions} = population \times \frac{GDP}{population} \times \frac{energy}{GDP} \times \frac{CO_2}{energy}$$

The two last parts of the Kaya identity, energy intensity of GDP and CO_2 content of energy production, have declined since 1990 in all developed and large developing countries mainly due to technology, changes in economic structure, the mix of energy sources, and changes in the participation of inputs such as capital and labour used (Blanco *et al.*, 2014).

Figure 4.71 shows the relative contribution of each term of the Kaya identity to the annual change in CO_2 emissions in Europe and Central Asia. By comparing the size of the different bars one notices that the growth of GDP per capita (second term of the Kaya identity) is the main driver of CO_2 emission increase, which is well-established (Blanco *et al.*, 2014) and that its effect has for most years only been partially offset by improvements in the energy intensity of GDP (third term) and the CO_2 emissions intensity of energy production (fourth term).

Figure 4 69 **Emission pattern for 2100, for CH_4 across the four representative concentration pathways (RCPs). Source: van Vuuren *et al.* (2011).**

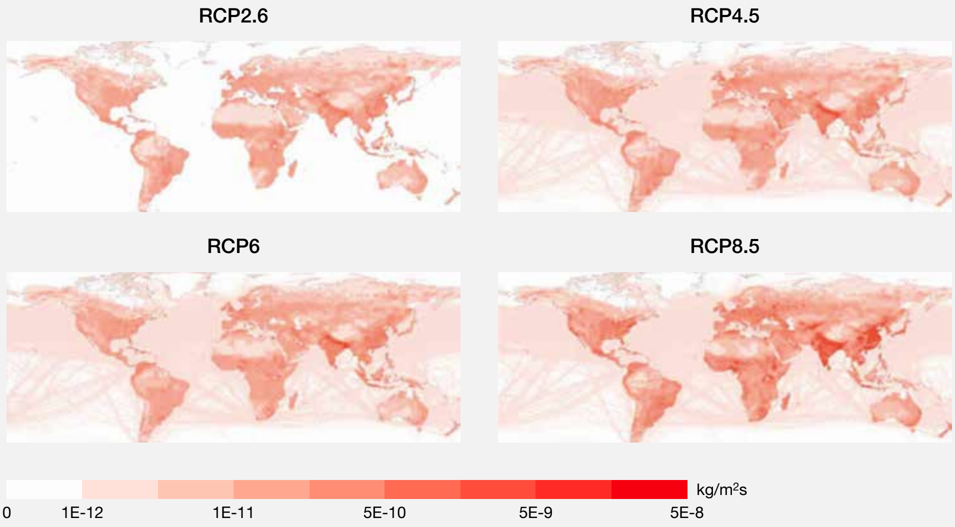
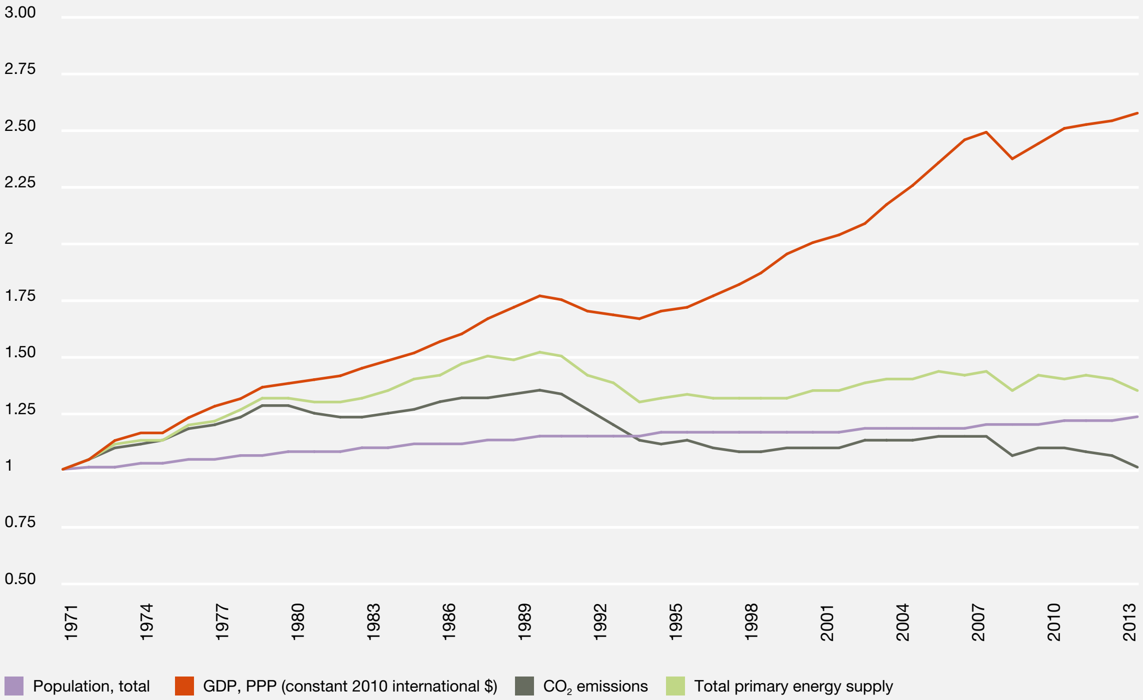


Figure 4 70 **Territorial CO_2 emissions in relation to other factors in Europe and Central Asia, 1971–2014. Source: Own representation based on OECD (2016).**



The time series in **Figure 4.71** shows two structural breaks, the first after the dissolution of the Soviet Union and the second following the great recession. These years with negative GDP growth (1991-1993 and 2009) were also the years with highest reduction in CO_2 emissions.

As reported in **Table 4.7**, between 1995 and 2008 energy and emissions increased at a lower rate than before 1990, while average GDP continued increasing at more or less the same rate (relative decoupling). In the last four years of available data (2011-2014), there is evidence of small increases in GDP growth, but decreasing paths in both energy and CO_2 emissions (absolute decoupling).

Figure 4 71 **Kaya decomposition of CO_2 emissions change in Europe and Central Asia. Source: Own representation based on OECD (2016). "Energy" is total primary energy supply, while "GDP" is taken in purchasing power parity values at 2010 international US dollars.**

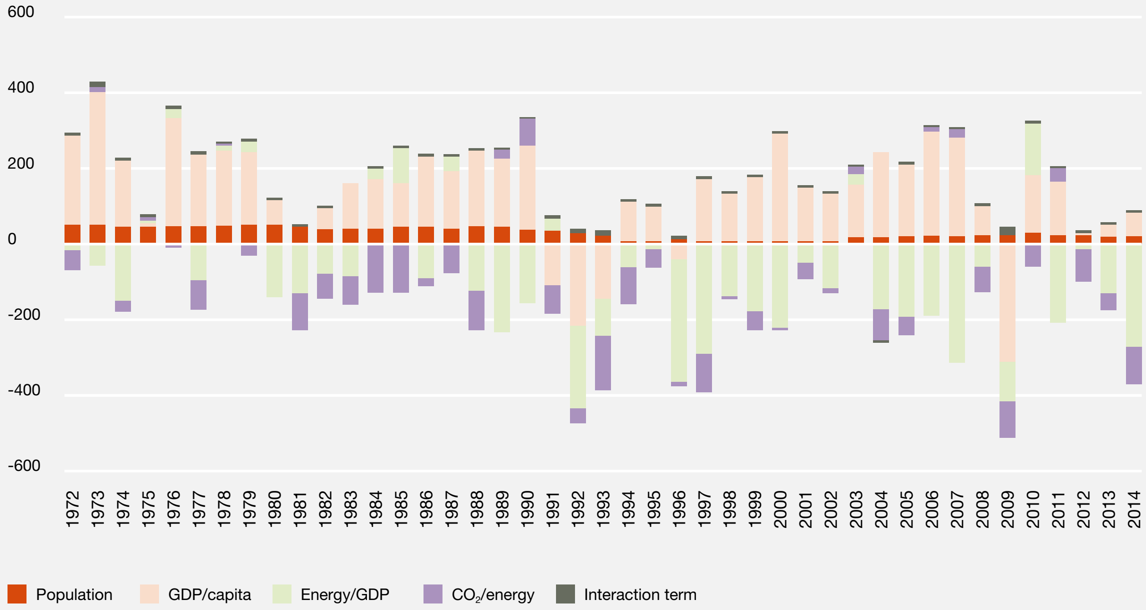


Table 4 7 **Rates of change of population, GDP, CO_2 emissions, and energy in Europe and Central Asia. Source: Own elaboration based on OECD (2016). PPP denotes purchasing power parity.**

Rates of growth of	1971-1990	1995-2008	2011-14
Population	0.7%	0.2%	0.4%
GDP, PPP (constant 2010 international US $)	3.0%	2.9%	1.4%
CO_2 emissions	1.6%	0.1%	-2.0%
Total primary energy supply	2.2%	0.7%	-1.2%

Two caveats are to be considered. First, the data refer to the aggregation of all countries in Europe and Central Asia. Within this region different patterns are observable and, as noted by the Intergovernmental Panel on Climate Change, the increase of emissions for an additional person varies widely, depending on geographical location, income, lifestyle, and the available energy resources and technologies (Blanco *et al.*, 2014). Second, there is no clear evidence whether (and to what extent) the relative decoupling of CO_2 emissions from GDP growth, indicated by much slower growth of CO_2 partial to GDP as observed from 1995, and the absolute decoupling, indicated by a CO_2 decrease at growing GDP from 2011 are the outcome of interregional flows, e.g. de-industrialization in the region caused by economic growth of countries in other regions. According to some researchers, the relevant decoupling is between prosperity and CO_2 emissions, not GDP growth and CO_2 emissions (Jackson, 2009; Raworth, 2017; van den Bergh, 2010).

The drivers of climate change are not limited to the energy and transportation sectors or the Kaya identity. In Section 4.5.1 we assessed intensive agriculture as a carbon source and sequestration by forests as carbon sink. A more comprehensive illustration of major drivers of climate change and their interactions, and impacts on biodiversity, is presented in **Figure 4.72**.

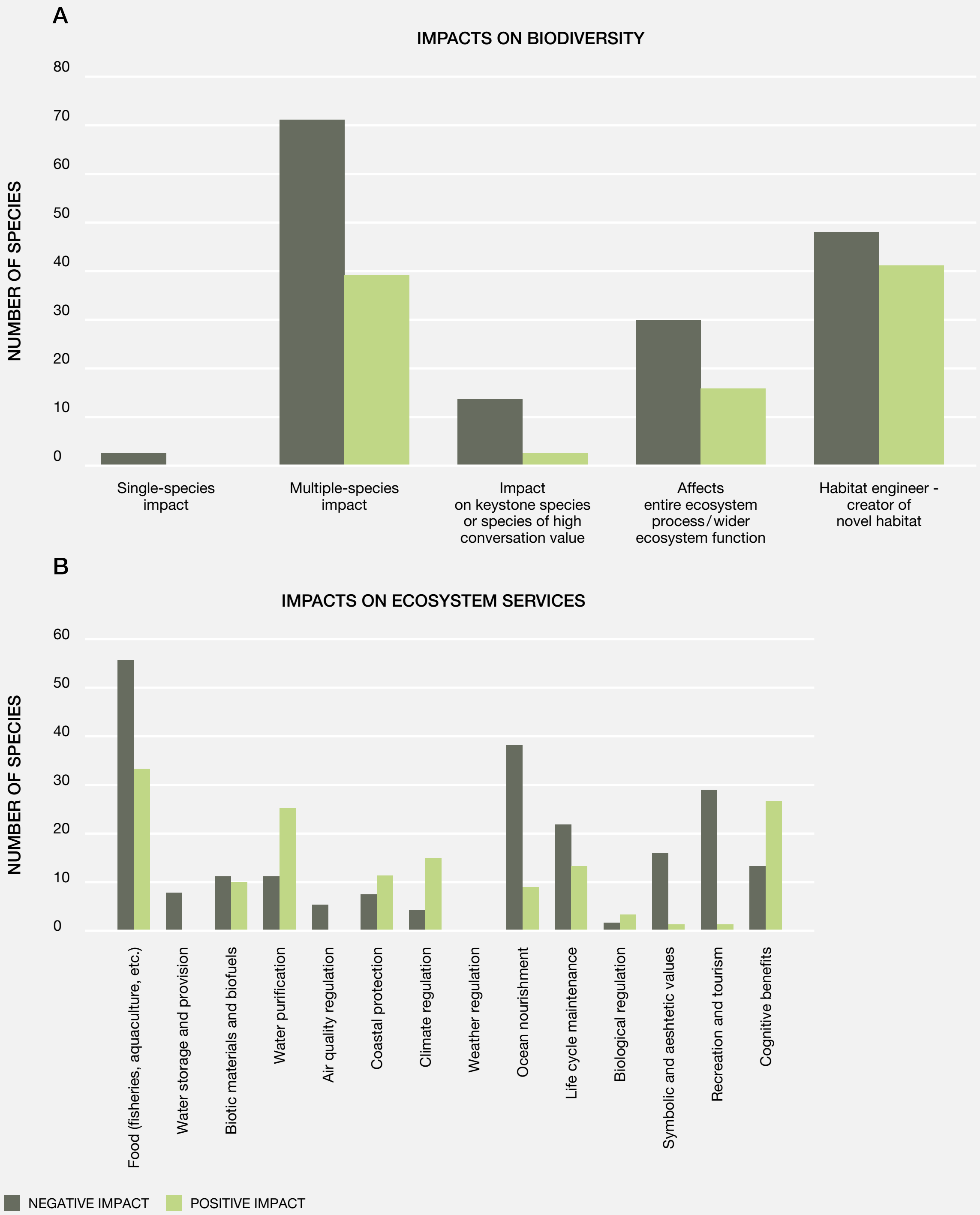
Figure 4 72 **Causal loop diagram of drivers of climate change, illustrating the main causes of climate change. Source: Own representation. See text for further clarification.**

4.8 DRIVERS AND EFFECTS OF INVASIVE ALIEN SPECIES

4.8.1 Effects of invasive alien species on biodiversity and nature's contributions to people

Invasive alien species are among the important direct drivers of loss of biodiversity and nature's contributions to people across Europe and Central Asia, especially in combination with other direct drivers (Section 4.9.1) (Anastasopoulou *et al.*, 2007; Clavero *et al.*, 2009; Katsanevakis *et al.*, 2014; MEA, 2005b; Nelson *et al.*, 2005; Sala, 2000). Invasive alien species generally tend to have negative effects on biodiversity **(Figure 4.73)**. However, their magnitude and direction vary both within and between types of impact, across taxa and environments (Bradshaw *et al.*, 2016; IPBES, 2016a; Potts *et al.*, 2016; Vilà & Ibáñez, 2011). Negative effects can include displacement and extinction of native species, gene pollution, homogenization of communities, modification of biological interactions, communities, habitats and ecosystem functions, with consequences for human health; and agricultural and economic production (IPBES, 2016a; Katsanevakis *et al.*, 2014; Vilà *et al.*, 2010). Some alien species, and even some invasive alien species, have positive impacts, which include provision of habitat; increasing local species richness and associated ecosystem services, with subsequent economic gains;

Figure 4 73 **Overview of the number of marine alien taxa (out of 110 investigated taxa) that have been reported to affect A biodiversity and B ecosystem services (nature's contributions to people) in marine habitats of Europe and Central Asia. Source: Katsanevakis *et al.* (2014).**



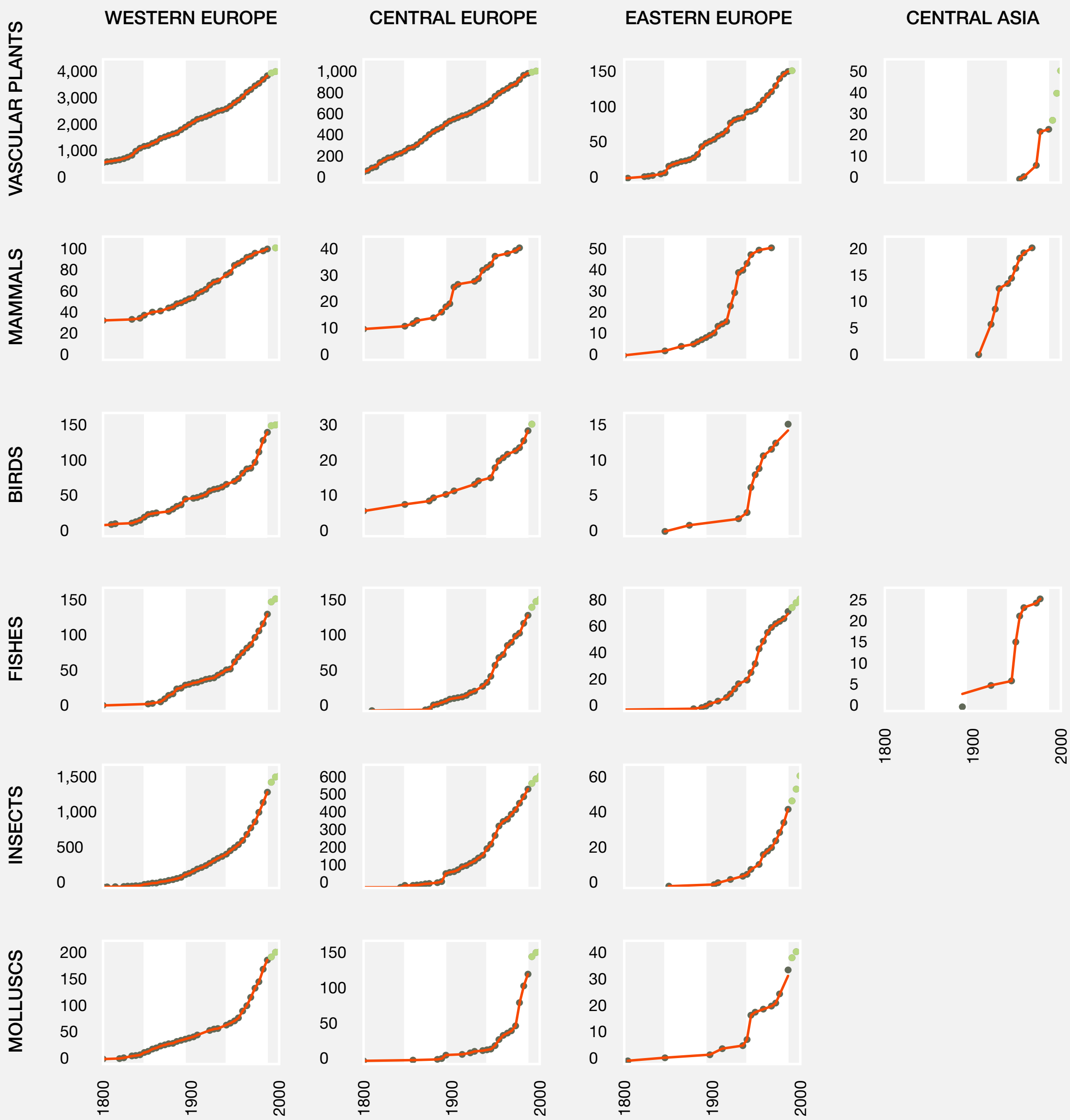
ecosystem engineering; and aesthetic and cultural value (Goodenough, 2010; IPBES, 2016a; Schlaepfer *et al.*, 2011). Data limitations across the region, particularly in Central Asia (Dinasilov, 2013; Khlyap & Warshavsky, 2010; Mamilov *et al.*, 2010; Reshetnikov, 2010) and for pathogens (Roy *et al.*, 2017), impede assessment of trends associated with invasive alien species. Priority should be given to improving the evidence-base for impacts of invasive alien species and thereby capacity to inform future assessments (Gurevitch & Padilla, 2004; Jeschke *et al.*, 2014).

Invasive alien species have considerable economic impacts on forestry (Roy *et al.*, 2014b) and agriculture (Paini *et al.*, 2016). Invasive alien insects alone have been estimated to cost US$2-3.6 billion per year in Western and Central Europe, mostly due to impacts on forestry and agriculture, while invasive alien species can have significant impacts on human health, for example via disease transmission and allergens (Bradshaw *et al.*, 2016; Schindler *et al.*, 2015). However, such impacts are considered to be grossly underestimated because of the limited number of studies available within and across Europe and Central Asia (Bradshaw *et al.*, 2016; Schindler *et al.*, 2015).

Most invasive alien species present in marine habitats in Europe and Central Asia have been reported to affect more than one species **(Figure 4.73)** (Katsanevakis *et al.*, 2014).

Figure 4 74 **Cumulative number of alien species between 1800 and 2000 (dots) for six taxonomic groups in subregions of Europe and Central Asia.**

The trend is indicated by a running median (red line). Data after 2000 (grey dots) are incomplete and not included in the trend analysis. Source: Adapted from Seebens *et al.* (2017).



Invasive alien species within freshwater environments can cause alterations to the physical, chemical and ecological state eliciting cascading effects that modify biodiversity (Martel *et al.*, 2014), and ecosystem structure and function (Kernan, 2015). Freshwater ecosystems are particularly vulnerable to invasions and the impacts of invasive alien species and so the magnitude of the impact and the consequential ecological transformations are often more severe than in terrestrial ecosystems (R. Francis, 2012; Ricciardi, 2015).

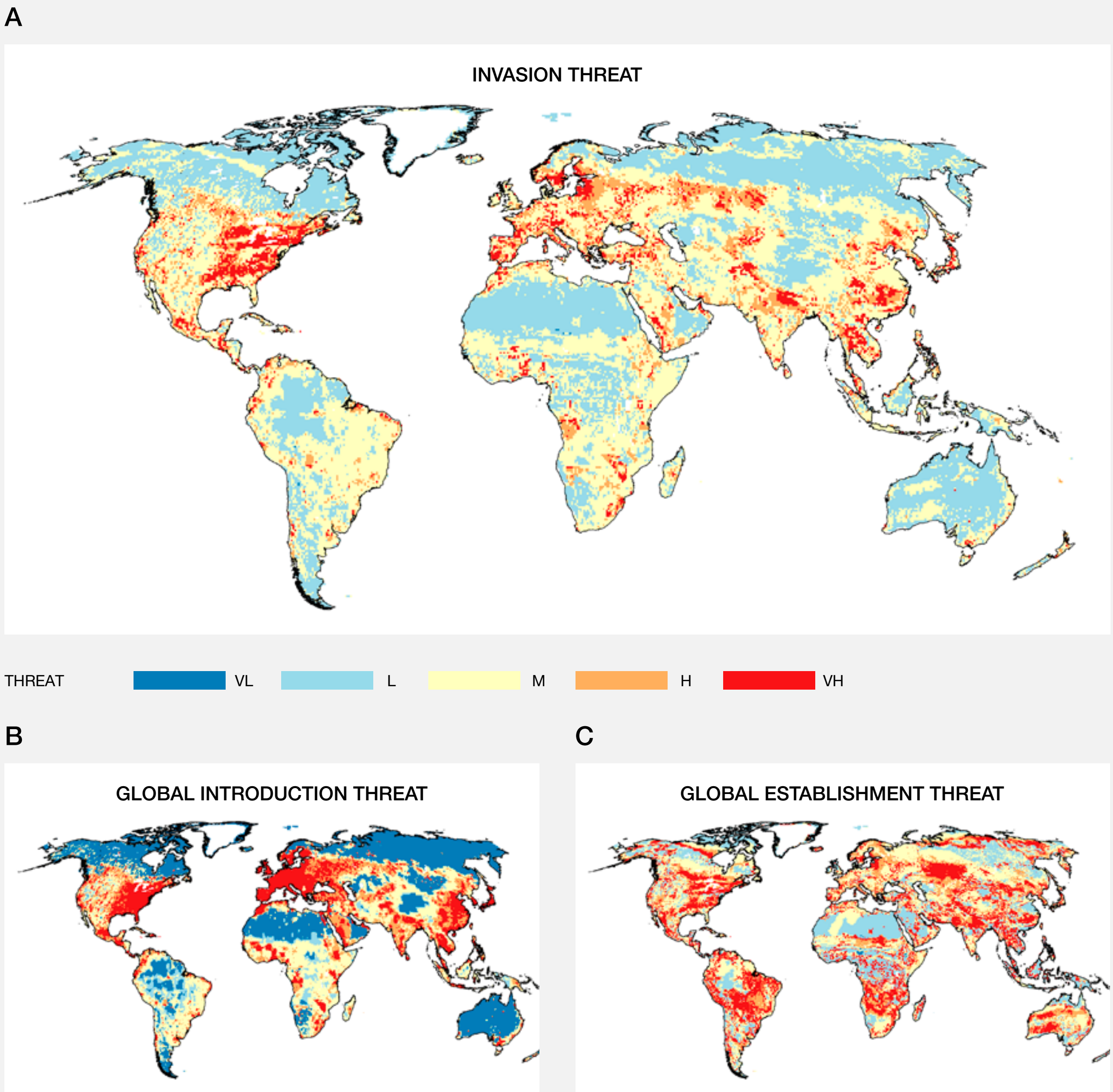
4.8.2 Trends in invasive alien species

4.8.2.1 Recent trends

Rates of invasions in Europe and Central Asia have increased markedly since the beginning of the 20th century and the scale and impacts are still increasing, despite increased legal and social responses in recent years (Rabitsch *et al.*, 2016). The number of alien species has increased by 76%

Figure 4 75 **Global invasion threat for the 21st century. Source: Modified from Early *et al.* (2016).**

Airport and seaport capacity, as well as animal, plant and total imports between 2000 and 2009, was combined into global introduction risk. Projected biome shifts and increase in agricultural intensity and fire frequency between 2000 and 2100 (emissions scenario A2) were combined into global establishment threat. Introduction and establishment axes were combined into overall invasion threat.
A invasion threat, B introduction threat, C establishment threat. All maps are displayed using the colour scheme from A, which runs from very high (VH; red) to very low (VL; blue). The scale was determined by ranking the threat value in each map grid cell, and binning cells into the following percentiles: 100–90% = very high; 90–80% = high; 80–50% = medium; 50–20% = low; and 20–0% = very low.



between 1970 and 2007 (Butchart *et al.*, 2010). This trend is similar across all environments, taxonomic groups (except mammals), and all subregions of Europe **(Figure 4.74)** (Butchart *et al.*, 2010; DAISIE, 2009; Seebens *et al.*, 2017). Even in remote Arctic and sub-Arctic regions in Europe the number of introduced alien species is substantial (Lembrechts *et al.*, 2014; Ware *et al.*, 2012). In Europe and Central Asia, the highest numbers of reported introductions for most species groups have occurred in Western Europe, but this is expected to increase in Central Europe and Eastern Europe. Data for Central Asia is less comprehensive than for the other subregions; but it is likely that the Central Asia trends are similar to other subregions based on comparable economic developments that are a major driver for invasions (Chytrý *et al.*, 2012; Seebens *et al.*, 2015; Vicente *et al.*, 2010).

The number of eradication attempts, and of successful eradications, have been increasing rapidly since the 1990s, but have been mostly confined to Western Europe (DIISE (2015); DAISIE: Database of Island Invasive Species Eradications http://diise.islandconservation.org/, 2017). Eradication of invasive alien species tends to be more successful in offshore island habitats and anthropogenic habitats than in (semi-) natural habitats (DIISE, 2015; Pluess *et al.*, 2012).

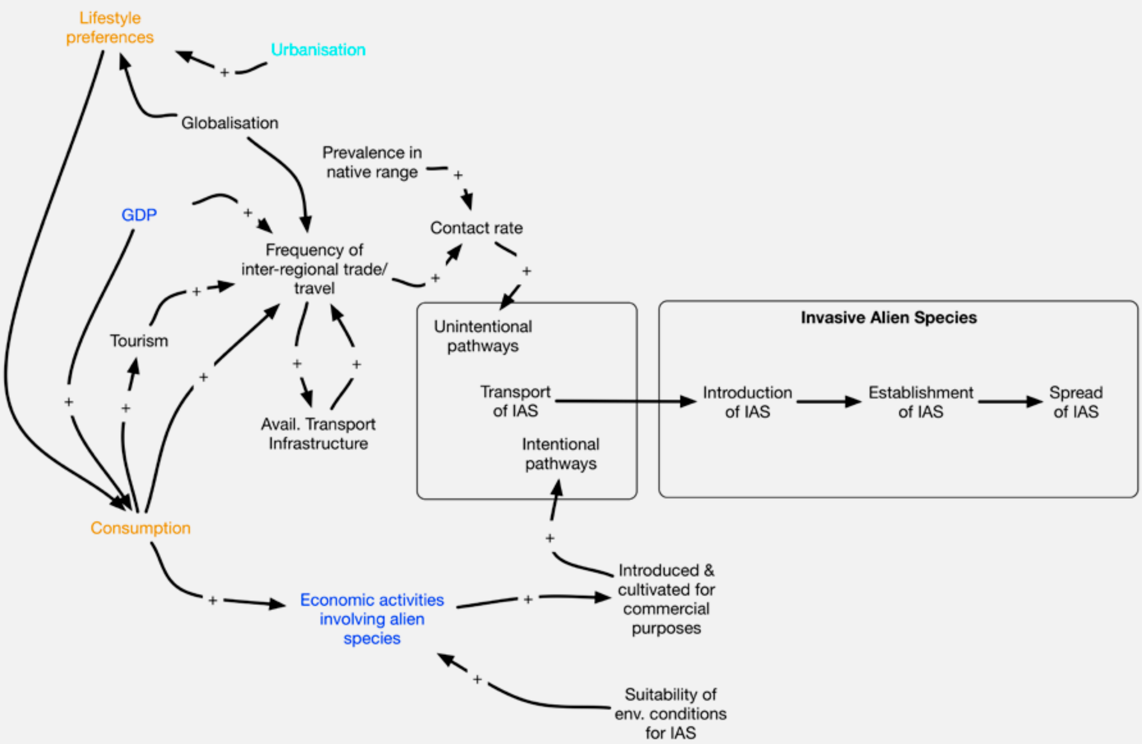
4.8.2.2 Projected future trends

The overall rate of introduction of alien species shows on average no sign of slowing (Chytrý *et al.*, 2012; Seebens *et al.*, 2015) and will most likely remain high or even accelerate due to increasing trade and changing climate (Bellard *et al.*, 2012; Seebens *et al.*, 2017). This high rate is very likely to continue in the short-term, but long-term trends are less clear because they depend on the success of management and policy interventions. Management of invasive alien species is receiving increasing attention but little remains understood about which factors affect the likelihood of successful management (Pluess *et al.*, 2012).

Overall, the invasion threat during the 21st century is expected to be medium to very high in most of the parts of Europe and Central Asia (Early *et al.*, 2016) **(Figure 4.75 A)**. The exceptions are northern areas of the region, where the threat of invasive alien species is still considered low,

Figure 4 76 **Causal loop diagram of drivers of invasion by alien species. Source: Own representation.**

The invasion process includes both intentional and unintentional introduction pathways. Interlinked economic, socio-cultural, and demographic drivers account for most introduction of alien species. IAS: Invasive alien species.



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

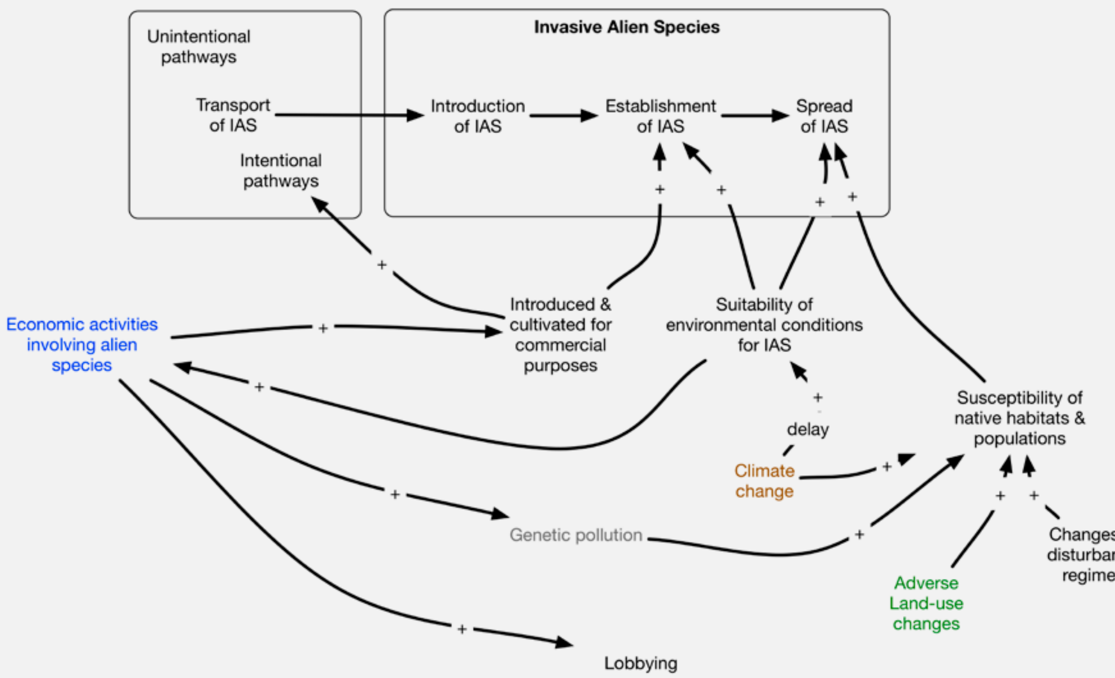
although rapidly increasing due to increasing tourism, more human disturbances, and climate warming (Lembrechts *et al.*, 2014, 2016; Pauchard *et al.*, 2016; Ware *et al.*, 2012) **(Figure 4.75 B)**. The future outcomes of invasions will depend on adoption of effective management and policy measures (Section 4.8.3). For example, plant invasion levels in Western and Central European regions are expected to remain high under "business-as-usual" scenario over the next 60 years (Chytrý *et al.*, 2012). In Eastern and Central European subregions, unprecedented increases in invasive alien species are expected during the 21st century, mostly due to increased transport and indirect effects of socio-economic drivers on other direct drivers (Early *et al.*, 2016). Increasing human population density and increasing national wealth (GDP) are associated with increased risk of alien species introduction and establishment (Chytrý *et al.*, 2008). Lower capacity to apply preventive or mitigation measures, for example in certain Eastern and Central European countries, means that the threats posed by invasive alien species will be greater (Early *et al.*, 2016).

The risk of further invasive alien species establishment is exacerbated because of projected growth in direct (e.g. land-use and climate changes, pollution) and indirect (e.g. trade) drivers facilitating invasions (Bellard *et al.*, 2013; Chytrý *et al.*, 2008, 2012; Early *et al.*, 2016; IPCC, 2014a; Seebens *et al.*, 2015; Vicente *et al.*, 2010) (see **Figure 4.75 C**). Some species could increase in abundance in many areas under changing climate conditions, such as grey squirrels that are replacing native red squirrels (Bertolino *et al.*, 2014). Other examples include the caterpillar *Thaumetopoea pityocampa* that is threatening Scots pine in locations that were previously too cold (Bernardinelli *et al.*, 2006); the overlap between native crayfish and invasive crayfish plague-transmitting species is also projected to increase in Europe (Capinha *et al.*, 2013). Especially in northern regions, climate warming is expected to affect the number and impact of alien species (Pauchard *et al.*, 2016).

The European Union has recently adopted European Union Regulation 1143/2014 (Section 4.8.3) on invasive alien species. The efficacy of such legislation depends on the commitment of member countries to allocate sufficient resources and ensure adequate enforcement. Furthermore, the ultimate success of regulatory approaches depends on raising public awareness of the threat of invasive alien species leading to changes in lifestyle and consumption preferences (Genovesi *et al.*, 2015). In many countries in the region, awareness, expert knowledge, legislation and allocation for managing threats from invasive alien species

Figure 4 77 **Causal loop diagram of the drivers of establishment and spread of invasive alien species (IAS). Source: Own representation.**

The suitability of environmental conditions has a strong influence on both the economic viability of intentionally introduced species as well as the establishment and spreading of invasive species. A number of indirect drivers including climate change and land-use change also influence the suitability of environmental conditions and the susceptibility of native habitats and populations to invasion.



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

is increasing (Early *et al.*, 2016; Turbelin, 2017) but the efficacy of these measures is yet to be assessed. Overall, the analysed literature suggests that neither Target 5 of the European Union Biodiversity Action Plan nor Aichi Biodiversity Target 9 ("protected areas increased and improved") of the Strategic Plan for Biodiversity 2011-2020, will be met for Europe and Central Asia.

4.8.3 Indirect drivers influencing invasive alien species

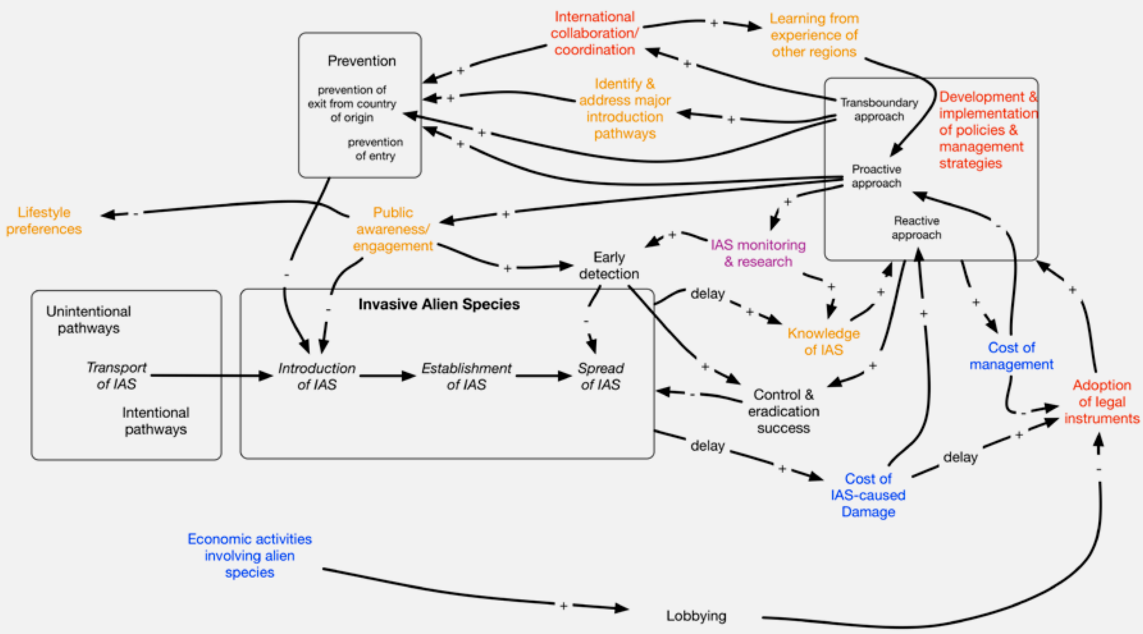
The invasion process (i.e. transportation, introduction, establishment and spread) is strongly influenced by economic factors including trade and tourism (see **Figure 4.76**) (Essl *et al.*, 2011; Pyšek *et al.*, 2010; Seebens *et al.*, 2017; Turbelin *et al.*, 2017). Economic activities, either intentional or non-intentional, are the foremost influence on introduction pathways of alien species (see **Figure 4.77**). Most economic drivers have increased in Europe and Central Asia, and they can be associated with an increase in numbers of invasive alien species (Katsanevakis *et al.*, 2013; Turbelin *et al.*, 2017; Zieritz *et al.*, 2017). Economic development, especially in emerging economies, will drive future invasions as tourism, trade (including the pet and aquaria trade) and infrastructure projects accelerate the introduction of invasive alien species via the escape, contaminant, stowaway and corridor pathways (Hulme, 2015) (see **Figure 4.80** and **Figure 4.81**).

The main pathway for intentional (and to some extent un-intentional) introductions of invasive alien species in all taxonomic groups in Europe and Central Asia is trade of horticultural and ornamental plants (Turbelin *et al.*, 2017; Zieritz *et al.*, 2017). Invasion pathways related to tourism are also likely to increase in importance over the next few decades. Tourists introduce alien species, including potential invasive alien species with a high survivorship, on their clothing, footwear and equipment, for example via transportation of soil containing living organisms (bacteria, fungi, seeds, nematodes, arthropods - McNeill *et al.*, 2011). A greater frequency of contact between tourists and potential invasive alien species is likely because current high levels of international tourist movements are expected to grow up to 2030 and there is increased tourist preference for recreation (e.g. golf, fishing), agrotourism, remote places (e.g., mountains, Arctic), national parks (Hulme, 2015; Pauchard *et al.*, 2016).

The establishment and spread of invasive alien species is ultimately influenced by the suitability of environmental conditions (see **Figure 4.77**) in recipient biomes, or the ability of the invading species to adapt to these conditions or otherwise to self-create suitable conditions.

Figure 4.78 **Causal loop diagram illustrating costs from and resulting policies due to invasive alien species (IAS). Source: Own representation.**

Impacts and costs resulting from increased abundance of invasive alien species has driven the adoption of legal instruments in Europe and Central Asia. Most policies are reactive in nature, focusing on control and eradication measures once species have become established.



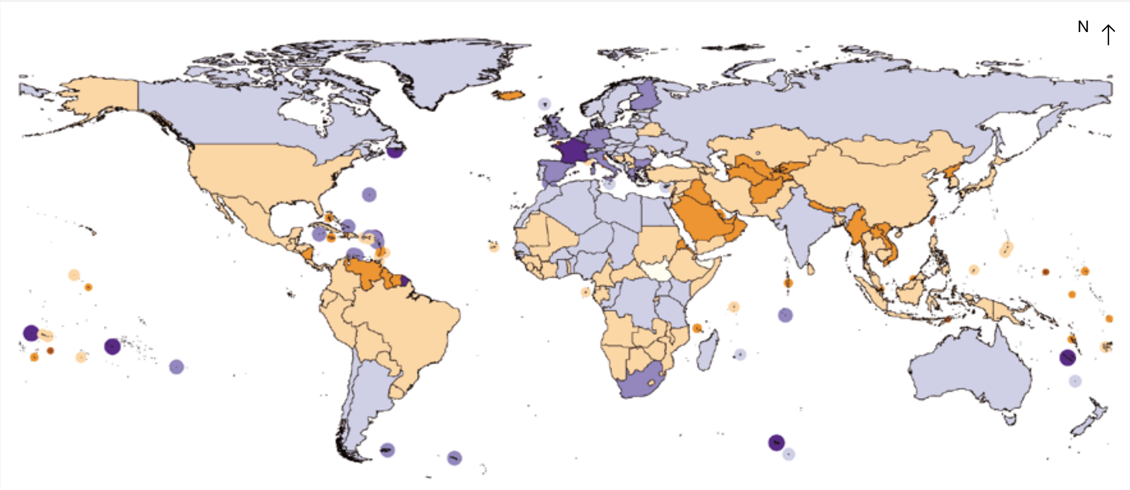
Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

Environmental suitability is a dynamic quality of biomes, subject to influence by climate change, and a key economic factor in determining species viability for import and cultivation (e.g. horticultural and silvicultural trade) and thus represents an important component of establishment processes (Chapman *et al.*, 2017; Early *et al.*, 2016). In addition to environmental suitability, the spread of established invasive alien species is also a factor of the susceptibility of native habitats and populations to further invasion. This susceptibility is influenced by a number of

Figure 4 79 **Global map of legal instruments (1933–2015) relevant to invasive alien species (IAS).**

Shown are A number of international treaties mentioning invasive alien species to which each country is signatory, including global and regional treaties for 1933–2015 and B map of the maximum relevance score for each country that has national or sub-national regulations of legislation in place, relevant to invasive alien species (1980–2015). Overseas territories have been allocated the same number of international treaties as their sovereign state. Source: From Turbelin *et al.* (2017).

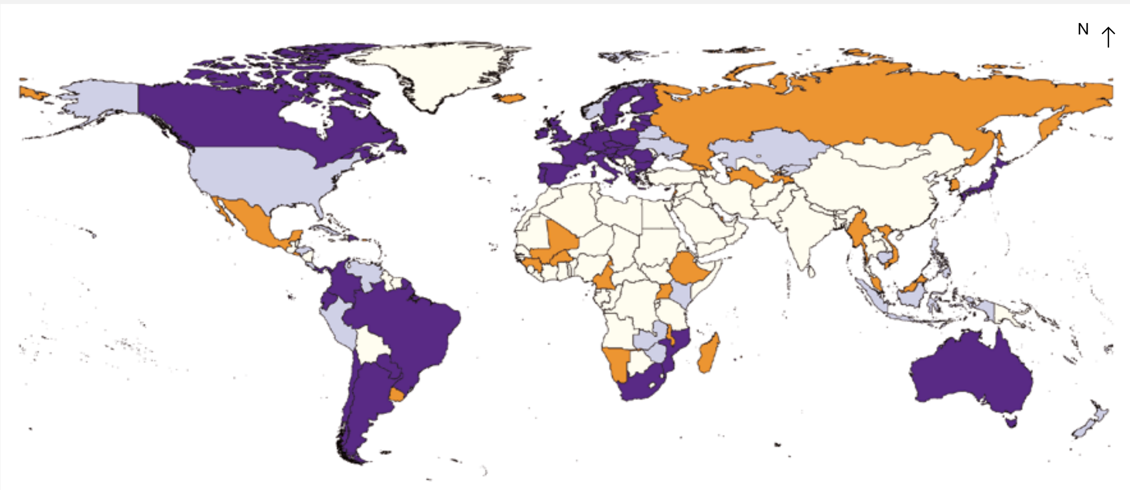
A



N_{IT} (#INTERNATIONAL TREATIES)

30 25 20 15 10 5 0 NO DATA

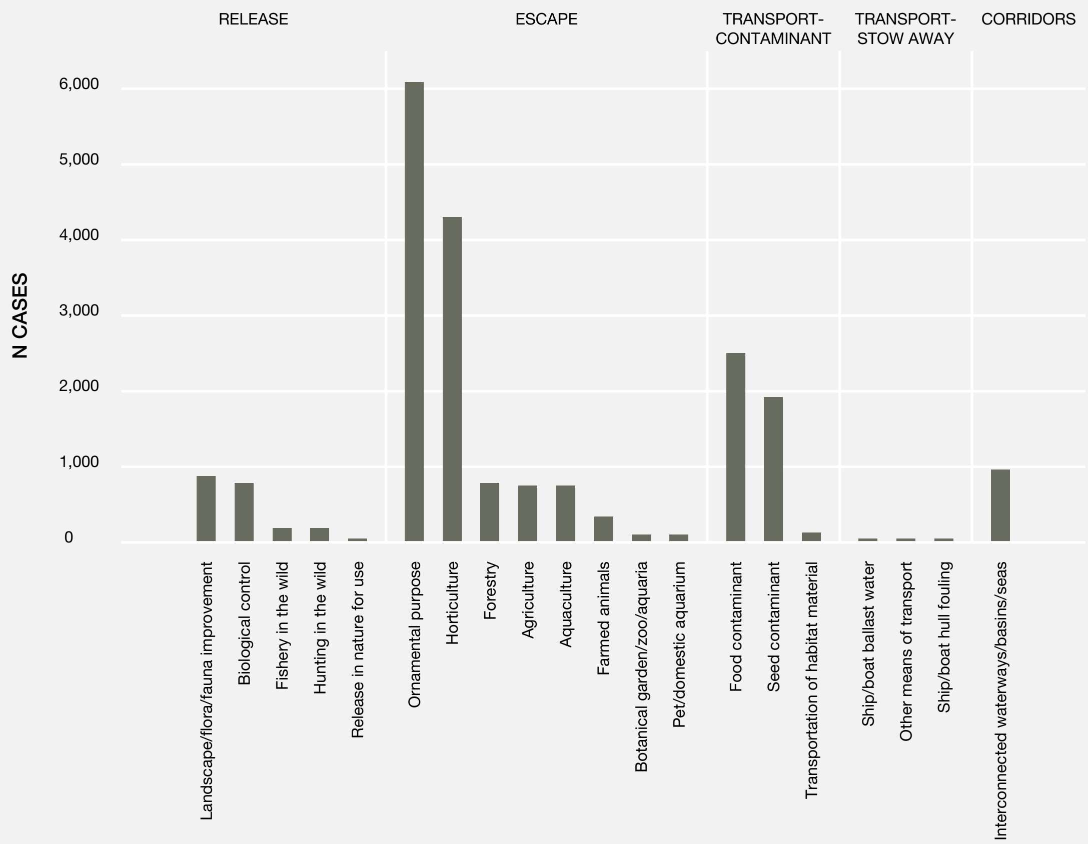
B



Maximum relevance score in country for legislations/regulations:

- Maximum relevance score = 4: The majority or entirety of an instrument dedicated to IAS.
- Maximum relevance score = 3: Has either a section, paragraph or chapter of an instrument dedicated to IAS.
- Maximum relevance score = 1 or 2: Refers to and mentions possible actions towards IAS.
- Has no IAS relevant regulations/legislations in ECOLEX.

Figure 4 80 **Frequencies of introduction pathways of known cases of introduction of over 14,000 invasive alien species profiled in the Delivering Alien Invasive Species Inventories for Europe (DAISIE); level 2 categories. Source: CBD (2014).**



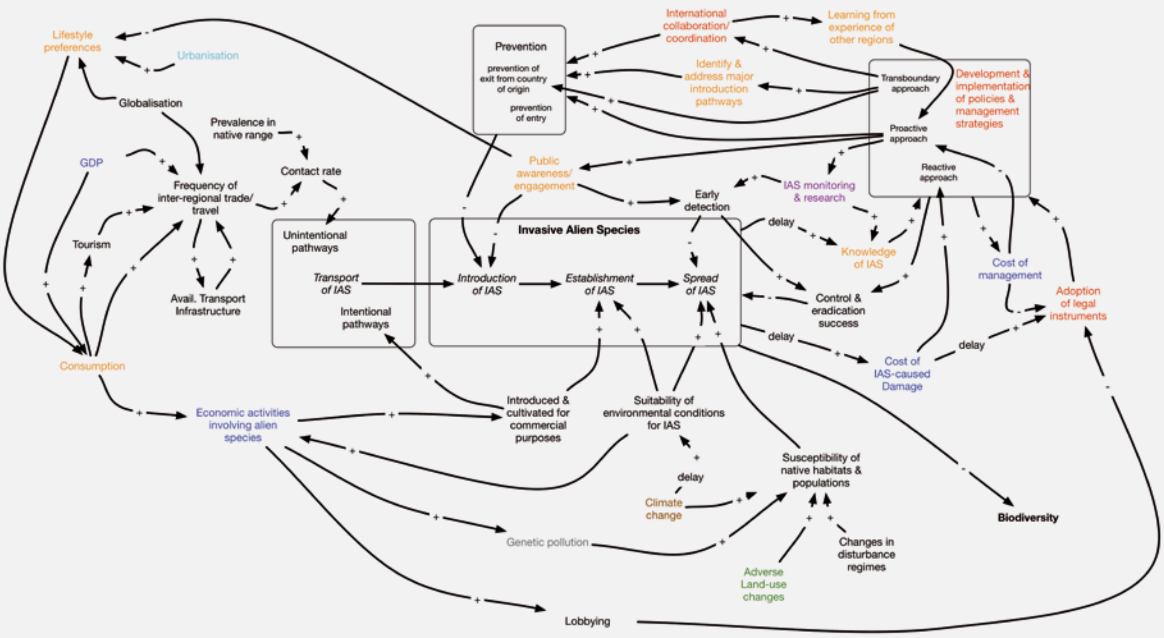
direct drivers of change including climate change, adverse land-use change, genetic pollution, and changes in natural disturbance regimes, which are, in turn, typically directly or indirectly driven by economic development and socio-economic trends (Early *et al.*, 2016).

Diverse impacts of invasive alien species and high eradication costs of already established invasive alien species have necessitated the adoption of legal instruments (see **Figure 4.78**). Countries with greater numbers of recorded invasive alien species have adopted more targeted international treaties **(Figure 4.79 A)** and national and subnational regulations and legislation (see **Figure 4.79 B**) specifically dealing with invasive alien species (Turbelin *et al.*, 2017). Western European countries have greater numbers of recorded invasive alien species due to trade and colonial histories (Turbelin *et al.*, 2017) and better scientific knowledge of species invasion status and native biodiversity (Lambdon *et al.*, 2008). Consequently, Western European countries have adopted numerous legal instruments targeting alien species; Central European and Eastern European countries have fewer legal instruments, and countries in Central Asia have the fewest legal instruments **(Figure 4.79)**. Within the European Union, the regulation on invasive alien species implemented in 2014 includes three types of interventions: prevention, early detection and rapid eradication, and management (European Union, 2014). Globally, the number of international agreements relevant to control of invasive alien species as well as the number of countries that are party to these agreements has consistently increased since the 1950s (McGeoch *et al.*, 2010).

Information on legal instruments concerning invasive alien species is largely missing from Central Asia, either because of a lack of data or a genuine lack of policy. In the latter case, the development of legislation and regulations in this subregion could (1) prevent the introduction of invasive alien species or (2) help reduce the spread and impact of existing ones. Species introductions as well as spread and impact of existing invasive alien species are likely to be exacerbated (Turbelin *et al.*, 2017) based on trends of other indirect drivers, especially socio-economic drivers such as development of the oil industry and its related infrastructure in Kazakhstan, Turkmenistan and Uzbekistan (Dimeyeva, 2013). From available information, mainly based on eports by the Convention on Biological Diversity, countries in

Figure 4 81 **Causal loop diagram of drivers of feedbacks mechanisms between effects of invasive alien species (IAS) and direct and indirect drivers. Source: Own representation.**

Feedbacks are largely limited to rarely implemented policies aimed at raising public awareness. Most current policy responses are reactive, directed towards control of existing invasive alien species populations, and do not address underlying drivers.



Indirect drivers: Institutional Economic Cultural Demographic Scientific and Technological

Central Asia currently have little capacity to respond to threats by invasive alien species and impending or future introductions, establishment or spread (Early *et al.*, 2016).

The majority of legal instruments are reactive, targeting introduction and spread of invasive alien species upon arrival within national borders. Very little attention has been given to preventing the arrival of invasive alien species, except for species that have known public health impacts (Turbelin *et al.*, 2017). Comprehensive border controls to prevent introduction of potential invasive alien species are adopted by very few countries in Europe and Central Asia (Early *et al.*, 2016). Current regulations lack a transboundary perspective and insufficiently cover major introduction pathways (Hulme, 2015). For example, most efforts in regulation of transport-related non-intentional introductions of invasive alien species have addressed the role of shipping, while tourism, another major route of stowaway alien species, remains largely neglected (Hulme, 2015).

A general recommendation from studies on invasive alien species regulation and management is to develop educational outreach programmes to raise awareness of the general public and industry (Hulme, 2015; Katsanevakis *et al.*, 2013; Turbelin *et al.*, 2017; Zieritz *et al.*, 2017). Increased public awareness could lead to changes in preferences for alien species as pets or other ornamental purposes, increased vigilance by tourists and the tourist industry, and improved early detection of alien species.

4.9 SYNTHESIS OF DIRECT DRIVER TRENDS AND IMPACTS IN EUROPE AND CENTRAL ASIA

4.9.1 Interaction among direct drivers and time-lagged effects on biodiversity and nature's contributions to people

Drivers, both direct and indirect, rarely act in isolation. In essence, a change in biodiversity and nature's contributions to people is almost always an outcome of several interacting drivers. While it may be possible to determine which drivers are involved, it is not always easy to assess or even quantify the respective contribution of the individual drivers in affecting biodiversity, including ecosystems. In addition, positive feedbacks can influence driver dynamics and amplify their combined effects. For example, land-use change and destruction of habitats can influence climate change (locally) due to the changes in land surface albedo and evapotranspiration (Kalnay & Cai, 2003).

Drivers do not act in isolation with interactions between them affecting driver trends and thus also the effects on biodiversity and nature's contributions to people. In **Box 4.7**, we exemplify the interaction of indirect and direct drivers using three examples of invasive alien species. They illustrate how different drivers – partly indirect and partly direct – jointly affect the driver "invasive alien species". Many other examples of driver interactions exist in the ecological literature. For example, the interplay of climate change, pollution and invasive alien species exacerbates the negative impact of land-use change and management intensity (Collier *et al.*, 2016; Haddad *et al.*, 2015; IPBES, 2016a; Kalnay & Cai, 2003; Mantyka-Pringle *et al.*, 2012; Segan *et al.*, 2016; Vilà & Ibáñez, 2011). Small and isolated populations of organisms are less well buffered against climate change (McInerny *et al.*, 2007), are more susceptible to invasion (Didham *et al.*, 2007; Haddad *et al.*, 2015) and can be more exposed to pollution

Box 4 7 Interaction of direct and indirect drivers in their effects on biodiversity and nature's contributions to people.

Economic and demographic drivers are both highly correlated with invasion of alien species

The number of invasive alien species is strictly correlated with economy and with human population. In particular, the level of wealth, defined as cumulative economic prosperity, has been shown to have a strong influence on the cumulative level of invasions (Pyšek *et al.*, 2010); this correlation has a temporal effect, and the number of invasive alien species reflects historic rather than contemporary economy (Essl *et al.*, 2011).

Climate change, habitat fragmentation and fish invasion

Connectivity is extremely important for freshwater fish migration, and natural and man-made barriers can consequently seriously facilitate or hamper fish dispersal. This has, for instance, been illustrated for pike (*Esox lucius*) in Sweden, where they are currently absent from isolated lakes and lakes upstream from channel slopes steeper than c. 7% (Hein *et al.*, 2011; Spens *et al.*, 2007). At the same time, pike are top predators, able to extirpate cold-adapted salmonid species under warmer conditions in small lakes, whereas those species co-exist under colder conditions and in larger lakes (Hein *et al.*, 2013). Due to human-mediated introductions and climate warming pike are now spreading upstream and to more northern latitudes, while at the same time climate warming improves pike performance, often resulting in local extinctions of cold-adapted specialist fish species (Hein *et al.*, 2013). The strong effect of climate change on these predator fish (both influencing their spread and their competitiveness) provides managers with a difficult challenge regarding the restoration of natural connectivity to improve the free movement of species. Whereas on the one hand connectivity is important to native species that need to track climate change, barriers such as waterfalls, dams and weirs can limit the upstream spread of problematic or very competitive species, thereby creating refuges and protection for threatened species. This example illustrates how climate change may alter the effect of connectivity restoration on fish biodiversity. It also illustrates trade-offs in biodiversity conservation.

Economic and demographic drivers, climate and land-use change, and invasive alien species

Distribution patterns of invasive alien species have been shown to be strongly linked to climate, land use, human demography and socio-economic activities (Bellard *et al.*, 2013, 2016; Gallardo & Aldridge, 2013; Gallardo *et al.*, 2015; Pyšek *et al.*, 2010). Specifically, in Europe and Central Asia, invasive alien species patterns are mostly driven by socio-economic activities (see Section 4.8.3). Climate acts as a broad-scale limiting factor to invasive alien species distributions, whereas land use (also driven by socio-economic activities) affects invasive alien species patterns at the global, regional and local scales (Bellard *et al.*, 2013). Consequently, changes in these drivers alter patterns in invasive alien species distribution and impact (Diez *et al.*, 2012; Dukes & Mooney, 1999; Hellmann *et al.*, 2008; Meyerson & Mooney, 2007; Walther *et al.*, 2009). Climate change (temperature and precipitation changes, CO_2 concentrations, extreme events) has been hypothesized to enhance biological invasions (Bellard *et al.*, 2013; Diez *et al.*, 2012; Dukes & Mooney, 1999; Hellmann *et al.*, 2008). Land-use change is expected to alter invasive alien species patterns depending on habitat types and uses, with the most intensely used and disturbed habitats being the most prone to invasions (Chytrý *et al.*, 2012). Increasing socio-economic activities are expected to increase invasions by increasing propagule pressure, introduction pathways and habitat disturbances (Bellard *et al.*, 2016; Essl *et al.*, 2011; Gallardo & Aldridge, 2013; Gallardo *et al.*, 2015; Pyšek *et al.*, 2010). Projected future patterns in plant invasions in relation to land-use change show strongest increases for the northern parts of Western Europe (all scenarios), and strongest decreases in the southern parts of Western Europe in scenarios of abandonment of agricultural land (Chytrý *et al.*, 2012). Future projections in distribution patterns of 100 of the world's worst invasive alien species in relation to both climate and land-use change project important increases in northern parts of Western Europe, slight increases in Central Asia and western parts of Eastern Europe, but decreases around the Mediterranean basin (Bellard *et al.*, 2013).

(Weathers *et al.*, 2001). Declining area of habitats and their increasing isolation also reduces the possibilities for the compensatory migration of species in response to changing climate (Bocedi *et al.*, 2014; Meier *et al.*, 2012; Vanbergen & The Insect Pollinators Initiative, 2013). Furthermore, a modelling study has shown that impact assessments focused on one sector (agriculture, foresty, water use, etc.) alone without considering interactions between these sectors will likely lead to over- or under-estimation of the projected impacts, as direct and indirect drivers affect each other mutually (Harrison *et al.*, 2016).

Individual and combined effects of different direct drivers can have chronic, prolonged and delayed consequences on biodiversity and nature's contributions to people, due to considerable time lags that many species and ecological systems have in response to changes in their environment (Dullinger *et al.*, 2012; Ewers & Didham, 2006; Halley *et al.*, 2016; Hanski & Ovaskainen, 2002; Helm *et al.*, 2006; Kuussaari *et al.*, 2009; Tilman *et al.*, 1994; Urban, 2015). Even if habitat conditions no longer meet the minimum requirements for species persistence (e.g. too small habitat area, too isolated habitats, climatic conditions becoming unsuitable), actual extinctions can take time, creating an extinction debt in many contemporary habitats or ecosystems (Hanski & Ovaskainen, 2002; Kuussaari *et al.*, 2009). Time-lags also characterize species colonizations of new habitats, termed "colonization credit" or "immigration deficit". Delayed immigration characterizes both non-native species invasions as well as natural, climate-driven or land use-driven migrations and colonizations of native species (Jackson & Sax, 2010). By masking the full extent of impacts of direct and indirect drivers on biodiversity and nature's contributions to people, time-delays in species dynamics pose considerable challenges for research and conservation. Extinction debt can last decades or even centuries and, if left unnoticed, can lead to serious overestimation of current biodiversity status and underestimation of the impact of combined and direct effects of direct drivers on biodiversity and nature's contributions to people (Kuussaari *et al.*, 2009). For example, taking extinction debt into account increased projected extinctions threefold from 5% to 15% under currently projected climate change scenarios (Urban, 2015). On the other hand, when recognized in good time, extinction debt and colonization credit can provide opportunity to avoid some of the projected extinctions or undesired colonizations via active and knowledgeable conservation and restoration activities (Halley *et al.*, 2016; Török & Helm, 2017).

4.9.2 Synthesis of direct driver trends and impacts

In this section, we summarize assessed trends and impacts of direct drivers. **Figure 4.82** and **Figure 4.83** illustrate the direction of driver trends and their inferred impact in the different subregions and units of analysis. An increasing trend (upward-pointing arrow) means that the direct driver shows an increasing trend, while downward pointing arrows indicate a decreasing trend. Impacts on biodiversity associated with the direct driver trends are indicated by colours, with red and green indicating negative and positive impacts. An increasing driver trend can have a positive impact on overall biodiversity in an area or unit of analysis. However, we assessed to what degree the trend affects the biodiversity typical for the unit of analysis in that area not simply biodiversity as a whole. For example, climate change can be expected to increase the overall biodiversity in an area, yet it will negatively affect the biodiversity of a given spatial unit, e.g. of temperate forests, if these are converted into other units of analysis, e.g. Mediterranean forests, over time. Hence, overall biodiversity might be higher in Mediterranean forests, but species associated with temperate forests would be lost.

In some cases, trends do not have a clear direction in a subregion and unit of analysis, but rather show both decreasing and increasing trends or impacts. We therefore also allowed trends and impacts to be of "variable" nature. The confidence in the statements on driver trends and impacts is indicated by the thickness of symbols or by the saturation of the colours. The notion of "irrelevant" was assigned to combinations of drivers, subregions and units of analysis that do not exist. For example, there are no "deep marine waters" or "Mediterranean forests" in Central Asia.

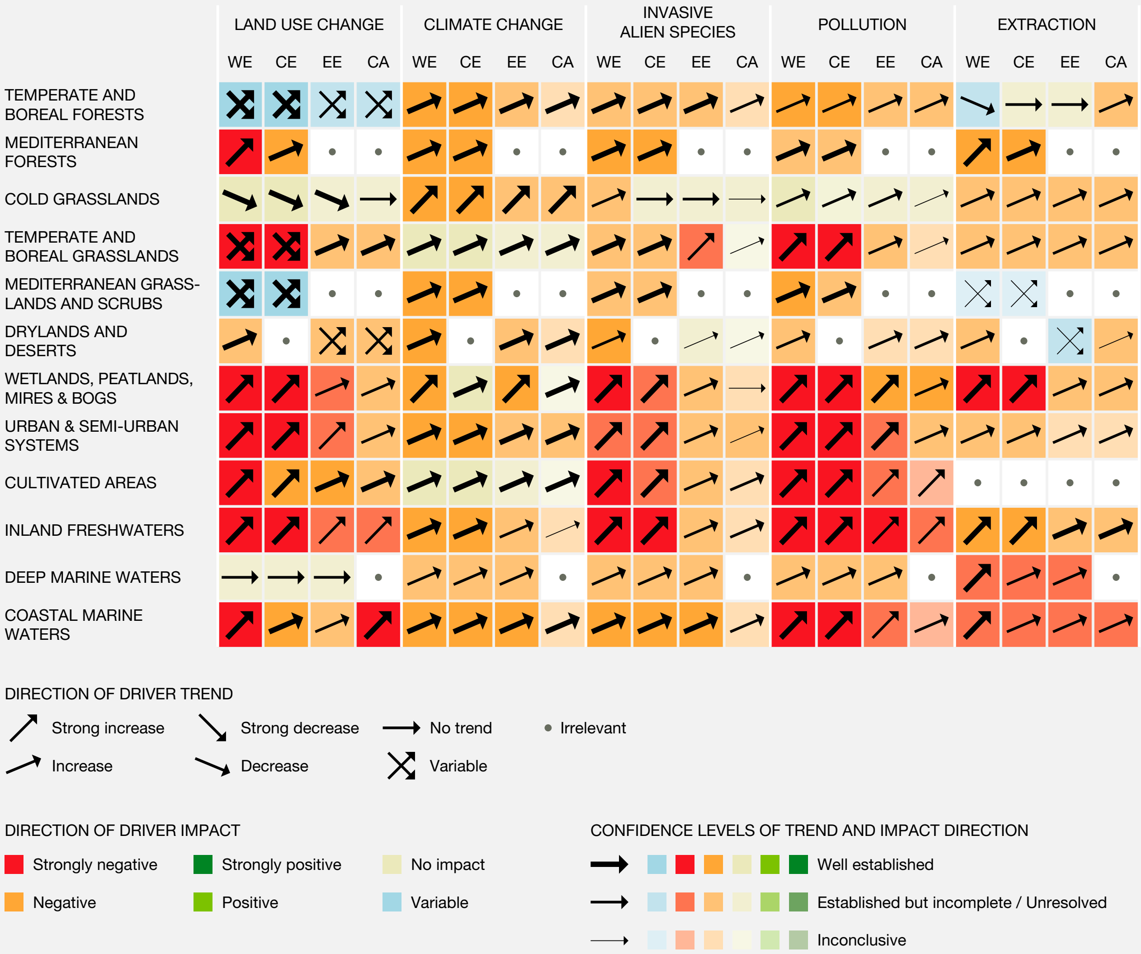
4.9.2.1 Recent trends in direct drivers and their impact

The recent trends in direct drivers and their associated impact on biodiversity and nature's contributions to people are summarized across Europe and Central Asia and major units of analysis within the study region (see **Figure 4.82**). Land-use change, pollution and partly natural resources extraction showed the strongest increase, and had the clearest negative impacts in many units of analysis or subregions. Invasive alien species have steadily increased as a driver of biodiversity alteration and loss, and already showed strong negative impacts in some (wetland types, cultivated areas and inland freshwaters), while in other systems the impact is less severe or still mostly lacking (e.g. cold grasslands). Climate change has also steadily increased as a driver, yet its impact on biodiversity is still marginal and confined to relatively few units of analysis (mostly urban and water systems).

Confidence is generally high in all statements, yet often somewhat decreasing towards Eastern Europe and Central Asia, usually due to a lack of accessible literature and insufficient number of studies analysing trends and impacts. The availability of repeated reports on climate change trends and impacts (e.g. IPCC, 2013b, 2014a, 2014b) results in

Figure 4 82 **Combination of recent trends in direct drivers and impacts of driver trends on biodiversity and nature's contributions to people.**

"Increase" stands for accelerating trends in direct drivers, while "decrease" stands for decelerating driver trends. Positive (green) and negative (red) impacts on biodiversity indicate the effects of the associated driver trends. Confidence levels are indicated by the thickness of arrows and saturation of colours. Units of analysis are: temperate and boreal forests; Mediterranean forests; cold grasslands; temperate and boreal grasslands; Mediterranean grasslands and scrubs; drylands and deserts; wetlands, peatlands, mires and bogs; urban and semi-urban systems; cultivated areas; inland freshwaters; deep marine waters; coastal marine waters. WE: Western Europe, CE: Central Europe, EE: Eastern Europe, CA: Central Asia. Source: Own representation.



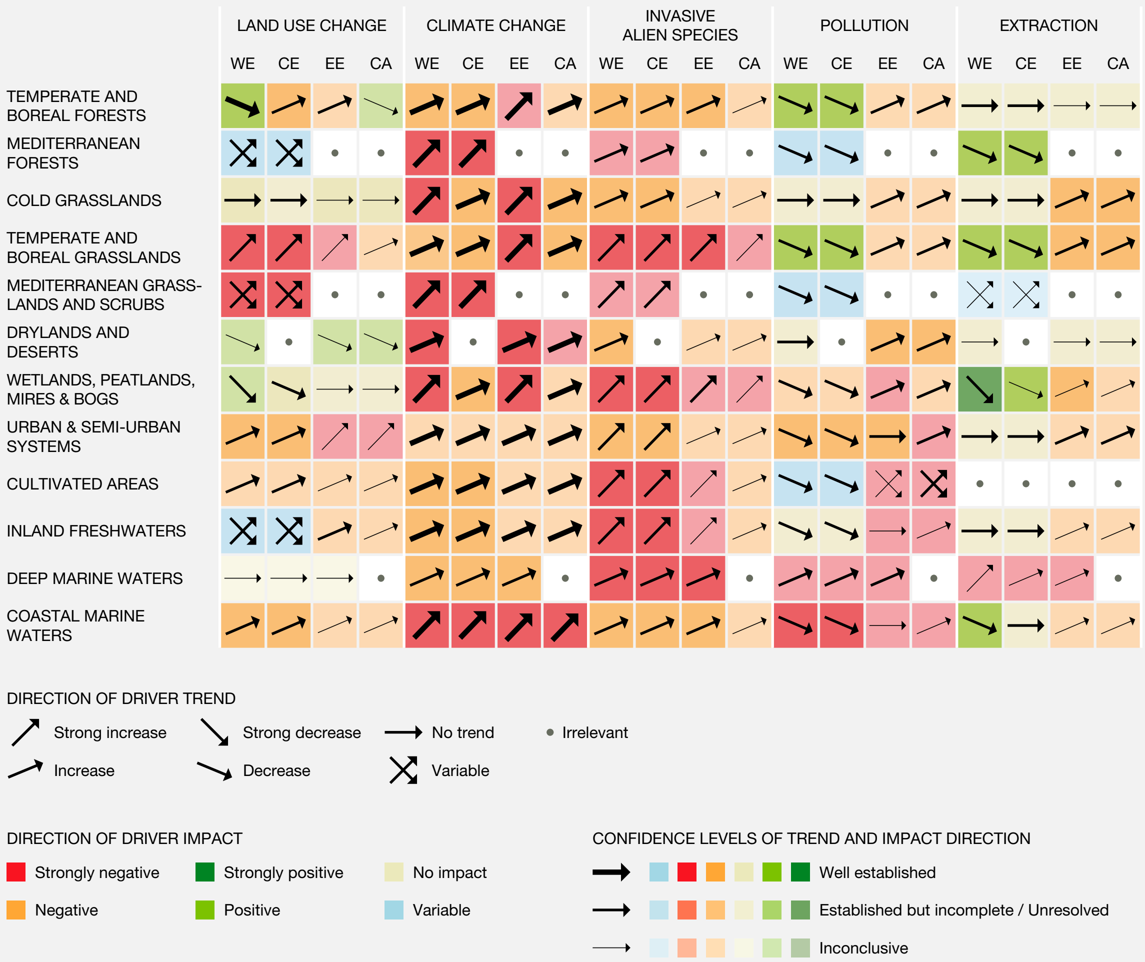
an overall very high level of confidence in all statements on trends and impacts throughout the study region. Lowest confidence levels were found for trends and impacts for the driver natural resources extraction. This driver is usually more limited in its spatial extent, and thus more difficult to quantify across larger regions, both for trends and impacts.

4.9.2.2 Projected future trends in direct drivers and their impact

The projected future trends in direct drivers and their associated impact on biodiversity and nature's contributions to people are summarized across Europe and Central Asia and major units of analysis within the study region **(Figure 4.83)**. Land-use change, pollution and partly natural resource extraction showed strongest projected decreases, and had overall some reduction in its impacts on biodiversity in several units of analysis or subregions. On the contrary, climate change and invasive alien species will become the most important threats to biodiversity compared to the other three drivers. The reduction of driver effects on biodiversity is stronger in Western and Central Europe than in Eastern Europe and Central Asia for land-use change, pollution and natural resources extraction. On the other hand, invasive alien species are still projected to be a bigger threat to units of analysis in Western and Central Europe than in Eastern Europe and Central Asia, reflecting the importance of traffic and economic growth for the trends in invasive alien species.

Figure 4 83 **Combination of projected future trends in direct drivers and impacts of projected driver trends on biodiversity and nature's contributions to people.**

"Increase" stands for accelerating trends in direct drivers, while "decrease" stands for decelerating driver trends. Positive (green) and negative (red) impacts on biodiversity indicate the effects of the associated driver trends. Confidence levels are indicated by the thickness of arrows and saturation of colours. Units of analysis are: temperate and boreal forests; Mediterranean forests; cold grasslands; temperate and boreal grasslands; Mediterranean grasslands and scrubs; drylands and deserts; wetlands, peatlands, mires and bogs; urban and semi-urban systems; cultivated areas; inland freshwaters; deep marine waters; coastal marine waters. WE: Western Europe, CE: Central Europe, EE: Eastern Europe, CA: Central Asia. Source: Own representation.



Confidence is generally lower for projected future (compared to recent) trends and impacts in all statements, and often even lower towards Eastern Europe and Central Asia. The exception to this rule is the confidence in trends of climate change, for which a wealth of information is available (e.g. IPCC, 2013b, 2014a, 2014b). For some systems only marginal information is available in the Europe and Central Asia region. Again, lowest confidence levels are available for trends and impacts in the driver natural resources extraction.

4.9.3 Synthesis of indirect drivers

Sections 4.4-4.8 presented Causal Loop Diagrams (CLDs) to illustrate the dynamic inter-relationships within and between indirect and direct drivers of change in biodiversity and nature's contributions to people. Our findings show that the general combination of indirect drivers that underpin trends in direct drivers is often similar across Europe and Central Asia. At the same time, causal relationships between individual indirect drivers and their effects on direct drivers are context specific.

Indirect drivers are often triggered by processes in different sectors of society and by the activities of diverse groups of actors and stakeholders. Their cumulative effects provoke dynamics of indirect drivers and as a consequence a specific impact on a direct driver. For example, intensification of conventional agriculture in Europe and Central Asia is influenced by cultural, institutional, economic, technological and demographic drivers. Whilst the consolidation of farms has led to some improvements in economic viability, it is also linked to the erosion of local traditions and of a sense of long-term stewardship and responsibility for the land, which are important for sustaining management practices for biodiversity.

The CLDs were also used to illustrate complex adaptive systems in terms of how the effects on biodiversity and nature's contributions to people feed back to the indirect drivers. Knowledge and awareness, filtered by beliefs and values, are often the primary cultural-religious drivers in this feedback. Environmental NGOs have had an important role in increasing awareness of forest biodiversity, while scientific organizations have been important for issues such as fishing and climate change. Public awareness has not always been necessary, e.g. in the case of invasive alien species, new regulations have been passed in response to scientific knowledge with less political pressure. There are also differences between subregions. For example, for agriculture, the Common Agricultural Policy in the European Union includes institutional and agri-environmental support (payments), which has a positive (green) effect on biodiversity **(Figure 4.84)**. However, these payments only reduce the effects of global trade and competition, so the economic drivers work in both ways (grey colour in **Figure 4.84**). Cultural change increases demand for organic food in Western Europe. Technological drivers in the resource extraction sectors generally increase degradation, while "end-of-pipe" technologies have successfully reduced pollution **(Figure 4.84)**.

Institutional drivers have often been used to soften the effects that economic profit-seeking drivers have on technological change and a range of direct drivers. Regulations have reduced some pollution, e.g. acidification and toxicity from heavy metals. Other direct drivers, e.g. pesticides and ammonia pollution from agriculture, have been regulated although not sufficiently to reverse negative trends.

Economic drivers have not changed very much as a result of knowledge and awareness of ecosystem degradation and have generally a negative effect on biodiversity and nature's

Figure 4 84 **Impact of indirect drivers (rows) on direct drivers (columns) of biodiversity loss and nature's contributions to people in Europe and Central Asia. Source: Own representation.**

The colour shows the impact of an indirect driver on a direct driver's effect on biodiversity and nature's contributions to people along a gradient from negative to positive effects. Abbreviations: WE = Western Europe, CE = Central Europe, EE = Eastern Europe, CA = Central Asia

	LAND USE CHANGE															
	Agricultural land use				Forestry				Traditional land use				Protected area development			
	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
INSTITUTIONAL	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	~	~	✓	✓	~	~
ECONOMIC	~	~	~	~	✗	~	✗	~	✓	✓	✗	✗			✗	✗
DEMOGRAPHIC			~	~					✗	✗	✗	✗				
CULTURAL	✓	~	✗	✗	✓	✓	✓	✗	~	~	~	~	✓	✓	✗	✗
TECHNOLOGICAL	~	~	~	~												

	Climate change				Pollution				Natural resource extraction				Invasive alien species			
	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA	WE	CE	EE	CA
INSTITUTIONAL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✗	✓	✓	~	~
ECONOMIC	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗		✗	✗	✗	✗	✗
DEMOGRAPHIC					✗	✗	✗	✗	✗	✗	✗	✗				
CULTURAL					~	~	~	~	~	~	~	~	✗	✗	✗	✗
TECHNOLOGICAL	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗				

✗ Negative ~ Both ways ✓ Positive Lack of evidence contributions to people **(Figure 4.84)**. Environmental and ecological fiscal reforms have not generally been implemented: environmental taxes have not increased since 2002. On top of this, harmful subsidies to fishing and mining provide market actors with strong incentives to continue externalising environmental costs. Hence, economic drivers still support intensive agriculture and forestry as well as unsustainable natural resource extraction, especially fishing and mining. When economic drivers have been employed to halt biodiversity loss, e.g. through agri-environmental schemes and carbon taxes or trading schemes, this has generally been insufficient to halt habitat fragmentation and degradation or climate change. As long as a good quality of life is associated with GDP growth, the perceived trade-off between a good quality of life and sustainable ecosystem management and governance will continue to be a major obstacle, if sustainable development is to be achieved.

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CHAPTER 5

CURRENT AND FUTURE INTERACTIONS BETWEEN NATURE AND SOCIETY

Coordinating Lead Authors:

Paula A. Harrison (United Kingdom of Great Britain and Northern Ireland), Jennifer Hauck (Germany)

Lead Authors:

Gunnar Austrheim (Norway), Lluís Brotons (Spain), Matthew Cantele (Austria), Joachim Claudet (France), Christine Fürst (Germany), Antoine Guisan (Switzerland), Sandra Lavorel (France), Gunilla Almered Olsson (Sweden), Vânia Proença (Portugal), Christian Rixen (Switzerland), Fernando Santos-Martín (Spain), Martin Schlaepfer (Switzerland), Cosimo Solidoro (Italy), Zharas Takenov (Kazakhstan), Jozef Turok (Slovakia)

Fellow:

Zuzana V. Harmáčková (Czech Republic)

Contributing Authors:

Armağan Aloe Karabulut (Turkey), Fanny Boeraeve (Belgium), Marta Coll Monton (France), Robert Dunford (United Kingdom of Great Britain and Northern Ireland), Niki Frantzeskaki (Greece), Yuliana Griewald (Russian Federation/Germany), Karl Grigulis (France), Sander Jacobs (Belgium), Jan Janse (The Netherlands), Viktar Kireyeu (Belarus), Kasper Kok (The Netherlands), Anastasia Lobanova (Russian Federation/Germany), Alejandra Morán-Ordóñez (Spain), Simona Pedde (Italy), Anton Shkaruba (Belarus), Anthony Sonrel (Switzerland), Fernando Viñegla (Spain), Marten Winter (Germany), Yves Zinngrebe (Germany)

Review Editors:

Ian Holman (United Kingdom of Great Britain and Northern Ireland), Tobias Plieninger (Germany)

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EXECUTIVE SUMMARY

Priorities for future sustainable development within Europe and Central Asia are formulated in visions by governments and societal actors. Integrated scenario and modelling studies enable the assessment of impacts on nature, nature's contributions to people, and a good quality of life resulting from these priorities, and help to co-design and co-deliver appropriate pathways to sustainable futures (*established but incomplete*) (5.1.2, 5.4.2, 5.4.3, 5.5.2). Priorities for future sustainable development are captured in regional visions, which describe a future desired by society or parts of society in Europe and Central Asia. Matching these priorities to the Sustainable Development Goals and Aichi Biodiversity Targets revealed that regional priorities include sustainable economic growth in tandem with sustainable industrialization (Goal 8, Goal 9), sustainable agriculture, forestry, aquaculture and management of natural resources (Goal 15, Target 7), all promoted by sustainable consumption and production patterns (Goal 12, Target 4). Climate action and sustainable energy (Goal 13, Goal 7) are also priorities. Reduced inequalities (Goal 10), gender equality (Goal 5) and peace, justice and strong institutions (Goal 16), as well as representation of a diverse range of values, are less emphasized (*established but incomplete*) (5.1.2, 5.4.2, 5.4.3).

Integrated assessments of future interactions between the priorities for sustainable development and nature and its contributions to people, which support proactive decision-making that anticipates change, mitigates undesirable trade-offs and fosters societal transformation in pursuit of a good quality of life, are rare due to the complexity of human and environment interdependencies (*well established*) (5.1.1, 5.3.1, 5.5.3, 5.5.4). Nevertheless, ignoring these complexities is likely to cause undesired trade-offs and to prevent the realization of synergies (5.3.1). Cross-sectoral and cross-scale integration of adaptation, mitigation and transformative actions and policies by multiple actors is key to the co-design and co-delivery of appropriate pathways to realize visions of future sustainable development (*established but incomplete*) (5.4.2, 5.4.3, 5.5.2, 5.5.3, 5.5.5, 5.5.6).

The choices made by decision-makers and societal actors are expected to lead to large differences in future impacts on nature, nature's contributions to people, and good quality of life within Europe and Central Asia (*established but incomplete*) (5.2.3, 5.3.3, 5.3.4). More positive impacts are projected under futures that assume proactive decision-making on environmental issues and promote a more holistic approach to managing human and environmental systems which supports multifunctionality and multiple contributions from nature to people (*established but incomplete*) (5.2.3, 5.3.3, 5.3.4). Projecting historical trends into the future under a *business-as-usual* scenario results in stable trends in nature (e.g. reflected in biodiversity vulnerability indices), negative trends in nature's regulating contributions (e.g. regulation of climate or hazards and extreme events) and mixed trends in nature's material contributions (e.g. food production) (*established but incomplete*) (5.3.3, 5.6.1).

Different assumptions about future trends in drivers lead to widely varying projected impacts on nature, nature's contributions to people and a good quality of life. Under *economic optimism* scenarios, where global developments are steered by economic growth and environmental problems are only dealt with when solutions are of economic interest, an increase in the provision of most of nature's material contributions to people (e.g. food and timber) is projected associated with a general decline in nature and its regulating contributions to people (e.g. air and water quality regulation) (*established but incomplete*) (5.3.3, 5.6.1). Under *regional competition* scenarios there is a growing gap between rich and poor, increasing problems with crime, violence and terrorism, and strong trade barriers. Consequently, its impacts are highly mixed with generally large declines in nature (e.g. habitat maintenance and creation) and the most negative impacts of all scenarios on nature's non-material contributions to people (e.g. learning and inspiration) and good quality of life indicators (e.g. health and well-being) (*established but incomplete*) (5.3.3, 5.6.1). *Inequality* scenarios, which assume increasing economic, political and social inequalities, where power becomes concentrated in a relatively small political and business elite who invest in green technology, result in negative impacts on nature's regulating contributions to people (*established*

but incomplete), but mixed or unclear impacts on other indicators (*inconclusive*) (5.3.3, 5.6.1).

Under *global sustainable development* scenarios, which are characterized by an increasingly proactive attitude of global policymakers towards environmental issues and a high level of regulation, positive impacts are projected for nature and its regulating contributions to people. Predominantly positive trends are also projected for nature's material contributions to people and good quality of life indicators, with some regional variation (*established but incomplete*) (5.3.3, 5.6.1). Under *regional sustainability* scenarios, which show increased concern for environmental and social sustainability and a shift toward local and regional decision-making, similar impacts are projected as for *global sustainable development*. *Regional sustainability*, however, leads to slightly fewer benefits for nature's regulating and material contributions to people (with decreases in food provision) than *global sustainable development* and more positive impacts on nature's non-material contributions to people and good quality of life, particularly traditional knowledge and supporting identities reflecting the local focus of the *regional sustainability* scenario (*established but incomplete*) (5.3.3, 5.6.1).

Trade-offs between nature and different contributions from nature to people are projected under all plausible futures for Europe and Central Asia (*established but incomplete*) (5.3.3, 5.3.4). How these trade-offs are resolved depends on political and societal value judgements within each plausible future. In general, those futures where environmental issues are mainstreamed across sectors are more successful in mitigating undesirable cross-sector trade-offs, resulting in positive impacts across a broad range of indicators concerning nature, nature's contributions to people and good quality of life indicators (*established but incomplete*) (5.3.3, 5.6.1). Trade-offs between nature's material and regulating contributions to people are commonly projected in the *economic optimism* and *regional competition* scenarios, which tend to promote a limited number of nature's material contributions to people. For example, increases in food provision (generally associated with the expansion of agricultural land or the intensification of livestock production and fish captures) are often associated with decreases in the provision of nature's regulating contributions to people (e.g. prevention of soil erosion, regulation of water quality and quantity) and nature values. Similar trade-offs were projected between increases in timber provision and decreases in nature's regulating (e.g. carbon sequestration) and non-material (e.g. aesthetic value) contributions to people. Such trade-offs lead to strong positive effects in nature's contributions to people with market values and negative effects in nature's contributions to people without market values (*established but incomplete*) (5.3.3, 5.6.1).

Trade-offs were also apparent under the sustainability scenario archetypes, particularly in relation to the use of land and water (e.g. effects of agricultural extensification – the opposite of agricultural intensification - or increases in bioenergy croplands on other land uses and biodiversity) (*established but incomplete*) (5.6.1). However, such scenarios proactively deal with such trade-offs through, for example, political choices aiming to maximize synergizes through mainstreaming and multifunctionality (*global sustainable development*) or through societal choices to live less resource-intensive lifestyles and, hence, reduce demand for nature's material contributions to people (*regional sustainability*).

Impacts of plausible futures differ across the regions of Europe and Central Asia. Hence, regional and national decision-makers face different trade-offs between nature and its various contributions to people. Cooperation between countries opens up possibilities to mitigate undesirable cross-scale impacts and to capitalize on opportunities (*established but incomplete*) (5.3.3). In Central Asia, significant water shortages are projected in the long-term. This affects farmers' choices between intensive crop production and more sustainable production with resulting impacts on nature's regulating contributions to people, such as water quality (*established but incomplete*) (5.3.3). Similar impacts on water stress are projected under future scenarios for Central Europe, including decreases in multiple contributions from nature to people from wetlands (*established but incomplete*) (5.3.3). Transboundary and integrated water management strategies that protect minimum water levels for the environment are projected to mitigate these negative impacts. In Eastern Europe, particularly Russia, trade-offs between wood extraction and carbon sequestration are projected. Sustainable forest management and reforestation of areas set aside from agricultural activities are suggested as having the potential to mitigate such trade-offs. Similarly, in mountain systems in Central and Western Europe and in marine systems in all subregions adaptive management strategies are projected to address the vulnerability of the majority of nature's contributions to people (*established but incomplete*) (5.3.3).

In the European Union (EU), significant differences between northern and southern countries are projected. Most scenarios indicate increases in agricultural production for food, feed and bioenergy for northern European Union countries, while decreases in agricultural and timber production, as well as increases in water stress, are projected for southern European Union countries. The latter is projected to have considerable negative impacts on nature's non-material contributions to people, such as national heritage and tourism-related services dependent on local food production. Scenarios which included international coordination of adaptive measures across geographical areas were projected to have better capacity to cope with, or mitigate, undesirable cross-scale impacts (*established but incomplete*) (5.3.3).

Future impacts of drivers of change on nature and its contributions to people in Europe and Central Asia are likely to be underestimated because scenario studies are dominated by a few individual drivers (e.g. climate change) and often omit other important drivers (e.g. pollution) that may adversely affect their impacts (*well established*) (5.2.2, 5.3.2). Scenario studies predominantly focus on single direct drivers and fail to capture interactions between drivers (*well established*) (5.2.2, 5.3.2). Climate change is the most represented single direct driver in scenarios of biodiversity and ecosystem change. By contrast other direct drivers, such as pollution and invasive alien species, which are known to have an adverse impact on nature and its contributions to people, are poorly represented in scenario studies (*well established*) (5.2.2). Single-driver scenarios fail to capture various dynamics such as feedbacks and synergies between and amongst indirect and direct drivers operating at different scales. Policy approaches that consider single drivers or single sectors are unlikely to successfully address environmental problems as they do not consider trade-offs between different drivers, impacts and responses. Integrated, multi-driver scenario studies offer a more realistic assessment of impacts to inform robust decision-making about future sustainable development pathways that avoid unintended consequences (*established but incomplete*) (5.2.1, 5.2.2, 5.2.4, 5.3.1, 5.3.3, 5.3.4, 5.4.4, 5.4.5, 5.5.5).

Priorities for future sustainable development expressed by governments and other societal actors for Europe and Central Asia are more widely achieved under plausible futures that consider a diverse range of values (*established but incomplete*) (5.3.4, 5.5.4, 5.5.5, 5.6.1). Recognizing the different time frame of the scenarios of plausible futures (often 2050 or later) to those stated in the Sustainable Development Goals and Aichi Biodiversity Targets (2030 or 2020), continuing current trends under a *business-as-usual* scenario is estimated to lead to failure in achieving most of the Sustainable Development Goals (13 out of 17), but mixed effects on achieving the Aichi Biodiversity Targets (8 achieved). *Economic optimism* is estimated to have a mixed level of success in achieving the goals (8 achieved), but would fail to achieve the majority of the targets (16 out of 20), while *regional competition* fails to reach the majority of all goals and targets (15 and 19, respectively). The focus of these scenarios on instrumental values and individualistic perspectives, with little acknowledgement of relational or intrinsic values, means they are unlikely to offer effective sustainable solutions to environmental and social challenges (*established but incomplete*) (5.3.4, 5.6.1).

In contrast, the *sustainability* scenarios (*regional sustainability* and *global sustainable development*) are estimated to achieve the majority of the Sustainable Development Goals and Aichi Biodiversity Targets. Such scenarios attempt to support nature and its multiple nature's contributions to people and aspects of a good quality of life. Thus, they represent a greater diversity of values, but often at the acceptance of lower, or more extensive, production of nature's material contributions to people (*established but incomplete*) (5.3.4, 5.6.1).

Multiple alternative pathways exist to achieve the priorities for future sustainable development set by governments and societal actors within Europe and Central Asia and in particular for mitigating trade-offs between nature and nature's contributions to people (*established but incomplete*) (5.5.2). The most promising pathways include long-term societal transformation through continuous education, knowledge sharing and participatory decision-making. Such pathways emphasize nature's regulating contributions to people and the importance of relational values in facilitating a holistic and systematic consideration of nature and nature´s contribution to people across sectors and scales (*established but incomplete*) (5.5.3, 5.5.4). Four types of pathways have been developed to address trade-offs between food, water, energy, climate and biodiversity at different scales (5.5.2). *Green economy* pathways focus on sustainable intensification and diversification of production activities coupled with the protection and restoration of nature. *Low carbon transformation* pathways focus on biofuel production, reforestation and forest management. Both types of pathways include actions related to *technological innovation*, *land sparing* or *land sharing*. *Green economy* and *low carbon transformation* pathways do not fully mitigate trade-offs between nature's material contributions to people, nature conservation, and nature's regulating and non-material contributions to people (*established but incomplete*) (5.5.2, 5.5.4).

Ecotopian solutions pathways focus on radical social innovation to achieve local food and energy self-sufficiency and the production of multiple contributions from nature to people. They include actions on multifunctionality within individual land uses with connecting green infrastructure, urban design and food production (*established but incomplete*) (5.5.2, 5.5.4). *Transition movements* pathways emphasize a change towards relational values, promoting resource-sparing lifestyles, continuous education, new urban spatial structures and innovative forms of agriculture where different knowledge systems are combined with technological innovation. Transformation is achieved through local empowerment, participatory decision-making processes, community actions and voluntary agreements. As opposed to other pathways, *transition movements* pathways address all of the Sustainable Development Goals identified as being important in the Europe and Central Asia visions (5.1.2, 5.5.4), except Goal 7 (sustainable energy). The narrative offers the broadest set of actions targeting elements of nature, multiple contributions from nature to people (material, regulating and non-material) and multiple dimensions of a good quality of life (*established but incomplete*) (5.5.2, 5.5.4, 5.6.1).

Different sets of actions and combinations of policy instruments are suggested by the different pathways. Joint instruments suggested across pathways give priority to participation, education and awareness raising, and often cross-scale integration and mainstreaming of environmental objectives across sectors (*established but incomplete*) (5.5.2, 5.5.3, 5.5.4, 5.5.6). The *green economy* and *low carbon transformation* pathways build towards sustainability without challenging the economic growth paradigm. They are implemented through combinations of top-down legal and regulatory instruments mixed with economic and financial instruments designed at regional (European Union) or national levels (Eastern Europe and Central Asia). Such pathways are often formulated at a sectoral level, and integration across sectoral pathways is critical. However, because *green economy* and *low carbon transformation* pathways do not fully mitigate trade-offs, they may not be sufficient alone to achieve sustainability (*established but incomplete*) (5.5.2, 5.5.4, 5.6.1).

The trade-offs are better addressed by diverse local bottom-up *transition movements* or *ecotopian solutions* pathways (5.5.2). Such pathways reconsider fundamental values and lifestyles through sets of actions focusing on less resource-intensive lifestyles, education, knowledge sharing, good social relations and equity (e.g. food and dietary patterns, transport, energy and consumption patterns). *Transition movements* pathways also develop bottom-up transformative capabilities by combining rights-based instruments and customary norms (including indigenous and local knowledge) and social and information instruments (*established but incomplete*) (5.5.3, 5.5.4). The sets of actions proposed in the pathways are not mutually exclusive and can be combined. For example, actions from gre*en economy* and *low carbon transformation* pathways may pave the way towards more transformative *transition movements* pathways. Moreover, future transitions to sustainability may be fostered through cross-scale integration and mainstreaming of environmental issues into sectoral policies and decisions, along with nurturing diverse social, institutional and technological experiments (*established but incomplete*) (5.5.5).

Participatory scenario, vision and pathway development is a powerful approach for knowledge co-production and has great potential for the explicit inclusion of indigenous and local knowledge (*established but incomplete*) (5.4.3, 5.5.1, 5.5.2, 5.5.6, 5.6.2). Many scenario, vision and pathways exercises include local stakeholders and their valuable knowledge and practices. However, the use of different knowledge systems, such as indigenous and local knowledge, was rarely explicitly mentioned in studies (5.6.2). Explicit examples that included indigenous and local knowledge (see **Boxes 5.2**, **5.6** and **5.10**), show a clear added value from combining different forms of knowledge with technological innovations, and cultural diversity, norms and customary rights when pursuing goals of sustainable development (5.2.2, 5.5.2, 5.5.3, 5.5.6).

Knowledge gaps and resulting uncertainties in exploring future interactions between nature and society are substantial because integrated assessments of future impacts on nature, nature's contributions to people and a good quality of life that take account of the complex interdependencies in human and environmental systems are rare (*well established*) (5.6.2). Very few studies were available for Central Asia and to a lesser extent for Eastern Europe (*well established*) (5.6.2). Less information was also available for marine systems than for terrestrial and freshwater systems (*well established*) (5.6.2). Few integrated scenario and modelling studies include indicators of nature's non-material contributions to people and good quality of life (5.3.2, 5.5.1, 5.6.2) and therefore existing assessments of synergies and trade-offs are limited in the interactions and feedbacks they represent (*well established*) (5.3.2). No studies were found that assessed future flows of nature's contributions to people across countries, which would have been important to assess the impacts of the scenarios and pathways for Europe and Central Asia on other parts of the world (*well established*) (5.6.2). There is also a significant gap in the current literature in recognizing the diversity of values, with the focus being mainly on instrumental values (*well established*) (5.6.2). Finally, scenario and modelling studies include many uncertainties in their projections of the future resulting from input data, scenario assumptions, model structure and propagation of uncertainties across the integrated components of the systems, which should be borne in mind when interpreting their results (*well established*).

5.1 INTRODUCTION

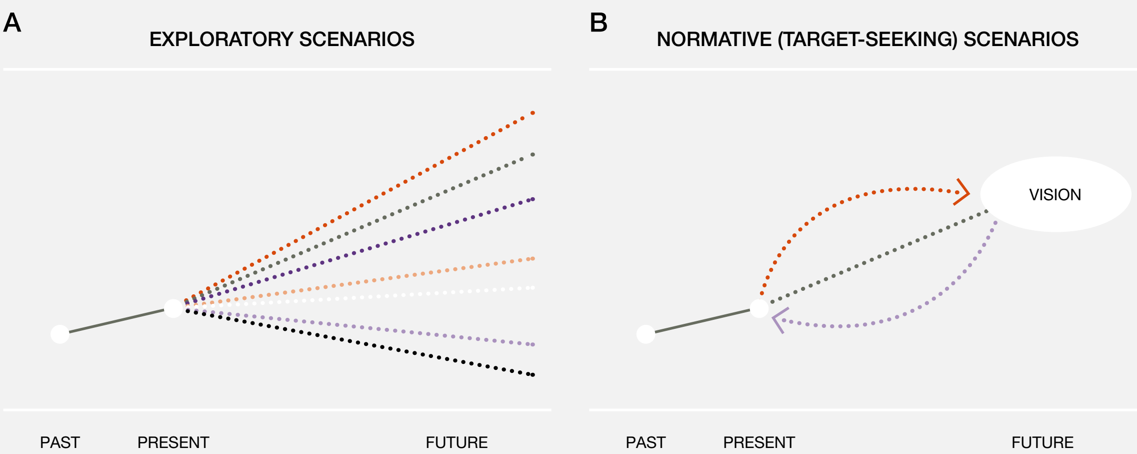
5.1.1 Chapter aims and structure

Nature and human society interact in complex ways as illustrated in the IPBES conceptual framework (IPBES, 2016a). For example, biodiversity underpins many of nature's contribution to people (NCP) but, at the same time, human development has caused significant losses in biodiversity through overexploitation and other drivers of change. Indirect drivers of biodiversity loss include human population change, economic development and policy or institutional change. These influence direct drivers, such as land use patterns or climate change, which in turn affect nature and its ability to deliver its contributions to people which support a good quality of life (Díaz *et al.*, 2015; Hauck *et al.*, 2015; Rounsevell & Harrison, 2016). The complex interactions result in significant uncertainties that make it difficult for societies to resolve an appropriate course of collective action to adapt to or to mitigate change and to pursue sustainable livelihoods (Rounsevell *et al.*, 2010). Despite these uncertainties and complex interactions, it is important to understand at least key interrelationships to develop effective management and policy strategies (Luck *et al.*, 2009).

However, social, economic and political conditions in the future may be very different from today. Scenarios and models provide a means for exploring uncertainties about how different drivers of change might develop in the future and for considering how those changes might alter society's vulnerability and ability to take action. Scenarios describe possible futures for drivers of change or policy interventions. These are then translated into projected consequences for nature, nature's contributions to people, and good quality of life by models (IPBES, 2016b). This improves understanding of the range of plausible futures in a region, alerts decision-makers to undesirable future impacts, and enables exploration of the effectiveness of policy options and management strategies. Thus, scenarios and models can contribute to the decision support that is needed for proactively developing policy that anticipates change and thereby minimizes adverse impacts and capitalizes on opportunities through insightful adaptation, mitigation and transformation strategies (adapted from IPBES/2/17: Report of the second session of the Plenary of the Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services, Annex VI: Initial scoping for the fast-track the IPBES Methodological Assessment on Scenarios and Models of Biodiversity and Ecosystem Services; IPBES, 2016b).

Scenarios are often categorized into two main types: exploratory and normative (but also see, for example, IPBES, 2016b; Rounsevell & Metzger, 2010). Exploratory scenarios describe a range of plausible futures based on assumptions about how trajectories of indirect and direct drivers may change (**Figure 5.1 A)**. They are particularly useful for the agenda-setting phase of the policy cycle in understanding "what might happen in the future". Normative or target-seeking scenarios are used to appraise alternative policy choices or management interventions **(Figure 5.1 B)**. They are useful for the policy design phase of the policy cycle in evaluating "what actions decision-makers can take to move away from undesirable futures towards more sustainable futures". This latter type of scenario is often related to a goal or vision of a desirable future, which represents the target for adaptation, mitigation and transformation actions. The normative scenarios then describe different pathways (which consist of policy choices or management interventions) that might achieve the vision

Figure 5 1 **Illustration of A exploratory scenarios; and B normative or target-seeking scenarios. Source: Adapted from IPBES (2016b).**



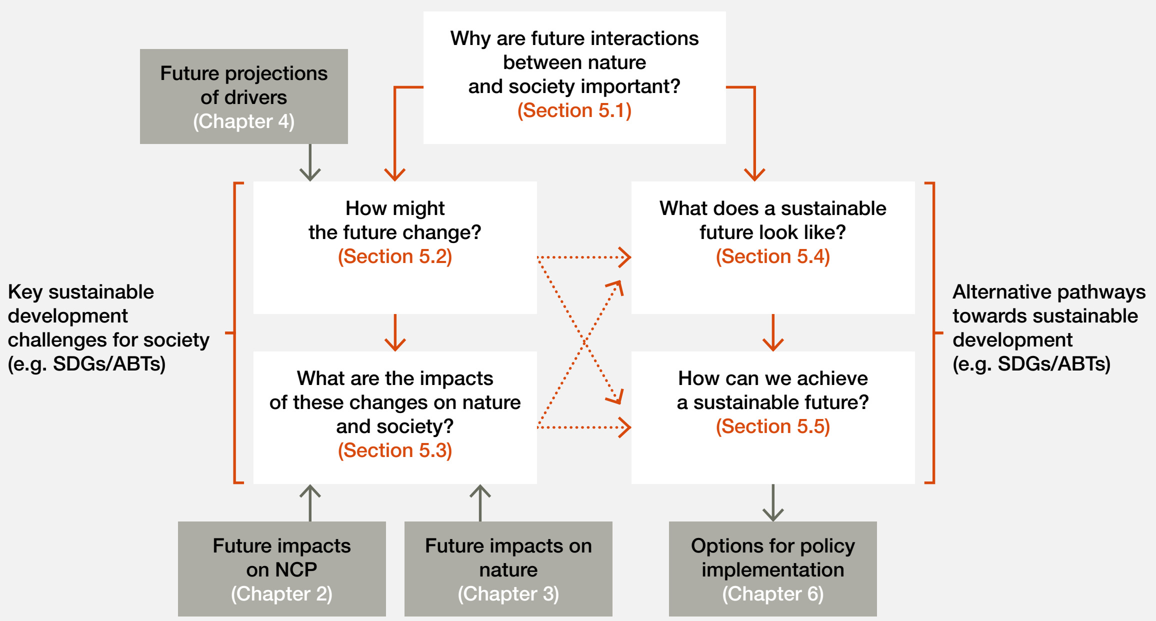
of the desired future. We focus on visions of sustainable development and the pathways for moving society towards such a sustainable future.

Chapter 5 is divided into two parts reflecting these two different types of scenarios **(Figure 5.2)**. The first part describes the range of plausible futures for Europe and Central Asia based on a review of exploratory scenarios (Section 5.2). The consequences of these futures for nature, its contributions to people, and good quality of life, as simulated by models, are described in Section 5.3. This first part provides an assessment of what might happen in the future taking account of uncertainties in projections of different drivers of change. It provides the foundation for understanding the key challenges that may be faced by society in moving towards a more sustainable future. The second part of the chapter describes what a sustainable future might look like by reviewing different visions of sustainable development and how these relate to the United Nations 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs), the Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets, and the long-term European Union Biodiversity Strategy for 2050 (Section 5.4). Possible pathways for achieving such visions are then appraised in Section 5.5 based on a review of pathways and normative scenarios. This analysis provides an assessment of the alternative policy choices or management interventions that can be used by decision-makers to move towards meeting sustainability goals. In so doing, it supports a good quality of life for the people of Europe and Central Asia by mitigating biodiversity loss and promoting a balanced supply of nature's contributions to people.

As Chapter 5 takes an integrated approach to assessing the relationship between nature and society, it reflects all the boxes and flows of the IPBES conceptual framework (IPBES, 2015a): nature, its contributions to people, and a good quality of life, and how they are influenced by natural and anthropogenic direct drivers as well as institutions and governance and other indirect drivers. Furthermore, it builds on the analysis presented in the previous chapters of this report, particularly the assessment of the impacts of scenarios on nature's contributions to people in Chapter 2 and nature in Chapter 3, and the assessment of indirect and direct drivers in Chapter 4 **(Figure 5.2)**. In addition, Chapter 6 builds on the findings in this chapter by considering the options for governance, institutional arrangements, and private and public decision-making for implementing the future policy responses analyzed in the scenario and modelling studies **(Figure 5.2)**.

Figure 5 2 **Schematic showing the key questions addressed in Chapter 5 and how these relate to the chapter structure.**

Links to other chapters in the Regional Assessment for Europe and Central Asia are also shown. SDGs = Sustainable Development Goals; ABTs = Aichi Biodiversity Targets; NCP = Nature's contributions to people.



Box 5 1 **Key definitions in Chapter 5.**

"Scenarios" are consistent and plausible pictures of possible futures (in line with Chapter 1 and IPBES, 2016b). "Exploratory scenarios" examine a range of plausible futures based on assumptions about a range of trajectories of indirect and direct drivers. "Normative scenarios", sometimes referred to as policy or target-seeking scenarios, explore the consequences of specific policy choices or management interventions.

"Models" are qualitative or quantitative representations of key components of a system and of relationships between these components. Throughout this chapter the term "models" usually, but not exclusively, refers to quantitative descriptions of relationships between drivers (indirect and direct) and nature (biodiversity and ecosystems), nature's contributions to people (ecosystem services) and a good quality of life (human well-being).

"Integrated assessment models" combine modelling of multiple environmental, social and economic system components and their interactions.

"Visions" are descriptions of a desirable future (an endpoint in time), which society or parts of society want to achieve. They usually consist of statements depicting orienting goals, and the assumptions, beliefs and paradigms that underlie the desired future. Visions can take the form of policy targets, but can also be formulated by a range of actors, e.g. from the private sector to address business targets or civil society to address social targets.

"Pathways" consist of descriptions of different strategies for moving from the current situation towards a desired future vision or set of specified targets. They are descriptions of purposive courses of actions that build on each other, from short-term to long-term actions into broader transformation. They are closely related to normative or policy or target-seeking scenarios.

5.1.2 Framing futures in the context of global sustainability targets and policy goals

Futures analysis can contribute to decision support in relation to major policy goals and targets. European and Central Asian Governments were among the 193 Member States of the General Assembly of the United Nations that adopted the "2030 Agenda for Sustainable Development" in 2015; and the Parties to the Convention on Biological Diversity that adopted the "Strategic Plan for Biodiversity 2011-2020" in 2010. Both documents are framed by visions and structured around key strategic goals (see Section 1.4), which represent priority areas for action and provide guidance for policy decisions and for the establishment of strategic plans at national and regional levels.

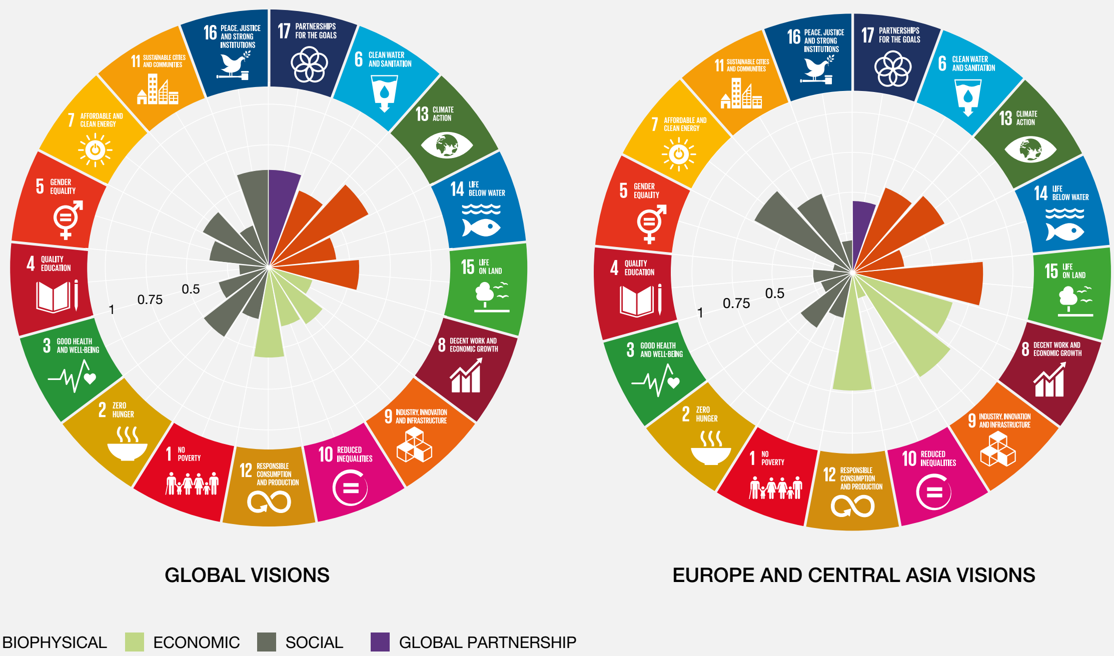
While the Sustainable Development Goals and Aichi Biodiversity Targets are shared globally, not all of them are formulated, nor expected to be equally relevant, for all countries or sectors. Activities to reach goals and targets can be tailored to the specific needs and visions of countries and sectors (CBD, 2010). Nonetheless, strictly focusing on those targets which are directly relevant for a specific sector or region bears the risk of causing unexpected trade-offs, or missed synergies, between targets (UNEP, 2015). This could potentially lead to conflicts between visions sharing the common goal of sustainable development. Analysis of how the Sustainable Development Goals and Aichi Biodiversity Targets are represented in regional (European and Central Asian) and global visions provides a framework for assessing the current coherence in policy goals across regional to global scales and sectors.

The cross-scale coherence between goals defined within visions of sustainable development globally and within the region of Europe and Central Asia are shown in **Figure 5.3** (see Section 5.4 for further information on the review underlying this figure). There are similarities, but also key differences, in the extent to which key sustainability goals and targets, such as the Sustainable Development Goals and Aichi Biodiversity Targets, are mainstreamed in global vs regional visions. Both global and regional visions prioritize Goal 12 of the Sustainable Development Goals (responsible consumption and production), Goal 13 (climate action) and Goal 15 (life on land). Biophysical values are also well represented in the visions at both levels, indicating a strong emphasis on environmental issues in the sustainability visions. However, visions for Europe and Central Asia place greater emphasis than global visions on Goal 8 (decent work and economic growth), Goal 9 (industry), Goal 7 (clean energy) and goal 11 (sustainable cities). In contrast, visions for Europe and Central Asia put less priority on Goal 10 (reduced inequalities), Goal 3 (health), Goal 5 (gender equality) and Goal 16 (peace, justice and strong institutions).

The coverage of targets similar to the Aichi Biodiversity Targets by the visions is limited at both the global and European and Central Asia levels **(Figure 5.4)**, with only a few of the 20 targets being covered. An overall narrowing of biodiversity concerns towards indirect (Target 4) and direct (Target 7) pressures is shown in visions for Europe and Central Asia. In particular, market pressures from consumption patterns and direct pressures from agriculture, aquaculture and forestry activity suggest a strong regional priority on actions to mitigate the cause of environmental impacts (Strategic Goals A and B, see Section 1.4).

Figure 5 3 **Coverage of goals similar to the Sustainable Development Goals by global (number of analyzed visions = 22) and Europe and Central Asia (number of analyzed visions = 25) visions of sustainable development. Dimensions of sustainability were assigned to Sustainable Development Goals based on their dominant character (Folke *et al.*, 2016).**

The size of the bar towards each Sustainable Development Goal shows the proportion of visions covering that Goal, ranging from 0 (not mentioned) to 1 (covered by all visions). Note the visions often concern a different (longer-term, beyond 2030) timescale to the Sustainable Development Goals. Source: Own representation.



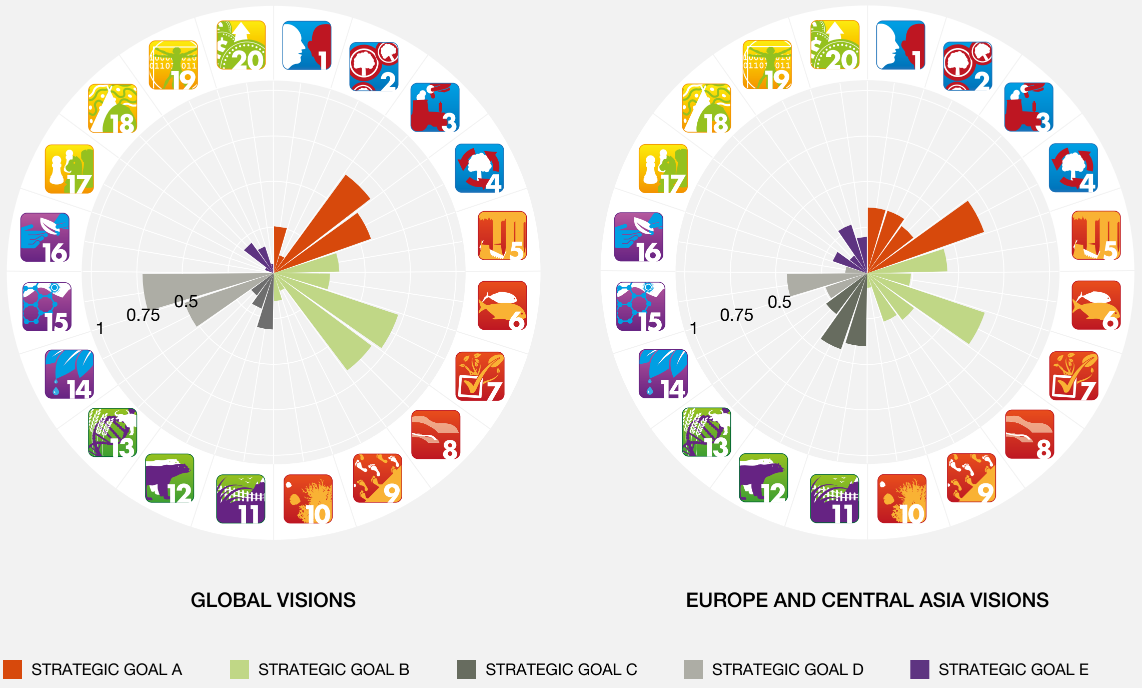
This analysis provides an overview of the policy priorities for Europe and Central Asia in comparison to global policy priorities. In the rest of this chapter, we use the insights gained from scenario, modelling and pathway studies to appraise (i) the likelihood of achieving goals similar to the Sustainable Development Goals and Aichi Biodiversity Targets under different plausible futures for Europe and Central Asia; and (ii) the policy options and management interventions which may potentially hinder or support the achievement of such goals. We do this by synthesizing knowledge on the future dynamics of biodiversity, ecosystem functions and nature's contributions to people that affect their contribution to the economy, livelihoods and quality of life in Europe and Central Asia (question 2 in IPBES/4/INF/9: Guide on the production and integration of assessments from and across all scales; see Chapter 1, Section 1.1.1). Our analyses of exploratory scenario and modelling studies show the effects of production, consumption and economic development on biodiversity, nature, and its contributions to people and to a good quality of life (Europe and Central Asia-specific question 7; see Chapter 1, Section 1.1.1), while our analyses of pathways studies highlight the role of investments, regulations and management regimes in protecting nature and nature's contributions to people (Europe and Central Asia-specific question 6; see Chapter 1, Section 1.1.1). In all our analyses, it should be recognized that futures studies concern longer time horizons than the deadlines for targets set within the Aichi Biodiversity Targets and Sustainable Development Goals, often to 2050, and hence they provide guidance on longer-term policy planning.

5.2 PLAUSIBLE FUTURES FOR EUROPE AND CENTRAL ASIA

Chapter 4 assessed past, current and future changes in indirect (demographic, economic, scientific and technological, cultural and institutional) and direct (climate change, land use/cover change, natural resource extraction, pollution and invasive alien species) drivers. Here we build on this assessment of individual drivers by reviewing exploratory scenarios which attempt to combine consistent changes in multiple indirect and direct drivers, including the effect(s) of indirect drivers on direct drivers, such as

Figure 5 4 **Coverage of goals similar to the Aichi Biodiversity Targets within global (number of analyzed visions = 22) and Europe and Central Asia (number of analyzed visions = 25) visions of sustainable development.**

Aichi Biodiversity Targets are organized by strategic goal of the Strategic Plan for Biodiversity 2011-2020, each goal addressing an area for action (A - the underlying causes of biodiversity loss, B - the direct pressures on biodiversity, C - the status of biodiversity, D - the benefits from biodiversity and ecosystem services, and E - implementation of biodiversity strategies and action plans). The size of the bar towards each Aichi Biodiversity Target shows the proportion of visions covering that target, ranging from 0 (not mentioned) to 1 (covered by all visions). Note the visions often concern a different (longer-term, beyond 2020) timescale to the Aichi Biodiversity Targets, which is more in line with the 2050 timescale of the vision of the Strategic Plan.
Source: Own representation.



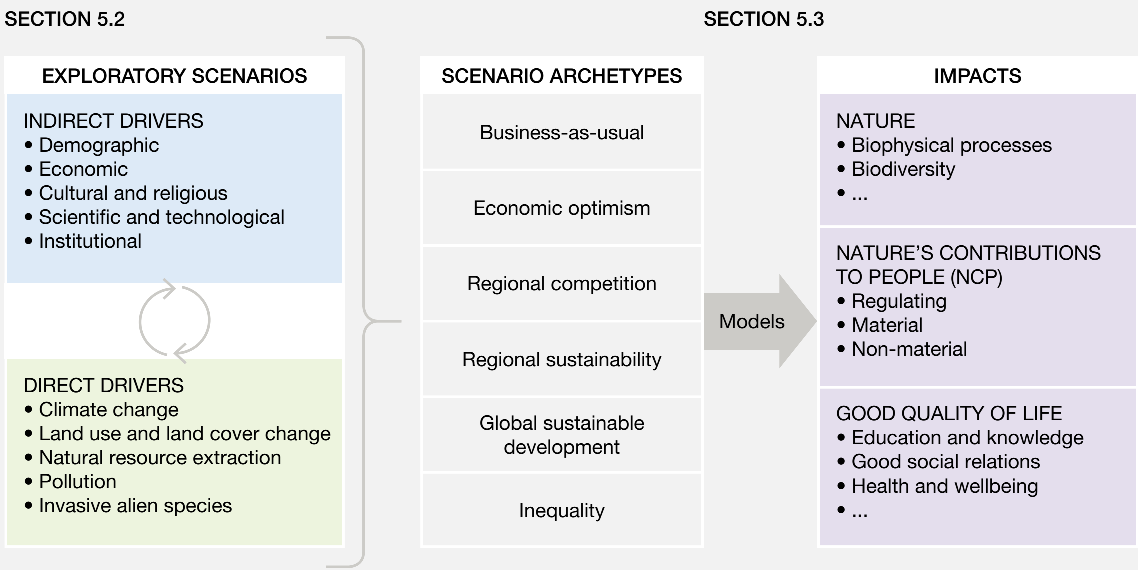
socio-economic impacts on land use (see Oesterwind *et al.*, 2016). Such scenarios portray a range of plausible futures for a region. Understanding the different ways in which the future might develop is helpful for identifying problems, evaluating and changing current thinking and improving decision-making. In this respect, exploratory scenarios set the context for assessing the robustness of future decisions on nature protection and sustainable development. They also facilitate the integration of knowledge across drivers, sectors, actors and disciplines stimulating solutions-oriented "out-of-the-box" thinking.

Section 5.2 describes different plausible futures for Europe and Central Asia, by reviewing exploratory scenarios for the region. These scenarios are subsequently grouped into broad categories of similar scenarios known as scenario archetypes. Projected future changes in the different indirect and direct drivers represented within the exploratory scenarios for Europe and Central Asia are described for each scenario archetype. This provides a rich picture of the types of futures that may occur for the region and the uncertainties associated with them. Such regional scenario archetypes are helpful for assessing the implications of future drivers of change on nature, its contributions to people, and a good quality of life using models (see Section 5.3 where these impacts are discussed). The relationship between the assessment of exploratory scenarios in Section 5.2 and the assessment of modelling studies in Section 5.3 is illustrated in **Figure 5.5**.

5.2.1 Review of exploratory scenarios for Europe and Central Asia

A formal review of exploratory scenarios was carried out based on peer-reviewed scenario literature for Europe and Central Asia using the Scopus database. This was supported by an informal review of grey literature using the knowledge of the author team. Both reviews focused on environment-related scenarios from 2005 until the present.

Figure 5 5 **Schematic showing how individual indirect and direct drivers are combined in exploratory scenarios, which in turn are categorized into scenario archetypes for the assessment of impacts on nature, nature's contributions to people, and a good quality of life using models. Source: Own representation.**



Articles were screened for the ten aggregated groups of drivers defined in Chapter 4, and their interactions **(Figure 5.5)**. Studies including only a single driver and studies with subnational spatial coverage were excluded from the review. These constraints were put in place to focus on multiple driver combinations (as single drivers are dealt with in Chapter 4) and on spatial scales relevant to the subregional and regional levels (but see **Box 5.2** for examples of local scenario studies).

A total of 436 scenarios in 143 studies from both the formal and informal reviews met the review criteria and were assessed. This section briefly describes the review database in terms of its coverage of regions, sectors, drivers and values.

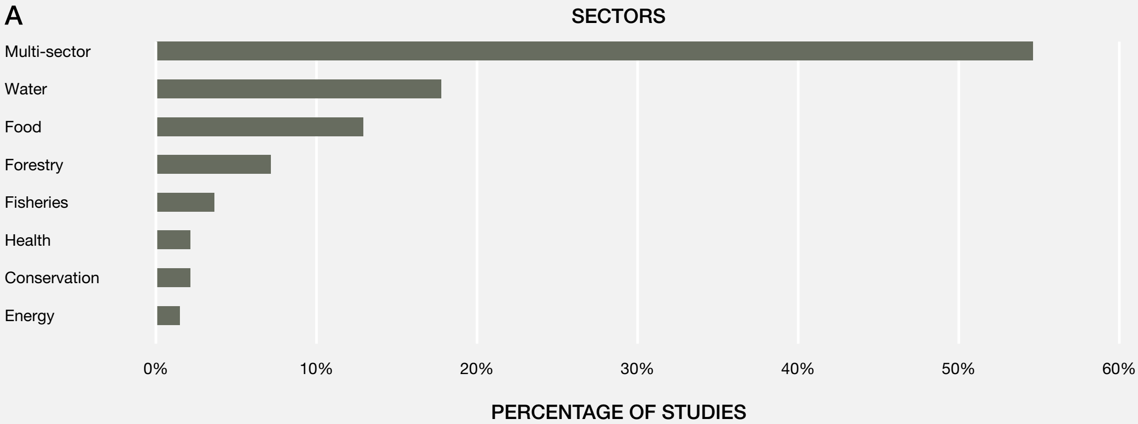
Regional coverage: The majority of studies originated from Western (64%) and Central Europe (30%), with many fewer studies from Eastern Europe (5%) and Central Asia (1%). Most scenario studies covered a specific geographic region, and examples of multi-scale or cross-scale scenarios were rare (Kok & Pedde, 2016).

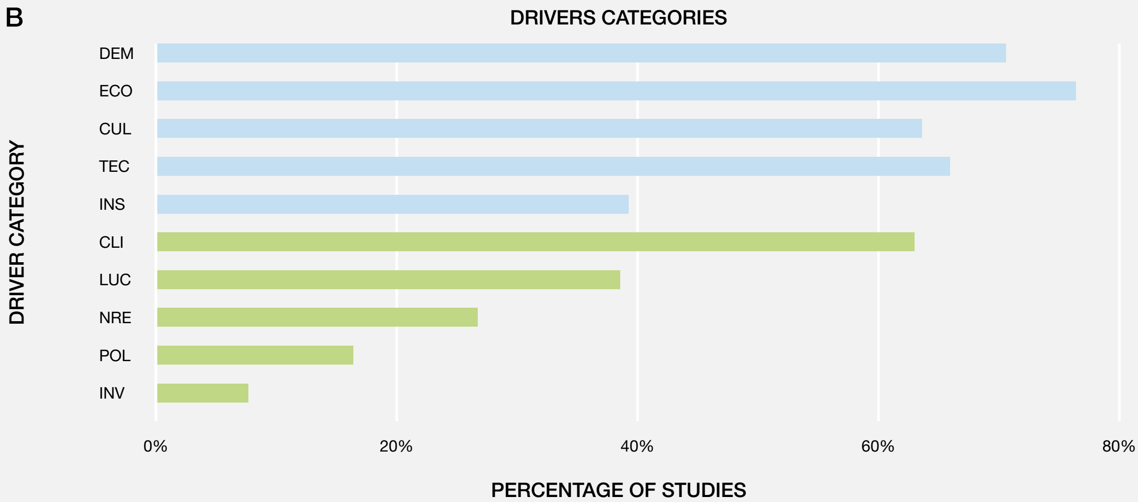
Sectoral coverage: More of the scenario studies focused on single (59%) than on multiple (41%) sectors **(Figure 5.6 A)**. Most of the single sector studies considered the water sector (21%; e.g. Flörke *et al.* 2012; Kok *et al.*, 2011; Nunneri *et al.*, 2007), followed by the agricultural sector and food production (18%; e.g. Rozman *et al.*, 2013; Uthes *et al.*, 2009; Wirsenius *et al.*, 2010). Sectors such as forestry, energy, health and fisheries were only covered by a limited number of scenarios (2-8%). Nature conservation as a single sector was only addressed in three studies, which developed scenarios based on the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (IPCC SRES) (Nakicenovic *et al.*, 2000) and applied these to land use change and species distribution models (Kolomyts, 2006; Louca *et al.*, 2015; Pont *et al.*, 2015). However, biodiversity and nature's contributions to people were covered in several of the multi-sector scenario studies (e.g. Grazhdani, 2014; Haines-Young *et al.*, 2011; Okruszko *et al.*, 2011; Pereira *et al.*, 2009).

Driver coverage: The vast majority of studies (approximately 80%) covered up to six drivers out of the ten categories of direct and indirect drivers defined in Chapter 4. The scenarios that considered six or more driver categories frequently belonged to large-scale assessments (e.g. CBD/MNP, 2007; Haines-Young *et al.*, 2011; MEA, 2005; Reder *et al.*, 2013; van Wijnen *et al.*, 2015) **(Figure 5.6 B)** or a small set of European Union scenario studies developed within large-scale research projects (e.g. ALARM (Chytrý *et al.*, 2012; Spangenberg *et al.*, 2012; Vogiatzakis *et al.*, 2015)CLIMSAVE (Audsley *et al.*, 2015; Harrison *et al.*, 2015; Kok *et al.*, 2013); EURuralis (Eickhout *et al.*, 2007; Verboom *et al.*, 2007; Verburg *et al.*, 2010); IMPRESSIONS (Kok & Pedde, 2016); OpenNESS (Hauck *et al.*, 2017); SCALER (Edjabou & Smed, 2013; Milestad *et al.*, 2014); SCENES (Flörke *et al.*, 2012; Okruszko *et al.*, 2011; Reder *et al.*, 2013)).

Figure 5 6 **Representation of A sectors, B driver categories, and C driver combinations (all as a percentage of 143 reviewed studies).**

Legend to driver abbreviations: DEM = demographic, ECO = economic, CUL = cultural & religious, TEC = scientific & technological, INS = institutional, CLI = climate change, LUC = land use/cover change, NRE = natural resource extraction, POL = pollution, INV = invasive alien species. In (C), the percentage of studies covering each driver combination is color-coded (blue shading for a greater number of studies through to red shading for low numbers of studies). Source: Own representation.





C

DRIVER COMBINATIONS

		Direct drivers					Indirect drivers				
		INV	POL	NRE	LUC	CLI	INS	TEC	CUL	ECO	DEM
Indirect drivers	DEM	4%	10%	18%	26%	45%	29%	65%	59%	69%	
	ECO	4%	10%	20%	29%	48%	31%	65%	59%		
	CUL	4%	10%	17%	22%	44%	28%	57%			
	TEC	4%	8%	17%	24%	43%	28%				
	INS	3%	7%	13%	17%	16%					
Direct drivers	CLI	8%	9%	17%	20%						
	LUC	2%	6%	6%							
	NRE	1%	4%								
	POL	1%									
	INV										

Box 5 2 Local participatory scenario planning.

A plethora of local-scale scenario studies have been conducted in Europe and Central Asia, predominantly in Western and Central Europe. While this section focuses on assessing scenario studies of subregional and regional relevance, this box briefly illustrates the richness of local-scale scenario approaches and their applications. The development of local scenarios typically involves key stakeholders and their local knowledge in the process of participatory scenario planning, in which participants and researchers collaborate to characterize a selected social-ecological system and plan for its future. Local-scale scenarios can also be used to model the effect of both large-scale and local-scale driving forces on nature and its contributions to people. Furthermore, they have the potential to facilitate the creation of bottom-up pathways for sustainable development (see **Box 5.10** in Section 5.5).

Central Europe: Bottom-up participatory approaches have been utilized in several Central European case studies to identify how driving forces at multiple scales influence local social-ecological systems. For example, a case study from southern Transylvania, Romania, presents a novel holistic approach for identifying future opportunities and risks (Hanspach *et al.*, 2014) (see also **Box 5.10**). In another case study, conducted in the Třeboň Basin UNESCO Biosphere Reserve, the Czech Republic, local narratives were combined with existing European Union scenarios to assess potential future trade-offs among nature's contributions to people (Harmáčková & Vačkář, 2015). In both cases, the results suggest that the main opportunities for the future of the study regions lie in maintaining and carefully capitalizing on their high natural capital and cultural heritage, e.g. through promoting biodiversity conservation and ecological and cultural tourism. Sustainability-related conclusions are central also to a case study from the Municipality of Koper, Slovenia, illustrating a substantial impact of industrial and commercial development on the loss of high quality agricultural land and the perceived quality-of-life (Murray-Rust *et al.*, 2013).

Western Europe: Multiple case studies undertaking place-based, participatory scenario planning in Western Europe, are included in a comprehensive review by Oteros-Rozas *et al.* (2015). These include the Peak District National Park, England (Reed *et al.*, 2013), Doñana National Park, Spain (Palomo *et al.*, 2011), the Conquense Drove Road, Spain (Oteros-Rozas *et al.*, 2013), and the French Alps (Lamarque *et al.*, 2013). The authors find that participatory scenario planning, when tailored to the local social-ecological context, results in improved environmental management and fosters scientific research. Other local scenarios were used to model how farmers' decisions are shaped by various factors (e.g. subsidies, social relationships, the need to prioritize food or biofuels) and how this influences land use patterns and species' populations, such as in the cases of the Lunan catchment, Scotland, and the Montado, Portugal (Acosta-Michlik *et al.*, 2014; Guillem *et al.*, 2015).

Eastern Europe and Central Asia: Participatory approaches are particularly suited to regions where resource constraints or knowledge gaps from expert-based sources are prevalent. Several case studies document the use of interviews and local participatory methods. For example, Kamp *et al.* (2015) employed a qualitative methodology comprising farmer interviews to examine the impact of diverse agricultural land management approaches on bird populations in Kazakhstan. This study revealed that, under the assumption of increasing agricultural production, intensification of existing cropland rather than conversion of abandoned land would have the least impact on avian biodiversity. Participatory approaches are also essential where governance and other regulatory apparatus have a weak influence and agreement among local stakeholders is key in achieving a desirable outcome. Schwilch *et al.* (2009) document how these approaches have been employed within the fight to mitigate desertification in Turkey and the Russian Federation through promotion of sustainable land management practices in local stakeholder workshops.

In most cases, the reviewed studies examined combinations of demographic, economic and technological drivers (approximately 60% of the studies; **Figure 5.6 C**), or combined these drivers with climate change (more than 40% of studies), land use change (approximately 26% of the studies) or natural resource extraction (approximately 18%). This illustrates that the studies commonly built on the IPCC SRES scenarios, combining these categories of drivers, as the basis for further analysis (e.g. De Vries & Posch, 2011; Murray-Rust *et al.*, 2013; Reidsma *et al.*, 2006; Rounsevell *et al.*, 2006). The newer IPCC shared socioeconomic pathways (SSPs) (O'Neill *et al.*, 2015), which focus on a similar set of drivers, were applied to a more limited extent due to their recent finalization (e.g. Blanco *et al.*, 2017; Popp *et al.*, 2017; Riahi *et al.*, 2017).

Among cultural drivers, the impact of diet (including the degree of meat consumption or food origin) was commonly examined, e.g. on greenhouse gas emissions (Fazeni & Steinmüller, 2011; Stehfest *et al.*, 2009), water use (Vanham *et al.*, 2013), nutrient emissions (Thaler *et al.*, 2015) and land use change (Milestad *et al.*, 2014; Wirsenius *et al.*, 2010). The interaction of institutional change with other drivers, was generally understudied, with some exceptions (Haines-Young *et al.*, 2011; Kok *et al.*, 2011; Kok & Pedde, 2016; MEA, 2005; Milestad *et al.*, 2014; Reder *et al.*, 2013; Strokal *et al.*, 2014).

From the perspective of direct drivers, scenario studies were strongly dominated by climate change, followed by land use and land cover change (Mitchley *et al.*, 2006). Scenarios including both climate and land use change were frequently linked to the role of agriculture as a driver of landscape change (Eitzinger *et al.*, 2013; Eliseev & Mokhov, 2011; Louca *et al.*, 2015; Nol *et al.*, 2012; Pukšec *et al.*, 2014; Thaler *et al.*, 2015) **(Figure 5.6 C)**. However, the proportion of land use change scenario studies that explicitly examined impacts on biodiversity was small relative to empirical studies showing that land use change is one of the most important past drivers of changes in biodiversity and nature's contributions to people in Europe and Central Asia (see Chapter 4, Section 4.5, and WWF Living Planet Report 2016 - WWF, 2016). Different levels of protection (Chytrý *et al.*, 2012; Haines-Young *et al.*, 2011) and degrees of fragmentation (Haines-Young *et al.*, 2011; Milestad *et al.*, 2014) were frequently considered in the reviewed scenarios. Yet, they were mostly related to pressures exerted on land use by policy, social, economic or climatic drivers, rather than as a driving force on nature and its contributions to people. These results are consistent with the finding by Titeux *et al.* (2016) that within biodiversity-related scenarios, compared to climate change, the impact of land use change is often neglected. Other direct drivers, such as pollution, natural resource extraction and invasive alien species, with adverse impacts on biodiversity and nature's contributions to people, were poorly represented in scenarios. While some pollution aspects such as the impact of nutrient emissions (phosphorous and nitrogen in fertilizers) on marine and freshwater ecosystems were frequently studied (Håkanson & Bryhn, 2014; Holguin-Gonzalez, 2014; Nol *et al.*, 2012; Nunneri *et al.*, 2007; Seitzinger *et al.*, 2010), others were greatly understudied (e.g. the impact of nanoplastics; Ryan *et al.*, 2009).

Finally, there were very few scenario studies which modelled feedbacks from direct drivers, such as climate change or land use change, to socio-economic trends (an integral component of the IPBES conceptual framework; Díaz *et al.*, 2015), highlighting a key gap in the scientific literature covering nature's contributions to people.

Values coverage: The concept of value (see Chapter 1, Section 1.5.2 for the definition of "value" within IPBES) was only considered in 30% of scenario studies in Europe and Central Asia, with 19% including values explicitly and 11% implicitly. For example, Verburg *et al.* (2008) included the concept of value explicitly when analyzing how changes in demand for agricultural products are likely to have a large impact on landscape quality and the value of natural areas. In contrast, Mitchley *et al.* (2006) considered the values concept implicitly through an assessment of how trends in agricultural systems result in negative impacts on biodiversity. Studies included different dimensions of value: 66% used the concept of value as nature's contributions to people (i.e. anthropocentric instrumental values); 26% as nature (non-anthropocentric or intrinsic values); and 8% as good quality of life (anthropocentric relational values). Most studies focused primarily on values associated with material contributions to people (44%), followed by regulating and supporting contributions (39%), then non-material contributions (17%). The purpose or target of valuation within the scenario studies covered agriculture (22%), spatial planning (20%), biodiversity and conservation (19%), and climate change (18%).

These findings show that only a minority of scenario studies take account of the value of nature, its contributions to people, and good quality of life (Murray-Rust *et al.*, 2013). They also indicate that most studies addressed the different dimensions of value only independently (e.g. MEA, 2005) or linked nature with a limited set of mainly instrumental values, excluding other dimensions such as intrinsic or relational values. This highlights a significant gap in the current scenario literature in recognizing the diversity of values (e.g. IPBES, 2016b). Closing this gap could be of particular importance as the transformative practices that may be needed for achieving sustainable futures can benefit from embracing such value diversity (Pascual *et al.*, 2017) (see Section 5.5).

5.2.2 Types of plausible futures for Europe and Central Asia

To synthesize findings from the plethora of existing scenario studies, scenarios may be grouped into several "scenario families" or "scenario archetypes" according to their underlying assumptions, storylines and characteristics **(Box 5.3)**. Scenario archetypes describe different general patterns of future developments and can be useful in summarizing and harmonizing the overwhelming amount of information in individual sets of scenarios. The scenario archetype approach has been recognized by IPBES (IPBES 2016a) to help to synthesize findings from scenarios throughout the four IPBES regional assessments. In addition, the use of scenario archetypes will facilitate a coherent comparison of scenarios across the regional assessments and their further synthesis in the IPBES Global Assessment on Biodiversity and Ecosystem Services. Consequently, IPBES (2016b) proposed a set of six global scenario archetypes based on scenario families described by van Vuuren *et al.* (2012).

To synthesize the exploratory scenarios reviewed for Europe and Central Asia, six scenario archetypes were selected:

1. Business-as-usual
2. Economic optimism
3. Regional competition
4. Regional sustainability
5. Global sustainable development
6. Inequality

These include five archetypes from IPBES (2016b); numbered 1 to 5 above. "Reformed markets" from IPBES (2016b) was omitted since, at the sub-global level, it is mostly synonymous with a change to more sustainable policies, and therefore falls within the *global sustainable development* archetype. An additional *inequality* scenario archetype (not included in IPBES, 2016b) was added reflecting the growing importance of this archetype in the scenario literature (see **Box 5.3**).

The scenario archetypes are described in detail in the following section**.** The six archetypes are not represented equally in the literature for Europe and Central Asia. The *business-as-usual* type of scenario is often used as a reference scenario (30% of scenarios). However, few of these studies develop a storyline of how indirect and direct drivers are projected to change over time (only three studies), rather they simply assume no change in current trends. *Economic optimism* is well-represented (24%) possibly due to its overlap with *business-as-usual* and the popularity of downscaled regional versions of the Intergovernmental Panel on Climate Change SRES A1B and A1FI scenarios (Nakicenovic *et al.*, 2000). *Regional competition* (17%), *global sustainable development* (14%) and *regional sustainability* (12%) are reasonably well represented in European and Central Asian scenario studies. By contrast, *inequality*, as a relatively new scenario developed as part of the recent Intergovernmental Panel on Climate Change-related SSPs (O'Neill *et al.*, 2015), is only covered in 2% of scenario studies, but this is expected to increase rapidly.

5.2.3 Description of plausible futures for Europe and Central Asia

This section describes projected future changes in the different indirect and direct drivers represented within the exploratory scenarios for Europe and Central Asia for each scenario archetype. These are summarized in **Table 5.3**. Representation of different dimensions of value within the scenario archetypes are summarized in **Figure 5.7** and described under each of the descriptions of the scenario archetypes.

5.2.3.1 Business-as-usual

Overview: *Business-as-usual* assumes that the future will be characterized by a continuation of past and current social, economic and technological trends. Sometimes referred to as a reference scenario, this archetype can also be considered as a less extreme variant of the *economic optimism* archetype. Although there is, on average, moderate population and economic growth under this archetype, development and income growth are uneven across countries. At the same time, inequality and societal stratification persist. International markets and institutions are mostly stable, but function imperfectly. Technological development is moderate, but without fundamental innovations, and the use of fossil fuels does not substantially decrease (O'Neill *et al.*, 2015).

Indirect drivers: Most scenarios under the *business-as-usual* archetype represent reference scenarios that assume current trends in population, GDP, consumption and management of natural resources (Popp *et al.*, 2010; Stehfest *et al.*, 2009; Wirsenius *et al.*, 2010). Only three scenarios are associated with storylines that explain future developments: "BAMBU" from the ALARM project (e.g. Stocker *et al.*, 2012), "go with the flow" from the UK NEA (Haines-Young *et al.*, 2011) and SSP2, also known as "middle of the road" (e.g. O'Neill *et al.*, 2015; Obersteiner *et al.*, 2016). These scenarios generally assume moderate population and economic growth, and a continued expansion of global free-market enterprises (Haines-Young & Potschin, 2010; O'Neill *et al.*, 2015; Stocker *et al.*, 2012), with some national differences, e.g. a relatively high increase in the UK population (Haines-Young *et al.*, 2011) **(Table 5.3)**. While environmental improvement is seen as important, society and industry are reluctant to adopt many global or national environmental policies that would lead to substantial change (Haines-Young & Potschin, 2010).

Direct drivers: The *business-as-usual* archetype assumes moderate to high intensity of climate change (Dullinger *et al.*, 2015; Fronzek *et al.*, 2012; Hickler *et al.*, 2012). For Western Europe and parts of Central Europe, increases in woodland and reductions in grassland are assumed (Mitchley *et al.*, 2006; Partidário *et al.*, 2009; Sheate *et al.*, 2008). Land homogenization trends differ across Western and Central Europe (e.g. substantial countryside homogenization in the UK - Haines-Young & Potschin, 2010) and limited concentration of agricultural land in Croatia (Pukšec *et al.*, 2014). Moderate to high levels of pest outbreaks and alien species invasions are expected (European Union - Chytrý *et al.*, 2012; UK - Haines-Young & Potschin, 2010; Austria - Seidl *et al.*, 2008).

Values: This scenario archetype is strongly focused on instrumental values (44%), although many business-as-usual studies did not explicitly or implicitly mention values (classified as a "no value perspective" in **Figure 5.7**). It typically lacks any acknowledgement of relational or intrinsic values implying a lack of long-term focus on conserving nature. For example, Spangenberg *et al.* (2012) identified that an extension of current trends in European Union policies may slow down the loss of biodiversity in many cases and in most biomes, but it will not be capable of halting or reversing the loss.

5.2.3.2 Economic optimism

Overview: Global developments steered by economic growth result in a strong dominance of international markets

Box 5 3 Scenario archetypes: comparing global archetypes with archetypes for Europe and Central Asia.

The approach of categorizing similar scenarios into "scenario archetypes" based on their underlying assumptions, characteristics and narratives, is particularly useful to summarize and harmonize large numbers of existing scenarios covering a particular area and period. This approach has been previously applied by scenario reviews at multiple scales. For instance, at the global scale, a review by van Vuuren *et al.* (2012) proposed six "scenario families" **(Table 5.1)**. In another study, Rothman (2008) provided a detailed and conceptually grounded overview of a number of archetypes found in environmental scenarios covering a broad range of sectors, scales and types. Both of these are in general agreement with other similar studies (e.g. Busch, 2006; Westhoek *et al.*, 2006; Zurek, 2006). In addition, there are scenario archetype studies that predominantly review subglobal studies, for example, a review of more than 160 local scenario studies by Hunt *et al.* (2012). Although none of these review papers specifically targeted nature or its contributions to people, they did consider the most influential scenario studies on these topics, including the Millennium Ecosystem Assessment (MEA, 2005) and multiple land use change scenarios (see Busch, 2006).

All of the studies presented above largely agree on similar, comprehensive sets of four to seven scenario archetypes **(Table 5.1)**. Furthermore, they all single out one particular set of scenarios in their analysis, namely the "global scenario group" scenarios (van Vuuren *et al.*, 2012), as being helpful to centre the scenarios around.

Table 5 1 Six global scenario families as proposed by van Vuuren *et al.* (2012), compared with a number of scenario archetype studies and characterizations.

van Vuuren *et al.* (2012)	Global scenario group	Hunt *et al.* (2012)	Kok *et al.* (2013)	Rothman (2008)	Philosophy[1]	Motto[1]
Economic optimism	Market forces	Market forces	Global markets	Market forces	Market optimism	Don't worry, be happy
Reformed markets	Policy reform	Policy reform	Global sustainability	Policy reform	Policy stewardship	Equity and growth
Global sustainable development	New sustainability paradigm	New sustainability paradigm	-	New sustainability paradigm	Sustainability as global social evolution	Human solidarity
Regional sustainability	Eco-communalism	Eco-communalism	Regional sustainability	Eco-communalism	Pastoral romance	Small is beautiful
Regional competition	Fortress world	Fortress world	Continental barriers	Fortress world	Social chaos	Order through strong leaders
-	Breakdown	Breakdown	-	Breakdown	Existential gloom	The end is coming
Business-as-usual	Muddling through	-	-	Muddling through	No grand philosophers	-

[1] Taken from Rothman (2008).

Comparing the exploratory scenarios for Europe and Central Asia with global scenario archetypes reveals that the *global sustainable development* and *regional competition* archetypes tend to be present in almost all of the scenario sets **(Table 5.2)**. This pair of contrasting scenarios ("global-good" and "regional-bad") seem to translate well to a variety of different scenario settings. The *economic optimism* archetype is also present in most scenario sets. It is absent only from the CLIMSAVE scenarios, which were constructed at the height of the 2008 global economic crisis.

A small proportion of scenarios for Europe and Central Asia do not match the global archetypes. Most notably SSP4 (and the similar CLIMSAVE *riders on the storm*; Harrison *et al.*, 2015) do not have an equivalent in the scenario families from van Vuuren *et al.* (2012). These scenarios depict a future with a fundamental increase in inequality between and within countries with a strong green elite, which is difficult to match to earlier scenario review efforts. This type of scenario might increase in importance with the growing use of the IPCC-related shared socioeconomic pathways (SSPs) (O'Neill *et al.*, 2015) in environmental assessments.

Box 5 3

Table 5 2 **The van Vuuren *et al.* (2012) scenario archetypes and their equivalents in Europe and Central Asia scenario sets.**

	Global scenario archetypes					Not matching
	Economic optimism	**Global sustainable development**	**Regional sustainability**	**Regional competition**	**Business-as-usual**	
ALARM	Growth applied strategy (GRAS)	Sustainable European development goal (SEDG)	-	-	Business as might be usual (BAMBU)	
CLIMSAVE	-	We are the world	-	Icarus; should I stay or should I go	-	Riders on the storm
EURuralis	Global economy	Global cooperation	Regional communities	Continental markets	-	
Hanspach *et al.* (2014)	Prosperity through growth	Balance brings beauty	-	Our land, their wealth	-	Missed opportunity
MA-Portugal	Global orchestration	Techno garden	Adapting mosaic	Order from strength	-	
SCENES	Economy First	Policy rules	Sustainability eventually	Fortress Europe	-	
SRES-Europe	A1B, A1FI	B1	B2	A2	-	
SSPs-Europe and Central Asia	SSP5	SSP1	-	SSP3	SSP2	SSP4
UK NEA	World markets	Nature @ work	Local stewardship; Green and pleasant land	National security	Go with the flow	

with a small degree of regulation. Population growth varies from low (assuming a strong drop in fertility levels) to stable and high depending on the specific scenario. Technological development is rapid and there is a partial convergence of income levels across the world. Environmental problems are only dealt with when solutions are of economic interest. A more extreme variant of this archetype is the SSP5 type of fossil fuel dominated markets with little environmental concern, but with highly equal and healthy societies. In terms of biodiversity and nature's contributions to people, this archetype can range from devastating (environmental destruction) to positive (economically viable nature-based solutions). Yet, in all cases, a reactive attitude to environmental management prevails.

Indirect drivers: Several scenarios corresponding to the *economic optimism* archetype describe a future with low population growth in Europe and Central Asia according to SRES A1 (European Union - Stocker *et al.*, 2014; Central Europe - Fischer *et al.*, 2011; Germany - Dietrich *et al.*, 2012; Hattermann *et al.*, 2015; Koch *et al.*, 2011; Steidl *et al.*, 2015), which is concentrated in cities and leads to substantial urban sprawl (Fazeni & Steinmüller, 2011; Kok *et al.*, 2011; Louca *et al.*, 2015; Reder *et al.*, 2013). However, several national scenarios outline a contrasting trend, assuming high population growth, for example in Sweden (Milestad *et al.*, 2014), the UK (*world markets*; Haines-Young *et al.*, 2011) and Portugal (*global orchestration*; Pereira *et al.*, 2009) **(Table 5.3)**.

This archetype is characterized by intensive economic development with the highest GDP growth of all archetypes (SSP5/SRES A1; MEA, 2005; Reder *et al.*, 2013) across the majority of countries in Europe and Central Asia

Table 5 3 **Trends in indirect and direct drivers in selected scenarios for each of the Europe and Central Asia scenario archetypes.**

Arrows in the table are based on expert interpretation of the magnitude of trends in given drivers: single arrow = moderate change, double arrow = strong change. Rows with grey background summarize general trends across all scenarios found within the archetypes. Color-coding of arrows is based on expert interpretation of the impact of the trend on nature or its contributions to people: blue = favourable, orange = unfavourable, grey = neutral. Trends in demographic (population), economic (GDP and globalization) and land use change (landscape homogeneity/deforestation) drivers were not interpreted in terms of impact (white). Legend to driver abbreviations: DEM = demographic, ECO = economic, CUL = cultural & religious, TEC = scientific & technological, INS = institutional, CLI = climate change, LUC = land use/cover change, NRE = natural resource extraction, POL = pollution, INV = invasive alien species. Source: Own representation.

Driver		DEM	ECO		CUL	TEC	INS		CLI	LUC	NRE	POL	INV
Trend		Population	GDP	Globalization	Sustainable consumption	Technology	Efficiency of governance	Envi. management proactivity	Temperature/ radiative forcing	Landscape homogeneity/ deforestation	Natural-resource exploitation	Pollution	Invasions
Archetype/Scenario	Region												
Business-as-usual[1]	ECA	⇧	⇧	⇧	↓	↑	↓	↑↓	↑	⇧	↑	↑	↑
SSP2[10]	ECA	⇧	⇧	⇧	↓	↑	↓	↓		⇨	↑	↑	
Go with the flow[7]	EU	⇧⇧	⇧	⇧		→			↑/↑↑	⇧⇧			↑
Economic optimism[1]	ECA	⇧⇧	⇧⇧	⇧	↓	↑↑	→	↓	↑↑	⇧	↑↑	↑	↑
Global orchestration[2]	Global	⇧⇧	⇧⇧	⇧	↓	→		↓	↑↑	⇨		↑	↑
Economy first[3]	EU	⇨	⇧⇧	⇧		↑↑	↓	↓	↑/↑↑	⇨	↑↑	↑	
Wealth-being[4]	EU	⇧⇧	⇧⇧	⇧	↓↓	↑↑			↑↑	⇧	↑↑		
CA SSP 5 Fossil-fuelled development[5]	Central Asia	⇧	⇧	⇧		↑	↑				→		
Global orchestration[6]	Black Sea region	⇧⇧	⇧⇧	⇧	↓	↑		↓		⇨	↑↑	↑	
World markets[7]	UK	⇧⇧	⇧	⇨	↓	↑			↑/↑↑	⇧	↑↑		↑
1A[8]	Sweden	⇧⇧	⇨	⇧		↑				⇧			
Regional competition[1]	ECA	⇨	⇨	⇩	→	↓	↓↓	↓	↑	⇧	↑	↑	↑
Order from strength[2]	Global	⇨	⇨	⇩	→	↓		↓	↑	⇧		↑↑	↑
Fortress Europe[9]	EU	⇨	⇨	⇩⇩		↓	↓↓	↓			↑	↑	
EU SSP3[5]	EU	⇩⇩	⇨	⇩⇩	→	↓	↓↓	↓	↑↑				
CA SSP3 Regional rivalry[5]	Central Asia	⇩	⇩	⇩⇩		↓	↓	↓↓			↑↑		
National security[7]	UK	⇧	⇨	⇩	→	↑			↑/↑↑	⇧⇧	↑		→
2A[8]	Sweden	⇧⇧	⇨	⇩		↓				⇩			

Driver		DEM	ECO		CUL	TEC	INS		CLI	LUC	NRE	POL	INV
Trend		Population	GDP	Globalization	Sustainable consumption	Technology	Efficiency of governance	Envi. management proactivity	Temperature/ radiative forcing	Landscape homogeneity/ deforestation	Natural-resource exploitation	Pollution	Invasions
Archetype/Scenario	Region												
Regional sustainability[1]	ECA	⇧	⇧	⇩	⬆	⬆	⬆	⬆	⬆	⇩	⬇	➡	⬇
Adapting mosaic[2]	Global	⇧	⇧	⇩	➡	➡		⬆	⬆⬆	⇨		➡	⬇
Sustainability eventually[9]	EU	⇨	⇨	⇩	⬆	➡	⬆⬆	⬆			⬇	⬇	
Rural revival[4]	EU	⇩	⇩	⇨	⬆⬆	⬇		⬆	⬆	⇨	⬇		
Adapting mosaic[6]	Black Sea region	⇧	⇧	⇩	➡	➡		⬆		⇨		➡	
Green and pleasant land[7]	UK	⇨	⇧	⇨	⬆	⬆⬆		⬆	⬆/⬆⬆	⇩	⬇		➡
Local stewardship[7]	UK	⇨	⇨	⇩	⬆	⬆⬆		⬆	⬆/⬆⬆	⇩⇩	➡		⬇
2B[8]	Sweden	⇧	⇧	⇩		⬇				⇩			
Global sustainable development[1]	ECA	⇨	⇧	⇧⇧	⬆	⬆⬆	⬆	⬆	⬆	⇧	⬇	⬇	⬇
Techno garden[2]	Global	⇧	⇧	⇧	➡	⬆⬆		⬆	⬆	⇨		⬇	➡
Policy rules[9]	EU	⇨	⇨	⇨		➡	⬇	⬆			⬆	⬇	
United we stand[4]	EU	⇧	⇧	⇨	⬇	⬆⬆		⬇	⬆	⇧	⬆⬆		
CA SSP1 Sustainability[5]	Central Asia	⇧	⇧⇧	⇧⇧		⬆⬆	⬆⬆	⬆			⬇		
Nature @ work[7]	UK	⇧	⇧⇧	⇧	⬆	⬆⬆			⬆/⬆⬆		⬇		⬇
1B[8]	Sweden	⇧	⇧	⇧		⬆				⇧			
Inequality[1]	ECA	⇩	⇧	⇧	➡	➡	⬇	⬇	⬆		⬆		
EU SSP4[5]	EU	⬇	⬆	⬆	➡	➡	⬇	➡	⬆				
CA SSP4 A game of elites[5]	Central Asia	➡	➡	⬆		➡	⬇	⬇			⬆		

References: [1]Archetypes: (IPBES, 2016b; van Vuuren *et al.*, 2012), [2](MEA, 2005), [3](Reder *et al.*, 2013), [4]OpenNESS project: (Hauck *et al.*, 2017), [5]IMPRESSIONS project: (Kok & Pedde, 2016), [6](Strokal *et al.*, 2014), [7]UK NEA: (Haines-Young *et al.*, 2011), [8](Milestad *et al.*, 2014), [9]SCENES: (Kok *et al.*, 2011), [10](O'Neill *et al.*, 2015).

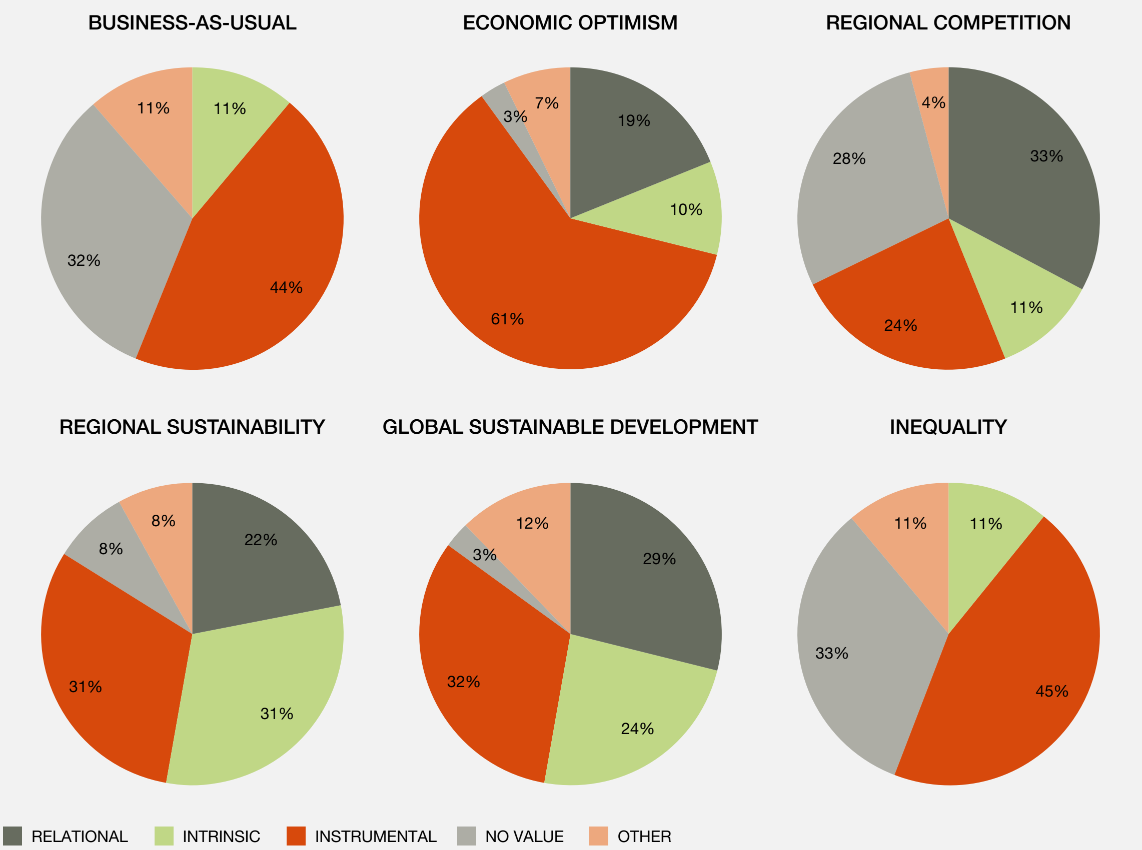
(Garrote *et al.*, 2016; Koch *et al.*, 2011) **(Table 5.3)**. The level of international cooperation is high (global orchestration - MEA, 2005; Reder *et al.*, 2013), however, this may involve only the privileged few (economy first - Okruszko *et al.*, 2011; Reder *et al.*, 2013). The scenarios assume a reactive attitude towards environmental management (economy first - Kok *et al.*, 2011; Reder *et al.*, 2013). Lifestyles are resource-intensive, with high meat and material consumption (world markets, global orchestration, EU SSP5) (Haines-Young *et al.*, 2011; Kok & Pedde, 2016; MEA, 2005; Strokal *et al.*, 2014). The globalization of lifestyles also influences diets. For example, the world markets scenario for the UK assumes increasing consumption of processed meals and fast food (Haines-Young *et al.*, 2011). In Central Asia, the respective scenario assumes globalization of lifestyles with consumption patterns mirroring those in other parts of the world (SSP5; Kok & Pedde, 2016). Technological development is rapid (SSP5/SRES A1 - Koch *et al.*, 2011; Reder *et al.*, 2013; Stocker *et al.*, 2014), with an emphasis on efficiency, including increasing agricultural productivity (global orchestration - Seitzinger *et al.*, 2010; Strokal *et al.*, 2014; CA SSP5 - Kok & Pedde, 2016). For example, the respective scenario for the UK assumes investments in multiple types of technologies, including IT, transport, military, pharmaceutical and genetic modification technologies (world markets - Haines-Young *et al.*, 2011).

Direct drivers: In terms of climate change, Europe and Central Asia is affected by the most severe warming (SRES A1B/A1FI) compared to other archetypes (Okruszko *et al.*, 2011; Reder *et al.*, 2013) **(Table 5.3)**. Surface and groundwater availability is expected to decrease in many countries due to changing precipitation patterns and higher evapotranspiration (Germany - Barthel *et al.*, 2012; Dietrich *et al.*, 2012; Hattermann *et al.*, 2015; Mediterranean - Garrote *et al.*, 2016), with subsequent implications for agricultural irrigation (Germany - Steidl *et al.*, 2015; Mediterranean - Garrote *et al.*, 2016). At the same time, the scenarios assume a substantial increase in natural resource and water consumption (around 30% in the European Union - Flörke *et al.*, 2012; Kok *et al.*, 2011; Okruszko *et al.*, 2011) and intensive utilization of biofuels (Milestad *et al.*, 2014; van Wijnen *et al.*, 2015). Accordingly, trends in fertilizer use and nutrient input are increasing (global orchestration, economy first) (MEA, 2005; Reder *et al.*, 2013; Strokal *et al.*, 2014), with subsequent implications for environmental degradation and pollution (Kok *et al.*, 2011; Reder *et al.*, 2013).

Values: As with *business-as-usual*, this scenario archetype consists of predominantly instrumental values (66%) and individualistic perspectives **(Figure 5.7)**. Management of nature and its contributions to people is based on an economic "internalization of externalities" (Reed *et al.*, 2013) and single-value approaches, which are unlikely to offer effective sustainable solutions to the progressive environmental degradation (Jacobs *et al.*, 2016).

Figure 5 7 **Representation of different dimensions of value within the reviewed scenario studies for Europe and Central Asia summarized by scenario archetype.**

Categorization undertaken by the author team. No value = no values were found (explicitly or implicitly) in the scenario studies. Source: Own representation.



5.2.3.3 Regional competition

Overview: *Regional competition* assumes a world regionalized according to economic developments. The market mechanism fails, leading to a growing gap between rich and poor. This, in turn, results in increasing problems with crime, violence and terrorism, which results in significant trade and other barriers. The effects on the environment and biodiversity are mixed. Overall, there is a tendency towards increased security, which can be either positive (by protecting biodiversity) or negative (by intensifying agricultural production).

Indirect drivers: The *regional competition* archetype assumes fragmentation and disintegration within Europe and Central Asia, leading to weak cooperation between countries, and regionalism (*fortress Europe*, EU/CA-SSP3) (Kok *et al.*, 2011, 2013; Kok & Pedde, 2016). Population growth projections are variable at the national level, ranging from low (*order from strength* scenario in Portugal - Pereira *et al.*, 2009) to high (Switzerland - Neteler *et al.*, 2013; Lithuania - Ozolincius *et al.*, 2014), and with contradictory trends projected for the whole of the European Union (SRES A2) (Eliseev & Mokhov, 2011; Gao & Giorgi, 2008; Kok *et al.*, 2011; MEA, 2005; Milestad *et al.*, 2014; Neteler *et al.*, 2013; Seitzinger *et al.*, 2010). By contrast, economic development is assumed to be slow in almost all scenarios (SRES A2; Eliseev & Mokhov, 2011; van den Hurk *et al.*, 2005; van Slobbe *et al.*, 2016) **(Table 5.3)**.

The archetype is characterized by high inequality, declining social cohesion and decreases in human capital (EU/CA-SSP3) (Kok *et al.*, 2011; Kok & Pedde, 2016). The emphasis on self-sufficiency is high (Thaler *et al.*, 2015), and the predominant approach to environmental issues is reactive (*fortress Europe*, *order from strength* scenarios) (Kok *et al.*, 2011; MEA, 2005). Barriers in collaboration lead to slow technological development (SRES A2/SSP3; Latkovska *et al.*, 2012; Reidsma *et al.*, 2006; van Meijl *et al.*, 2006), even described as strongly decreasing or failing (*fortress Europe*, EU SSP3) (Kok *et al.*, 2011; Kok & Pedde, 2016) **(Table 5.3)**. In Central Asia, this archetype suggests potentially serious consequences for societal functioning (CA-SSP3) (Kok & Pedde, 2016).

Direct drivers: Climate change is expected to be relatively severe (SRES A2; Bourdôt *et al.*, 2012; Eliseev & Mokhov, 2011; Kelly *et al.*, 2014; Latkovska *et al.*, 2012; Neteler *et al.*, 2013). The pattern of land use change largely differs among countries, with mixed trends in the extent of agricultural land (Eliseev & Mokhov, 2011; Pereira *et al.*, 2009), land use intensification (Haines-Young *et al.*, 2011; Seitzinger *et al.*, 2010) and land homogenization (Haines-Young *et al.*, 2011; Milestad *et al.*, 2014). Conflicts regarding natural resources are expected to increase (*order from strength*; MEA, 2005), with substantial use of local energy resources (*national security* - Haines-Young *et al.*, 2011). Similarly, projections of the likelihood of biotic invasions vary from high (Kelly *et al.*, 2014; Millennium Ecosystem Assessment, 2005; Ozolincius *et al.*, 2014) to low (Haines-Young *et al.*, 2011) **(Table 5.3)**.

Values: This scenario archetype is strongly focused on relational (33%) and instrumental values (24%), but also includes a no value (28%) perspective **(Figure 5.7)**. Although scenarios under this archetype include relational values (good quality of life indicators), they assume that regions will focus more on self-reliance, national sovereignty and regional identity. This leads to diversity in values, but also to tensions among regions or cultures (van Vuuren *et al.*, 2012). In such futures, it may be difficult to protect biodiversity because of a combination of strong control of institutions (generally top-down) and lack of synergy between different levels of governance. Approaches to biodiversity protection are local (if any) and further constrained by a lack of concern for global environmental problems (Kok *et al.*, 2013).

5.2.3.4 Regional sustainability

Overview: *Regional sustainability* assumes a regionalized world based on an increased concern for environmental and social sustainability. International institutions decline in importance, with a shift toward local and regional decision-making. Decision-making is increasingly influenced by environmentally aware citizens, with a trend toward local self-reliance and stronger communities that focus on welfare, equality, and environmental protection through local solutions. A proactive attitude to environmental management prevails, which is beneficial for biodiversity and nature's contributions to people. The strong regional character and poor international collaboration, however, causes problems with technology transfers, generates a relatively high demand for agricultural land, and obstructs coordination to solve global issues such as climate change, which all put pressure on the environment. Two sub-types can be discerned:

a) Focus on local governance: Fundamental change is initiated by a broadly supported and bottom-up enforced paradigm shift, often accompanied by a dematerialization process and a "back to nature" attitude.
b) Focus on collaborative solutions to local issues: Fundamental change is initially fostered by higher-level institutions, recognizing the value of local action in a slowly regionalizing world.

Indirect drivers: The *regional sustainability* scenario archetype is characterized by empowerment of local decision-making and bottom-up governance both at the national (e.g. *local stewardship* - Haines-Young *et al.*, 2011) and the European Union level (*sustainability eventually* - Kok *et al.*, 2011). Most scenarios corresponding to this archetype assume medium population growth (SRES B2) in both the European Union (Reidsma *et al.*, 2006; van Meijl *et al.*, 2006) and individual European Union countries (Germany - Dietrich *et al.*, 2012; Latvia - Latkovska *et al.*, 2012). In contrast, in some scenarios population growth is assumed to be low (Germany and the UK - Haines-Young *et al.*, 2011; Koch *et al.*, 2011), or even to decrease (European Union: *rural revival* - Hauck *et al.*, 2017) **(Table 5.3)**.

The estimates of potential future economic development at the scale of Western Europe and parts of Central Europe under *regional sustainability* range between slow and medium (SRES B2 - Kok *et al.*, 2011; Strokal *et al.*, 2014). Several scenarios assume uneven levels of economic development among countries (e.g. *adapting mosaic* - MEA, 2005; Seitzinger *et al.*, 2010). Furthermore, contrasting projections are reported for several countries (e.g. Germany - Dietrich *et al.*, 2012; Koch *et al.*, 2011; Cyprus - Gao & Giorgi, 2008; Louca *et al.*, 2015). The archetype is characterized by consumption patterns oriented towards local food and products, as well as food self-sufficiency (*local stewardship* - Haines-Young *et al.*, 2011; Austria - Fazeni & Steinmüller, 2011; Sweden - Milestad *et al.*, 2014) and organic farming (Austria - Thaler *et al.*, 2015). Meat consumption is medium both in global and national scenarios, with an emphasis on different regional and local products, fresh food, meat and fish (*local stewardship* - Haines-Young *et al.*, 2011; *adapting mosaic* - MEA, 2005). As with economic development, technological development is assumed to be medium and uneven across the European Union (SRES B2 - Latkovska *et al.*, 2012; Reidsma *et al.*, 2006; van Meijl *et al.*, 2006), ranging from energy-related technologies (Germany - Koch *et al.*, 2011) through clean and resource-efficient technologies (Austria - Thaler *et al.*, 2015; Cyprus - Louca *et al.*, 2015; Black Sea region - Strokal *et al.*, 2014) to a highly diversified technological portfolio developed at a moderate pace (Germany - Dietrich *et al.*, 2012; Latvia - Latkovska *et al.*, 2012) **(Table 5.3)**.

In general, a strong focus on sustainability is assumed, namely in terms of the development of sustainable technologies and increasing energy efficiency (*local stewardship* - Haines-Young *et al.*, 2011), higher efficiency in fertilizer use (*adapting mosaic* - Strokal *et al.*; 2014) and water saving technologies (*sustainability eventually* - Kok *et al.*, 2011), as well as higher standards for environmental protection and strong conservation policies (Bolliger *et al.*, 2007; Koch *et al.*, 2011).

Direct drivers: Climate change assumptions range from medium (Mediterranean - Gao & Giorgi, 2008; Ireland - Kelly *et al.*, 2014; Latvia - Latkovska *et al.*, 2012) to high (Germany - Dietrich *et al.*, 2012; Koch *et al.*, 2011), particularly in terms of temperature increases across the European Union (*sustainability eventually* - Okruszko *et al.*, 2011). The regionalized character of this archetype results in diverse, heterogeneous patterns of land use and land cover change both within individual countries (particularly northern Europe Union - Haines-Young *et al.*, 2011; Milestad *et al.*, 2014) and across Western and Central Europe (increase in non-intensive open land in Switzerland - Bolliger *et al.*, 2007; increase in artificial surfaces in Cyprus - Louca *et al.*, 2015). Similarly, projected trends in natural resource exploitation are mixed. For example, although some scenarios assume decreases in total water withdrawals at the European Union level (Okruszko *et al.*, 2011), scenarios for Germany (Dietrich *et al.*, 2012) project increasing water consumption and decreasing water availability. In terms of pollution, the emphasis on sustainability leads to stable or decreasing fertilizer use (Nol *et al.*, 2012; Strokal *et al.*, 2014), low increases in O_3 emissions across the European Union (Jiménez-Guerrero *et al.*, 2013) and a substantial decline in nutrient emissions to the Black Sea and the Mediterranean (Ludwig *et al.*, 2010). The regionalized character of the archetype leads to low dispersion of invasive alien species and reductions in invasions due to stricter border control (local stewardship, adapting mosaic - Haines-Young *et al.*, 2011; MEA, 2005) **(Table 5.3)**.

Values: The *regional sustainability* archetype is centred on a broad and even coverage of intrinsic (31%), instrumental (31%) and relational (22%) values **(Figure 5.7)**. The inclusiveness and balance among different types of values is favourable for sustainability efforts because it leads to regional solutions for environmental and social problems, often through combining drastic lifestyle changes with decentralization of governance (van Vuuren *et al.*, 2012). These diverse values could have positive effects on biodiversity conservation through a focus on management styles such as low-impact farming and energy-efficient lifestyles based on local low-tech development (Kok *et al.*, 2013).

5.2.3.5 Global sustainable development

Overview: *Global sustainable development* assumes a globalized world with an increasingly proactive attitude of policymakers and the public at large towards environmental issues and a high level of regulation. Important aspects on the road to sustainability are technological change, strong multilevel governance, behavioural change through education, and a relatively healthy economy. All variations of this archetype are beneficial for biodiversity, either through behavioural change, top-down "green" policies or through green technology development. In all cases, this is reinforced by a proactive attitude to dealing with environmental problems. Sub-types include:

a) Focus on technological development and technology transfer: Solutions are mainly found in (green) technological change in all sectors, including for example engineered ecosystems to deliver nature's contributions to people.
b) Focus on strong governments: Strong, mostly top-down, governance structures are effective in enforcing a more sustainable world, e.g. through taxes, pricing mechanisms, and strict regulations.
c) Focus on paradigm shift: An increased collaboration of private and public partners across scales leads to strong behavioural change towards environmental protection and sustainable development.

Indirect drivers: The *global sustainable development* archetype is characterized by a high degree of international cooperation (MEA, 2005) and top-down governance (Kok *et al.*, 2011). The scenarios corresponding to this archetype assume low to medium population growth across the European Union (SRES B1 - Ozolincius *et al.*, 2014; Reidsma *et al.*, 2006; van Meijl *et al.*, 2006; van Slobbe *et al.*, 2016), but moderate population growth in Central Asia (SSP1 - Kok & Pedde, 2016). The assumptions regarding future economic development in the European Union under this archetype are highly variable, ranging from rapid (SSP1 in Central Asia - Kok & Pedde, 2016; *nature @ work* in the UK - Haines-Young *et al.*, 2011; Hungary - Gálos *et al.*, 2011) through to medium (EU SSP1 - Kok & Pedde, 2016; Central Europe - Uthes *et al.*, 2009; Sweden - Milestad *et al.*, 2014) and slow (*policy rules* scenario for Europe - Kok *et al.*, 2011; Cyprus - Louca *et al.*, 2015) **(Table 5.3)**.

In both Europe and Central Asia, the scenarios envision strong increases in human and social capital, and high levels of social respect and cohesion (Kok *et al.*, 2013; Kok & Pedde, 2016). In Central Asia, *global sustainable development* is the only archetype under which the cooperation between countries in the region increases and transboundary water governance is implemented (CA-SSP1; Kok & Pedde, 2016).

In terms of cultural trends, the scenarios assume low to medium material consumption for the European Union (Kok & Pedde, 2016; MEA, 2005) with a proactive approach to environmental management (Kok *et al.*, 2011; MEA, 2005). While the UK *nature @ work* scenario (Haines-Young *et al.*, 2011) assumes higher consumption of local products, a generally similar scenario for Sweden assumes lower consumption trends (Milestad *et al.*, 2014). Technological development is rapid, focusing on green and resource-efficient technologies (SRES B1/SSP1, *techno garden* - Kok *et al.*, 2011; Kok & Pedde, 2016; MEA, 2005), biotechnology and sustainable technologies (Haines-Young *et al.*, 2011; Kok *et al.*, 2011) **(Table 5.3)**.

Direct drivers: Climate change is assumed to predominantly follow the SRES B1 pathway with the lowest increase in surface temperature compared to other scenario archetypes (Fischer *et al.*, 2011; Ozolincius *et al.*, 2014; Scholten *et al.*, 2014). In terms of water regime, the discharge from major rivers is assumed to decrease, for example in the case of the Black Sea and the Mediterranean Sea (Garrote *et al.*, 2016; Ludwig *et al.*, 2010). Multiple studies assume medium dispersion of invasive species both at the European Union level (Chytrý *et al.*, 2012) and in individual countries (Central Europe - Fischer *et al.*, 2011; the Baltic countries - Ozolincius *et al.*, 2014). In contrast, the UK *nature @ work* scenario assumes low dispersion of invasive species due to extensive national programmes (Haines-Young *et al.*, 2011) **(Table 5.3)**.

Values: As with *regional sustainability*, *global sustainable development* is centred on instrumental (32%), intrinsic (24%) and relational (29%) values **(Figure 5.7)**. Again, due to the inclusiveness and balance among different types of values, this archetype favours sustainability efforts. This scenario explores visionary solutions to the sustainability challenge at the global scale, including new socio-economic arrangements and fundamental changes in values (Kubiszewski *et al.*, 2017).

5.2.3.6 Inequality

Overview: *Inequality* assumes increasing economic, political and social inequalities and fragmentation both across and within countries. This future is characterized by power becoming more concentrated in a relatively small political and business elite across the globe. Economic growth is moderate in industrialized and middle-income countries, while low income countries lag behind. Technology develops unevenly. Environmental policies focus on local issues and are limited to higher-income areas (O'Neill *et al.*, 2015). The European Union increases its commitment to find innovative solutions to the depletion of natural resources and climate change, which initiates a shift towards a high-tech green Europe. However, there are increasing disparities in economic opportunity, leading to substantial proportions of populations having a low level of development. The European Union becomes an important player in a world full of tensions. In Central Asia, the concentration of wealth and power in a narrow class of elites grows, while the standard of life of the majority gradually deteriorates. Political regimes in the region are increasingly authoritarian and repressive, with growing incidence of social unrest, conflicts and ethnic clashes on the one hand, and outmigration and resignation on the other. Environmental issues are addressed only to a limited extent, particularly in relation to water and energy supplies, so as not to threaten the position of the elites (Kok & Pedde, 2016).

Only four scenarios in the review for Europe and Central Asia fall into the *inequality* scenario archetype. These are the Europe and Central Asian SSP4 scenarios (Kok & Pedde, 2016) from the IMPRESSIONS project, the Romanian *missed opportunity* scenario (Hanspach *et al.*, 2014), and the European *riders on the storm* scenario (Kok *et al.*, 2013) from the CLIMSAVE project; the latter being applied in a number of studies (e.g. Brown *et al.*, 2015; Dunford *et al.*, 2015a; Harrison *et al.*, 2015; Mokrech *et al.*, 2014; Wimmer *et al.*, 2015).

Indirect drivers: Scenarios under this archetype show contrasting trends in population for Europe and Central Asia with population increasing in Central Asia until the middle of the century when it stabilizes, but decreasing in Western and Central Europe (EU/CA-SSP4) (Kok & Pedde, 2016). Similar differences are seen for economic growth, which remains stable in Central Asia compared to high economic development in Europe. Although the efforts of the elite mostly aim at increasing (economic) power, there is increasing interest in addressing certain environmental issues, including basic rules of conduct regarding water management, infrastructural projects (water, road, rail), and energy production, which further drives technological development (EU/CA-SSP4) (Kok *et al.*, 2013; Kok & Pedde, 2016) **(Table 5.3)**.

In Central Asia the national governments gradually increase their own power by concentrating wealth and power in the upper class (CA-SSP4) (Kok & Pedde, 2016). Anti-elite movements gradually become more widespread resulting in social unrest, but the elite ensure the masses receive a minimum of services to decrease the chance of revolts.

Direct drivers: This archetype is associated with an intermediate level of climate change in Europe and Central Asia (RCP4.5, which has temperature increases of between 2 and 3˚C). Land use in Europe sees a steadily declining agricultural area and an increase in forests and biofuels. Alternatively, in Central Asia there is a gradual move towards large collective farms controlled by elites. Little information is provided on pollution and invasive alien species, but these issues are expected to be strongly regulated when advantageous to the elites (Kok & Pedde, 2016) **(Table 5.3)**.

Values: As in *business-as-usual*, this scenario archetype is strongly focused on instrumental values (45%), but also with a no value (33%) perspective **(Figure 5.7)**. In such a future, it may be difficult to conserve biodiversity because of a lack of acknowledgement of the diverse values of nature resulting in conservation efforts focusing on nature's contributions to people (i.e. anthropocentric instrumental values). Additionally, the increasing trend of social inequalities might create social conflict amongst different stakeholders around environmental issues (van Egmond & de Vries, 2011).

5.2.4 Linking plausible futures for Europe and Central Asia to policy goals and targets

Several of the Sustainable Development Goals and Aichi Biodiversity Targets refer to trends in indirect or direct drivers. These include those related to climate change, pollution, invasive alien species, sustainable management of ecosystems, and sustainable consumption and production. Here, we relate the six plausible futures for Europe and Central Asia, as described in Section 5.2.3, to the Sustainable Development Goals and Aichi Biodiversity Targets and discuss how they are likely to affect their realization, as preconditions for sustaining nature and its contributions to people. Our interpretation is based on the changes in indirect and direct drivers across scenarios within each archetype (as summarized in **Table 5.3**).

Climate change: Combating climate change (Goal 13 of the Sustainable Development Goals) is not completely achieved in any scenario archetype as they all assume some level of global warming. However, the degree of climate change varies considerably among archetypes, with the *global sustainable development* archetype moving the least away from Goal 13.

Pollution and invasive alien species: Decreasing pollution to non-detrimental levels (Target 8 of the Aichi Biodiversity Targets) and controlling invasive alien species (Target 9, Goal 15) are least likely to be achieved in Europe and Central Asia under the *business-as-usual*, *economic optimism* and *regional competition* scenario archetypes. Pollution-related targets could potentially be easier to achieve under the *global sustainable development* archetype, while decreasing biological invasions could be reached under the *regional sustainability* archetype.

Habitat/ecosystem management: Sustainable management of habitats and sustainable use of ecosystems (Target 5, Goal 15) in Europe and Central Asia are negatively affected by most archetypes, although to different extents and with diverse resulting land use patterns across the region. For example, the *economic optimism* and *regional competition* archetypes hamper the realization of these targets due to land use intensification and degradation of natural habitats. Deforestation does not represent a major threat in most archetypes (except for *regional competition*).

Sustainable consumption and production: Sustainable consumption and production (Target 4, Goal 12) are assumed to be negatively affected by the *business-as-usual*, *economic optimism*, *regional competition* and *inequality* archetypes. In contrast, the *regional sustainability* and *global sustainable development* archetypes are assumed to have a positive impact, namely in terms of sustainable consumption (*global sustainable development*) and decreasing natural resource exploitation (*regional sustainability*).

5.3 FUTURE IMPACTS ON NATURE, NATURE'S CONTRIBUTIONS TO PEOPLE, AND A GOOD QUALITY OF LIFE

Chapters 2 and 3 assessed impacts of future exploratory scenarios on nature and its contributions to people. Here we build upon and extend these assessments by reviewing integrated assessment methods and models of future impacts that attempt to represent the complex interdependencies within human and environmental systems (see **Box 5.4**). Such integrated methods and models aim to offer a more realistic assessment and set of future projections of the impact of future changes in indirect and direct drivers on biodiversity, nature's contributions to people, and a good quality of life than studies that focus on individual system components or single drivers. Integrated methods and models help to build the capacity of decision-makers to understand the full extent of future risks and vulnerabilities, rather than considering single sectors or contributions of nature to people in isolation.

5.3.1 Understanding interactions between nature and society through integrated assessment studies

This section describes future impacts on nature, its contributions to people, and a good quality of life under the different plausible futures described for Europe and Central Asia in Section 5.2. It does this by reviewing integrated modelling studies, which have been applied to exploratory scenarios for the region. The impacts are grouped according

Box 5 4 Integrated assessment models and uncertainty.

A number of different, but related, types of "integration", which are not mutually exclusive, have been used in the context of integrated assessments within a given study system. This includes integration of different: (i) issues or components (e.g. agriculture, markets and water); (ii) disciplinary views of a management problem (e.g. economic and ecological perspectives); (iii) processes (e.g. biological, chemical, physical, economic or social); (iv) temporal and spatial scales (e.g. from local to global); or (v) stakeholders through cooperation and knowledge transfer between modellers and stakeholders at all stages of a modelling process (Jakeman & Letcher, 2003; Kelly *et al.*, 2013).

Integrated assessment models typically link models (numerical or expert-based) representing different sectors, e.g. agriculture, forestry, biodiversity and water, with scenarios of drivers of change, such as climate change and socio-economic change (the latter including a range of indirect drivers). Kelly *et al.* (2013) identified five types of integrated assessment models and provide examples of each of them:

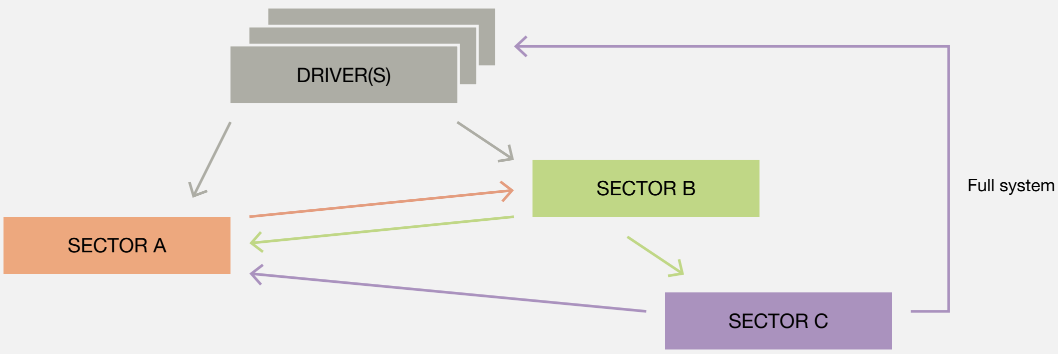
- ***System dynamics models*** are particularly good for modelling feedbacks, delays and non-linear effects, and are more commonly found in climate change-related impact assessments.
- ***Bayesian network models*** fit probabilistic relationships between system variables, and are therefore often found in modelling assessments where uncertainty needs to be properly quantified, such as for supporting decision-making and management.
- ***Coupled component models*** combine models from different disciplines or sectors to derive an integrated outcome. They can incorporate or handle complex representation of system components and their interlinkages (see **Box 5.5** for an example).
- ***Agent-based models*** define interactions between autonomous entities in a system, often humans (individuals or groups), but also other species or biophysical entities (e.g. water). Some entities (usually humans) are agents that share the same resources, can communicate or compete and react to changes in their environment through individual and social learning.
- ***Knowledge-based approaches*** encode knowledge elicited from experts using a logic system to infer conclusions. They can be used to encapsulate a wide range of complex feedbacks which are difficult to incorporate explicitly in quantitative methods, but care should be taken in using such approaches where knowledge about the system is uncertain or incomplete. Such approaches are often associated with a larger representation of impact indicators including nature, its contributions to people, and a good quality of life (or a combination of all three), which is possible due to the simplified way in which system relationships are represented.

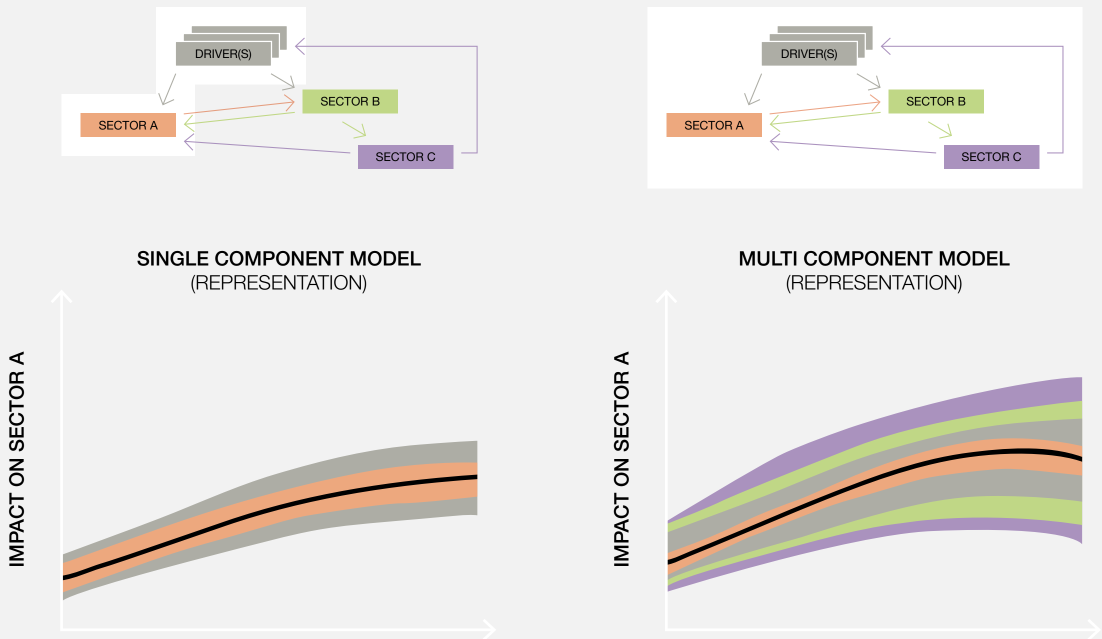
Integrated assessment models are the only approaches available to quantitatively assess future changes in socio-ecological systems that account for the non-linear, interconnected nature of their multiple components (IPBES, 2016b). However, compared with simpler, single component models (single driver versus multi-driver, or single sector versus multi-sector), integrated assessment models have increased structural model complexity adding additional uncertainty to the model outputs and their interpretation **(Figure 5.8)**.

Box 5 4

Uncertainty in model structure arises from the fact that different studies may assume different conceptual representations of reality or choose to focus on different variables and processes, which are portrayed in different ways within models. In addition, uncertainty can arise from the choice of scenarios, assumptions about initial or boundary conditions within model runs, the datasets used as inputs to models, and through error propagation within an integrated modelling framework (Alexander *et al.*, 2017; Cheung *et al.*, 2016; Dunford *et al.*, 2014; Payne *et al.*, 2015). Such uncertainty can be accessed via: (i) systematic sensitivity analysis of key parameters to highlight their relative importance in influencing the results (e.g. Kebede *et al.*, 2015; (ii) quantification of error propagation through the linked components of the model chain (e.g. Alexander *et al.*, 2017; Dunford *et al.*, 2014; Prestele *et al.*, 2016); and (iii) inter-model comparison of different types of integrated models (e.g. Alexander *et al.*, 2017; Prestele *et al.*, 2016). Exploration, quantification and communication of this uncertainty in an informative and standardized way is a major challenge for current and future IPBES assessments (IPBES, 2016b).

Figure 5 8 **Visual representation of the impacts of a driver on a sector "A" in single component (left) and multiple component (right) models and their associated uncertainty in projecting impacts under future scenarios. A detailed visualization of a coupled-component model is given in Figure 5.13 in Box 5.5. Source: Own representation.**





to the Europe and Central Asia scenario archetypes as far as possible. This helps to capture the range of projected impacts on nature, its contributions to people, and a good quality of life while explicitly acknowledging the uncertainties associated with them.

Impacts of future changes in indirect and direct drivers on nature, its contributions to people, and a good quality of life can be studied by looking at socio-ecological systems. Interactions within socio-ecological systems are important since changes in one sector can affect another sector either directly (e.g. changes in agriculture affect biodiversity and regional hydrology), or indirectly through policy (e.g. measures designed for coastal flood defence also impact on coastal habitat) (Holman *et al.*, 2008a, 2008b). Ignoring critical interactions and feedbacks can lead to either over- or under-estimation of impacts and the need for responses that limit societal vulnerability (Harrison *et al.*, 2015). For example, Harrison *et al.* (2016) showed that there were cases where the direction of change in some sectoral indicators and indicators of nature's contributions to people projected by single sector models was the opposite to that projected by an integrated model **(Figure 5.9)**. Furthermore, significant differences in the magnitude of change (>50%) were apparent even when the single-sector and integrated models agreed on the direction of change. The authors concluded that single sector studies may misrepresent the spatial pattern, direction and magnitude of most impacts and this may lead to poor decisions about adaptation.

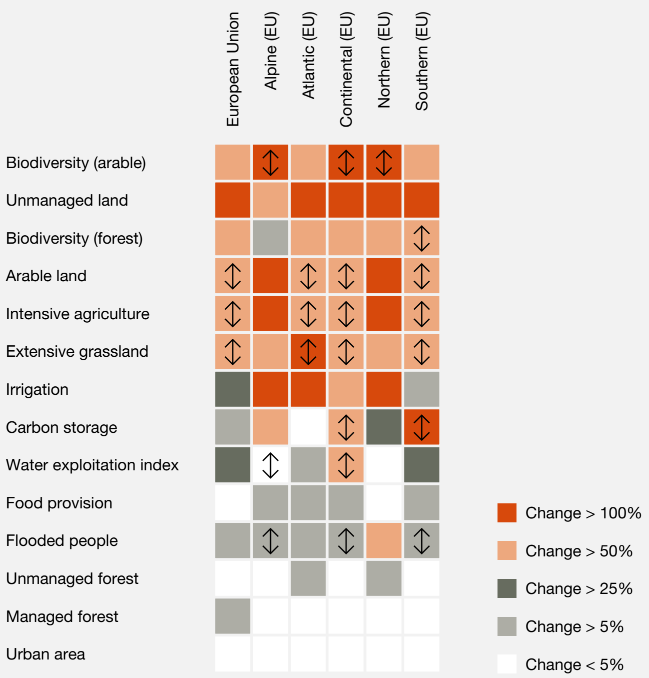
Thus, integrated studies can provide essential support to guide planning and decision-making by highlighting critical interdependencies and potential synergies and trade-offs between nature's contributions to people under different plausible futures. They also allow exploration of responses that are robust to multiple, uncertain futures, and which avoid unintended consequences (e.g. maladaptation). This is likely to become increasingly important if future changes in indirect and direct drivers lead to amplified interdependencies between different sectors.

5.3.2 Review of integrated assessment studies for Europe and Central Asia

A formal review of the literature on integrated modelling of impacts on nature, its contributions to people, and a good quality of life for Europe and Central Asia was carried out

Figure 5 9 **Differences between single sector and integrated models by regions within the European Union (EU).**

Magnitude of difference between single sector and integrated models is shown by colours. They reflect the maximum absolute change with respect to either the minimum or maximum results across multiple scenarios summed for each indicator. The double arrow symbol identifies where the direction of change (positive or negative) differs between the single sector and integrated models. Source: Adapted from Harrison *et al.* (2016).



using the Scopus database. This was complemented with extensive searches using the IPBES expert network and additional efforts by the author team to reduce gaps (i.e. for Central Asia and marine ecosystems). The review applied a broad definition of integrated assessments as described in **Box 5.4**. Articles were screened to include only those that included projections of future impacts of multiple drivers on multiple components of nature and its contributions to people.

As the majority of impact assessment studies still rely on single component models (Harrison *et al.*, 2015), only 37 articles were found from both the formal and informal reviews that met the review criteria. However, these 37 articles led to a total of 3,151 entries in the review database representing different combinations of integrated approaches, scenarios, regions and modelled system indicators for nature, its contributions to people, and a good quality of life.

Spatial coverage: The information gathered ranged from subnational studies conducted at relatively local scales to global assessments providing information for Europe and Central Asia. However, for studies conducted at the subregional or local levels, the review showed a very strong bias towards studies conducted in Western Europe (57%) versus studies conducted in other subregions (Eastern Europe 6%, Central Europe 6%, Central Asia 6%). This highlights that integrated assessments are rare in Eastern Europe and Central Asia, with most impact studies usually only considering one driver, most typically climate change. Of the integrated studies that were found for these subregions, trends for nature's non-material contributions to people indicators were absent.

Model type coverage: The review revealed that the majority of integrated studies in Europe and Central Asia use a coupled-component approach (76%). Other integrated approaches found in the review include system dynamic approaches (7%) and knowledge-based approaches (13%).

Driver coverage: A range of indirect and direct drivers were represented in the review of integrated modelling studies. The most common combination of direct drivers was climate combined with another driver (62%), mainly land use (or land management), with a smaller number of studies combining climate with resource use (12%), pollution (7%) or the effect of invasive alien species (<1%). This supports the finding in Section 5.2.1 of the dominance of climate change studies in the literature. Indirect drivers (often represented as socio-economic scenarios) were included in 51% of the studies. However, combinations of indirect and direct drivers were only considered in around 15% of database entries associated with large European Union projects, such as CLIMSAVE (Brown *et al.*, 2015; Dunford *et al.*, 2015a; Harrison *et al.*, 2015), SCENES (Okruszko *et al.*, 2011), ALARM (Lorencová *et al.*, 2016) and ATEAM (Schröter *et al.*, 2005).

Cross-sectoral coverage: Most studies involved multiple sectors and investigated cross-sectoral interactions, including goal conflicts between maximizing production of nature's material contributions to people and meeting environmental quality objectives (e.g. Forsius *et al.*, 2013). The agricultural sector featured most frequently in the reviewed studies in various combinations with nature conservation, water management, forestry, tourism and energy. Combinations between fisheries, aquaculture, water management and conservation were also observed.

Cross-scale coverage: Representation of cross-scale interactions was much less frequent than cross-sector interactions. Where included, this was often implemented by combining global, downscaled climate projections with drivers directly estimated at a lower spatial scale, such as land use and pollution (Paul *et al.*, 2012). Nested approaches for evaluating interactions across multiple scales were identified for some studies focusing on land use drivers (Maes *et al.*, 2015). These approaches use information on indirect drivers such as demography or energy at the global and regional level to drive spatially-explicit land use models at a range of spatial scales including subnational levels.

Values coverage: The concept of value was only considered in 50% of the integrated assessment studies, with 29% including values explicitly and 21% implicitly. For example, Garcia-Llorente *et al.* (2012) included the concept of value explicitly when analyzing local preferences for different land use management options in two watersheds in Spain. In contrast, Ay *et al.* (2014) considered values only implicitly, through an assessment of model-based scenarios linking climate, land use and biodiversity. The studies included different dimensions of value: 41% used the concept of value as nature's contributions to people (i.e. anthropocentric instrumental values); 3% as nature (non-anthropocentric or intrinsic values); and 6% as good quality of life (anthropocentric relational values). Most studies focused primarily on values associated with material contributions to people (39%), followed by regulating or supporting contributions (46%), then non-material contributions (25%). The purpose or target of valuation within the scenario studies covered agriculture (21%), spatial planning (21%), biodiversity/conservation (15%) and climate change (18%). These findings show that only half of integrated assessment studies take account of the value of nature, its contributions to people, and good quality of life. This supports the finding from the review of value representation in exploratory scenarios in Section 5.2.1 that there is a significant gap in the current literature in recognizing the diversity of values (e.g. IPBES, 2015a).

5.3.3 Future trends in indicators of nature, nature's contributions to people, and a good quality of life

Out of the 37 articles found through the review, yielding 3,151 entries in our review database, only seven evaluated indicators related to a good quality of life (e.g. equity, employment, education), 30 assessed indicators of nature's contributions to people (e.g. provision of energy, food and materials, regulation of freshwater quality or learning and inspiration) and 14 evaluated nature indicators (e.g. ecosystem functioning, species population trends). Eight studies evaluated at least two indicator types, and only two studies made a holistic evaluation across the different types of indicators (nature, its contributions to people, and a good quality of life).

The trends for the different indicators are described by scenario archetype **(Figure 5.10)** and geographic region **(Figure 5.11)**.

5.3.3.1 Business-as-usual

Overview: The future of the Europe and Central Asia region under the *business-as-usual* scenario archetype is complex to interpret due to the regional variability of the results. Generally, southern parts of Western and Central Europe are associated with decreasing trends in nature indicators and nature's material contributions to people, while northern parts are likely to benefit from enhanced material contributions. Central Europe may face moderate impacts in the future, except for nature's regulating contributions to people which are more greatly impacted in this subregion than for other indicators. Results for Central Asia are very limited and only concern nature's material contributions in a lake system of Uzbekistan. No results were available for Eastern Europe. Overall for all subregions, the future under this archetype is more positive than *economic optimism* scenario archetype (Section 5.3.3.2), but less than *regional sustainability* (Section 5.3.3.4).

Nature: Nature indicators assessed under *business-as-usual* in European countries generally present a stable trend (**Figure 5.10** and **Figure 5.11**). In continental parts of Western and Central Europe, the biodiversity vulnerability index is projected to remain stable (Harrison *et al.*, 2013). This stable trend was also confirmed in land ecosystems of Central Europe and aquatic ecosystems of southern parts of Western Europe, associated with stable diversity indexes (Hirschi *et al.*, 2013; Kirchner *et al.*, 2015) and stable measures of ecosystem functioning such as net primary production or community respiration (Lazzari *et al.*, 2014). A notable exception to these projections are forest and arable species of Alpine and southern regions of Western and Central Europe, which are projected to increase in vulnerability under this scenario archetype (Dunford *et al.*, 2015a). These findings are based on nine articles which used integrated modelling approaches and as such should be treated with caution due to the low number of studies. They can be compared to the much larger number of single component biodiversity modelling studies under *business-as-usual* scenarios reported in Chapter 3, Section 3.5, which show widespread shifts and contractions in species' distributions, and a general deterioration in conservation status.

Nature's regulating contributions to people: Trends in nature's regulating contributions to people in Western and Central Europe are complex to define as the studies using the *business-as-usual* scenario archetype projected results that were highly variable across subregions, indicators and the time period considered (**Figure 5.10** and **Figure 5.11**). For example, carbon sequestration is projected to decrease in Western and Central Europe by 2030 (-17%, representing -17 Tg C year^{-1}), but then to follow an increase to 2050 (from 7.4 to 8.7-9.2 Mt year^{-1}; Dunford *et al.*, 2015b; Verkerk *et al.*, 2014). For both time periods, however, Central Europe is associated with decreasing carbon sequestration for pastures and grasslands (Lorencová *et al.*, 2016; Lorencová *et al.*, 2013). In Central Europe, the future of other regulating contributions is unclear. For example, some authors project an increase in habitat diversity and unmanaged lands and a decrease in nitrogen leaching (Harrison *et al.*, 2013; Hirschi *et al.*, 2013; Lorencová *et al.*, 2016), while other studies associate the *business-as-usual* archetype with a decline in the regulation of climate, negative impacts on nutrient cycling and stable greenhouse gas emissions from agriculture (Hirschi *et al.*, 2013; Kirchner *et al.*, 2015).

Nature's material contributions to people: The future of nature's material contributions to people generally varies between the northern and southern regions of Western and Central Europe, but is overall more positive than the nature indicators or regulating contributions (**Figure 5.10** and **Figure 5.11**). Several local and international studies mentioned important trade-offs between nature's material and marketable contributions to people, and its non-marketable contributions, which could explain this duality (Dunford *et al.*, 2015b; Hirschi *et al.*, 2013; Kirchner *et al.*, 2015; Verkerk *et al.*, 2014). Northern and Alpine parts of Western and Central Europe are projected to benefit from the *business-as-usual* scenario archetype because of increased food production (e.g. + 3-9% agricultural biomass production) and increased forest yield by 2050 (Dunford *et al.*, 2015b; Harrison *et al.*, 2013; Kirchner *et al.*, 2015). In contrast, food production and forest yield are both projected to decrease in southern parts of Western and Central Europe (Dunford *et al.*, 2015b; Harrison *et al.*, 2013). In continental parts of Western and Central Europe, the production of food remains stable but the forest area

Figure 5 10 **Projected future impacts on nature, nature's contributions to people (NCP), and good quality of life indicators according to the six scenario archetypes (in columns): *business-as-usual, economic optimism, regional competition, regional sustainability, global sustainable development,* and *inequality*.**

The number of indicator-scenario combinations per scenario archetype, resulting from the 37 relevant articles, is shown in the bottom row. Source: Own representation.

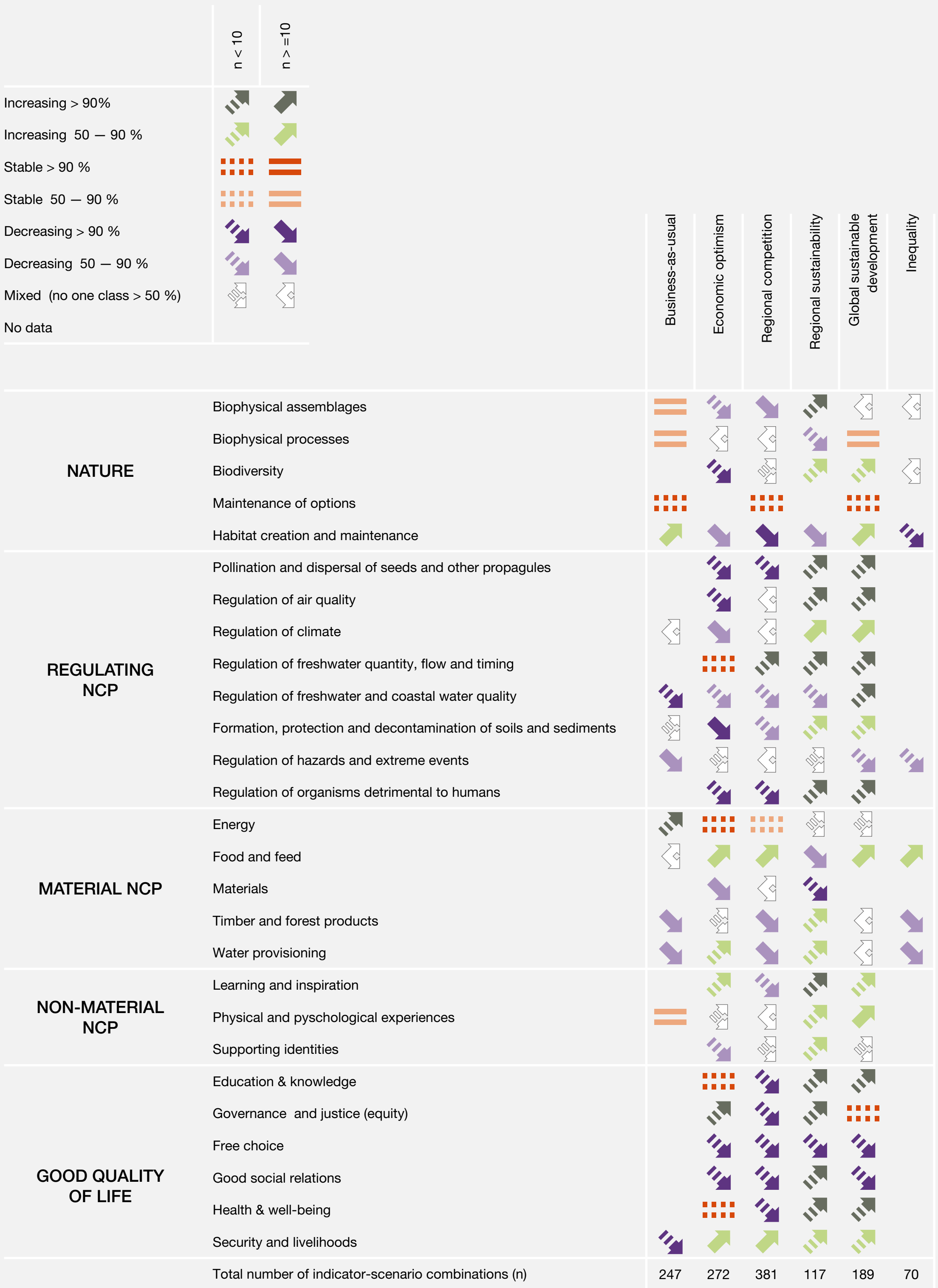
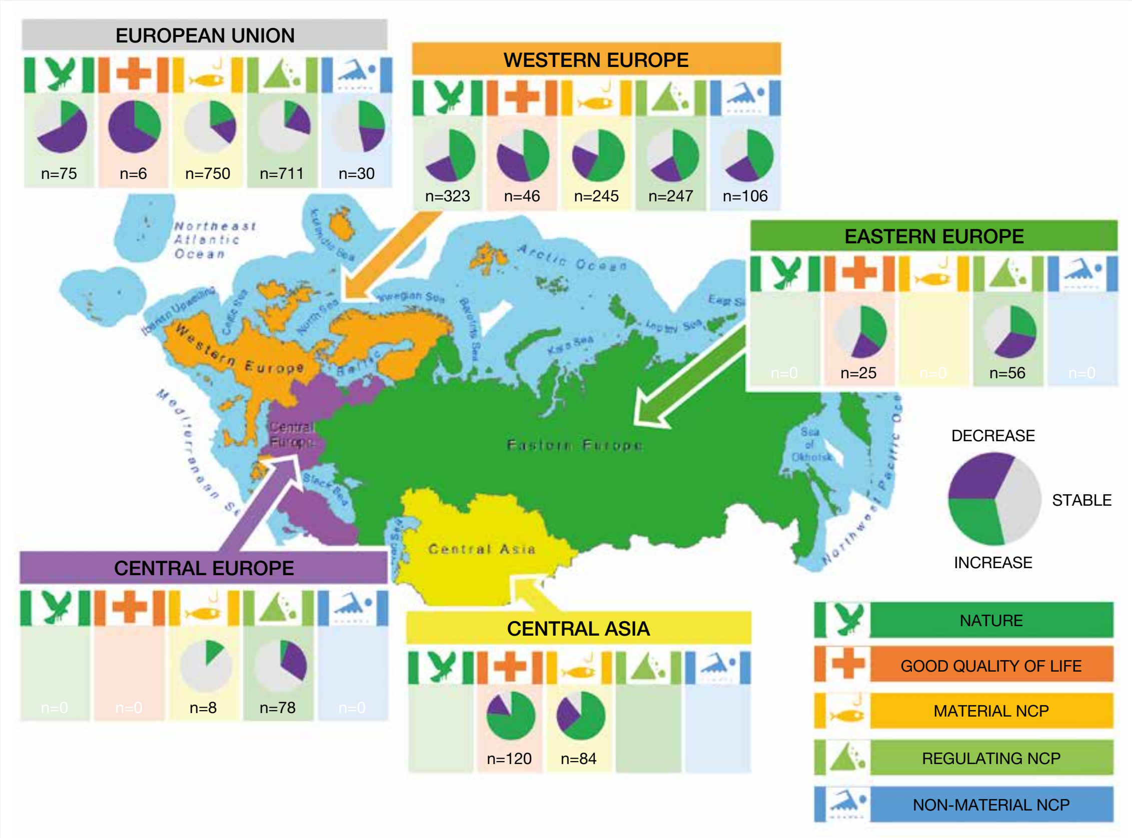


Figure 5 11 **Summary of trends for groups of nature, nature's contributions to people (NCP), and good quality of life indicators extracted from the literature review by geographic region.**

Trends are summarized across the six scenario archetypes. Numbers refer to the number of scenario-indicator combinations for each indicator group and region extracted from the 37 relevant articles. Source: Own representation.



decreases, possibly because of increased roundwood production (+15%, representing +73 million m^3 $year^{-1}$) and increased logging residues extraction (+180%, representing +25 Tg dry matter $year^{-1}$; Dunford *et al.*, 2015b; Harrison *et al.*, 2013; Verkerk *et al.*, 2014). The water exploitation index (the balance between water availability and use) is also projected to increase in Western and Central Europe, except in northern regions, where it remains stable (Dunford *et al.*, 2015b; Harrison *et al.*, 2013). In Central Asia, the water volume of the Aydar-Arnasay lake system is projected to decrease (Rodina & Mnatsakanian, 2012).

Nature's non-material contributions to people and quality of life: Trends in nature's non-material contributions to people and good quality of life indicators under the *business-as-usual* archetype are overall stable or negative (**Figure 5.10** and **Figure 5.11**). In the future, citizens of Western and Central Europe may benefit from stable services such as recreational activities, tourism and landscape beauty, but they may be more reticent about paying for recreation in forests (Hirschi *et al.*, 2013; Verkerk *et al.*, 2014). On the other hand, the landscape experience index is projected to increase, which suggests a greater "naturalness" of the landscape in much of Western and Central Europe (Dunford *et al.*, 2015b).

5.3.3.2 Economic optimism

Overview: The focus of this archetype on economic growth is reflected by an increase in the provision of most of nature's material contributions to people (e.g. food and timber), but the challenges posed by the environmental limits within these scenarios result in general declining trends in the majority of the nature indicators, especially in aquatic ecosystems, and a decline in regulating contributions in general **(Figure 5.10)**. It should be noted that ecosystem functioning and regulation of air quality show opposite directions of change compared to these overall trends. Where data are available, the archetype leads to improvements in learning and inspiration, and physical and psychological interactions with the environment, as society invests in education, recreation and tourism, but to declines in indicators related to supporting identities as society becomes more globalized. Few studies were associated with a good quality of life, but those that were available reflect the pro-growth ethos of this archetype through considerably more increases than decreases in income levels.

Nature: Most integrated studies under this archetype project decreases in biodiversity. This is the case, for instance, for: coastal and wetland fishes (Forsius *et al.*, 2013; Okruszko *et al.*, 2011); pelagic predators and other fish communities in southern waters of the Europe and Central Asia region (Blanchard *et al.*, 2012; Lazzari *et al.*, 2014; Merino *et al.*, 2012); birds in Western and Central Europe (Okruszko *et al.*, 2011); mountainous and Mediterranean species in Western Europe (Schröter *et al.*, 2005); coastal species of Finland (especially endangered species; Forsius *et al.*, 2013); and an overall decrease in biodiversity in northern Spain (Palacios-Agundez *et al.*, 2013) (**Figure 5.10** and **Figure 5.11**).

Nature's regulating contributions to people: Nature's regulating contributions to people in terrestrial ecosystems are likely to be heavily impacted by future changes under the *economic optimism* scenario archetype in Europe and Central Asia (**Figure 5.10** and **Figure 5.11**). A large number of the integrated studies based on *economic optimism*-like scenarios project decreases in several regulating contributions, such as carbon sequestration provided by wetlands in Western and Central Europe (Okruszko *et al.*, 2011), as well as by grasslands and pastures in the Czech Republic (Lorencová *et al.*, 2013), and crops and livestock in regions of Switzerland (Briner *et al.*, 2013) and the Austrian Alps (Schirpke *et al.*, 2013). In addition, numerous local studies project decreases in air quality regulation and erosion control in south-western Spain (Palomo *et al.*, 2011), climate regulation in regions of Switzerland (Hirschi *et al.*, 2013), and protection against natural hazards and soil stability in the Austrian Alps (Schirpke *et al.*, 2013). However, some positive trends were projected, such as increased carbon fluxes to Western and Central European lands in the short-term due to increased net primary production enhanced by increased atmospheric CO_2 (Schröter *et al.*, 2005). At the regional scale, such decreases in regulating contributions would result in increased demand for erosion control, water regulation or disturbance mitigation by humans (Palacios-Agundez *et al.*, 2013). Many studies further highlight important trade-offs between regulating and material contributions, mainly because marketable services would be preferred over non-marketable services under some policies (Briner *et al.*, 2013; Hirschi *et al.*, 2013; Schirpke *et al.*, 2013).

Nature's material contributions to people: The material contributions provided by land systems, such as wood production, are often projected to increase (**Figure 5.10** and **Figure 5.11**). In western and northern countries of Western Europe, especially in higher latitudes, forests are expected to spread (up to +80% growth rate) because of an increased growth season, resulting in higher stemwood and timber production (Eggers *et al.*, 2008; Forsius *et al.*, 2013; Schröter *et al.*, 2005). The same trend was described at a smaller scale in part of the Basque Country in Spain (Palacios-Agundez *et al.*, 2013). Agricultural production is projected to increase both in Central Asia, with increased crop yields in semiarid and humid areas (Bobojonov & Aw-Hassan, 2014) and in the European Union with food production exceeding food demand (Schröter *et al.*, 2005) **(Figure 5.10)**. Some regional studies showed increased crop diversity, winter cereals production and potential distribution of bioenergy crops for northern countries of Western Europe (Forsius *et al.*, 2013; Schröter *et al.*, 2005) and increased agricultural production in south-western Spain (Palomo *et al.*, 2011). A notable exception was reported for some regions of Switzerland, where food provision was projected to drastically decrease under *economic optimism*-like scenarios because of reduced financial help from the State and increased economic competition with Western and Central European farmers (-75% to -81% food production; Briner *et al.*, 2013; Hirschi *et al.*, 2013). In the rest of Europe, both energy supply in Spain (Palacios-Agundez *et al.*, 2013) and hydropower across the European Union (Schröter *et al.*, 2005) are expected to increase.

In contrast, materials production (cotton in Central Asia - Bobojonov & Aw-Hassan, 2014; and reeds in wetlands of Western and Central Europe - Okruszko *et al.*, 2011), is projected to decrease. Nature's material contributions to people provided by aquatic systems, such as fish provision, are also projected to decrease in Europe and Central Asia, but with great variation depending on the regions and ecosystems considered **(Figure 5.10)**. The strongest decrease in fisheries production (-15%) is predicted in Spain. However, fish provision is projected to increase in Nordic countries, both in marine and riparian areas. An expected 30% to 60% increase in fisheries production is expected by 2050 in these regions, along with an increase of 26% of fishmeal production, which greatly mirror the increase of phytoplankton biomass in these areas (Blanchard *et al.*, 2012; Forsius *et al.*, 2013; Merino *et al.*, 2012).

Quality of life: Most studies agree that, as a result of these trends in nature and nature's contributions to people, quality of life may be negatively affected at various scales and in all subregions of Europe and Central Asia, with a gradual disappearance of winter tourism and urban green areas in Western Europe (Forsius *et al.*, 2013; Hirschi *et al.*, 2013; Schröter *et al.*, 2005), landscape beauty and tourism in regions of Switzerland (Hirschi *et al.*, 2013), recreational activities in regions of Spain (Palacios-Agundez *et al.*, 2013), and diving in the Mediterranean Sea (Galli *et* *al.*, 2017). In contrast, farmers' revenues in Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan are projected to increase in general related to the increases in crop production (Bobojonov & Aw-Hassan, 2014) (**Figure 5.10** and **Figure 5.11**).

5.3.3.3 Regional competition

Overview: The *regional competition* scenario archetype reflects a future where regionalization occurs as a result of fragmentation and competition between (and even within) countries. It is often characterized by low technological development and limited policy effectiveness. The archetype's limited focus on the environment is reflected in declining nature indicators associated with declining biodiversity and habitat creation/maintenance. The trends in other indicators such as nature's material and regulating contributions to people are particularly variable across countries, types of indicators and the socio-economic or climatic scenario considered. However, more indicators were available for this archetype than for other archetypes, which covered the entire Europe and Central Asia region.

Nature: Most studies assessing the future of nature indicators reported that the *regional competition* archetype generally leads to negative impacts on biodiversity (**Figure 5.10** and **Figure 5.11**). In Western and Central Europe, several studies project a decrease in biodiversity, especially important for woodland and arable species (Dunford *et al.*, 2015b; Schröter *et al.*, 2005). Northern parts of Western and Central Europe are particularly affected as they are projected to experience increased biodiversity vulnerability in both land and marine ecosystems, as well as a decrease in the quality of the fisheries (e.g. species composition and mortality) and a decrease in the species of recreational interest such as seals and cetaceans (Harrison *et al.*, 2013; Hattam *et al.*, 2015). In other parts of Western and Central Europe, however, impacts on nature indicators are less clear. In western countries, plant diversity and flowering onset are negatively affected by the *regional competition* archetype, but litter quantity, reflecting ecosystem functioning, is projected to increase (Lamarque *et al.*, 2014). In southern parts of Western and Central Europe, biodiversity is projected to be more vulnerable and the Mediterranean basin is projected to have 5.6% less plankton and bacterial biomass (Harrison *et al.*, 2013; Lazzari *et al.*, 2014; Palacios-Agundez *et al.*, 2013).

Nature's regulating contributions to people: Trends in nature's regulating contributions to people under *regional competition* are not uniform and highly depend on the types of indicators or regions considered (**Figure 5.10** and **Figure 5.11**). European Union studies forecast declining soil organic carbon stocks, affecting mostly croplands (between -5.4 and -5.8 Pg C by 2080) and grasslands (between -2.7 and -2.8 Pg C - Dunford *et al.*, 2015b; Hattam *et al.*, 2015; Schröter *et al.*, 2005). However, carbon fluxes to lands and seas are projected to increase, as well as the total carbon stocks of forests (Eggers *et al.*, 2008; Hattam *et al.*, 2015; Schröter *et al.*, 2005). In southern and western parts of Western Europe, carbon storage may remain stable or even decrease (Lamarque *et al.*, 2014; Palacios-Agundez *et al.*, 2013). In the same areas, stable nitrate leaching and decreased pollination and pest regulation can also be expected (Lamarque *et al.*, 2014; Palomo *et al.*, 2011). Variability across scenarios categorized within the regional competition archetype also affects the projections of the indicators. For instance, the number of people affected by flooding events in Western and Central Europe is projected to decrease or remain stable under the *should I stay or should I go* socio-economic scenario, whereas under the *Icarus* scenario the number of people flooded was reported to increase (Brown *et al.*, 2015; Harrison *et al.*, 2013). In parts of Spain, two studies found opposite trends regarding air quality, climate regulation, water regulation and quality, erosion control and soil fertility even though they both used local participatory-based approaches (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011).

Nature's material contributions to people: Projected trends in food and feed production in Western and Central Europe are highly dependent on the area considered (**Figure 5.10** and **Figure 5.11**). Even though a net increase in food production is projected across Western and Central Europe under the *regional competition* archetype (+15% increase of KCal capita^{-1} day^{-1} by 2050; Dunford *et al.*, 2015b; Harrison *et al.*, 2013), several studies show regional dependencies. The southern part of Western and Central Europe is generally reported to experience decreased food production and reduced grazing areas (Dunford *et al.*, 2015b; Harrison *et al.*, 2013; Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011). Agriculture in western countries of Western Europe may also face a decline in its production because of decreased farming intensity and decreased forage quality (Harrison *et al.*, 2013; Lamarque *et al.*, 2014). However, the yield of bioenergy crops in Western and Central Europe is likely to increase because more areas are dedicated to them, especially in northern countries of Western Europe (16 – 34% increase; Schröter *et al.*, 2005). In Central Asia, food production is projected to increase for most of the crops in Kazakhstan and Kyrgyzstan (e.g. +30% potatoes production by 2100), but in Tajikistan and Uzbekistan, agricultural yield is projected to decrease for cotton (Bobojonov & Aw-Hassan, 2014).

Regional dependencies also concern other nature's material contributions to people such as wood production. Stemwood production is likely to increase in northern regions of Western Europe (up to 40 – 80% increase in Finland; Forsius *et al.*, 2013) in contrast to southern regions where it decreases (Palacios-Agundez *et al.*, 2013;

Palomo *et al.*, 2011). Larger studies conducted at the European Union level are highly divided on the trend in nature's contributions to people associated with forests. For instance, forest area in the European Union is expected either to decrease (Harrison *et al.*, 2013) or to increase by 2050 (Eggers *et al.*, 2008). Finally, a decreased biomass and abundance of fish and shellfish populations is projected in northern waters of Western Europe (Hattam *et al.*, 2015), although studies conducted in southern parts of Western Europe show contradictory results concerning fisheries (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011).

Nature's non-material contributions to people and quality of life: As with other contributions from nature to people, the trends of non-material contributions and quality of life indicators are highly variable among the studies (**Figure 5.10** and **Figure 5.11**). The scope of the results is also limited because the only studies available for these indicators were conducted in Spain and Central Asia. The authors of the studies conducted in Spain project an increase in recreational activities, good social relations, aesthetic and spiritual value, and local identity, but a decrease in health, traditional knowledge and beach tourism (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011). In Kazakhstan and Tajikistan, farmers may benefit from increased income due to increased crop yields (Bobojonov & Aw-Hassan, 2014). In Uzbekistan, farmers may benefit from increased gross margins from food products (e.g. potatoes and wheat), but may face reduced gross margins from cotton by the 2070 – 2100 period.

5.3.3.4 Regional sustainability

Overview: The *regional sustainability* scenario archetype focuses on approaches that are customized to local conditions with a drive to local self-sufficiency. Nature's regulating contributions to people may particularly benefit from this scenario archetype as all parts of Western and Central Europe show positive trends (**Figure 5.10** and **Figure 5.11**). On the other hand, the future of nature's material contributions to people is highly area dependent and the projections of nature indicators are not clear among studies conducted at different scales. All of these projections only concern Western and Central European subregions as no data are available for Eastern Europe and Central Asia.

Nature: The future of nature indicators under the *regional sustainability* scenario archetype is not clear among the studies conducted in Western and Central Europe (**Figure 5.10** and **Figure 5.11**). The authors often use different socio-economic assumptions and climate models and their projections are applied to different areas and ecosystems. For instance, two studies project a decrease of biodiversity by 2050–2080 in terms of number of species and habitats, which are especially significant for birds, Mediterranean and mountain species (Okruszko *et al.*, 2011; Schröter *et al.*, 2005). However, in the Basque Country in Spain and Switzerland, habitat diversity and biodiversity are projected to increase substantially by 2030–2050 (Hirschi *et al.*, 2013; Palacios-Agundez *et al.*, 2013).

Nature's regulating contributions to people: Several Western and Central European studies project an increase in nature's regulating contributions to people on land ecosystems (**Figure 5.10** and **Figure 5.11**). For instance, two international studies project an increase in carbon sequestration by land systems, particularly forests, resulting in better air quality (Eggers *et al.*, 2008; Schröter *et al.*, 2005). In 2100, Western and Central European forests may thus accumulate up to 110 Mg C ha^{-1} (Eggers *et al.*, 2008). Wetlands may, however, be more vulnerable under this scenario as they store carbon at a slower rate and are less effective at removing nutrients affecting water quality (Okruszko *et al.*, 2011). A local study from Central Europe projected similar trends with increased carbon sequestration (approximately +25% by 2036) and more stable soils (Schirpke *et al.*, 2013). In south-western parts of Western Europe, local studies associated with the *regional sustainability* scenario archetype showed an enhancement in several of nature's contributions to people, such as water regulation, natural hazards mitigation, soil fertility and pest regulation (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011).

Nature's material contributions to people: Impacts on nature's material contributions to people are mixed under the *regional sustainability* archetype, but a notable increase is projected for wood provision in Western and Central European countries (**Figure 5.10** and **Figure 5.11**). Forests in these countries are projected to benefit from greater area (+6-32% increase by 2080) and increment rate (+9-12% increase), leading to increased wood quantity and quality (Eggers *et al.*, 2008; Schröter *et al.*, 2005). Here again, wetlands may be more vulnerable as they yield reduced quantities of reed and fish provisions (Okruszko *et al.*, 2011). Impacts on northern countries in Western Europe are positive overall, with growth of forests more pronounced than in other parts of Western and Central Europe, and with a substantial increase in the potential distribution of bioenergy crops (Eggers *et al.*, 2008; Schröter *et al.*, 2005). In Western Europe, forest growth rate is likely to decrease in, for example, the Alpine areas of France, Switzerland and Austria (Eggers *et al.*, 2008; Schröter *et al.*, 2005). Impacts on food and feed are, however, less clear as a decrease of food production (-60%) is projected in regions of Switzerland (Hirschi *et al.*, 2013) whereas, in Austria, better forage quality and quantity suggest an increase of food production (Schirpke *et al.*, 2013). In southern regions of Western Europe, trends in agricultural production are also variable (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011), but these local studies agree that this scenario archetype may result in decreased fisheries production.

Quality of life: Good quality of life indicators generally benefit from the socio-economic and climatic changes associated with the *regional sustainability* archetype (**Figure 5.10** and **Figure 5.11**). In two regional studies of Spain, authors project an increase in recreational activities, nature tourism, aesthetic and spiritual values, health and satisfaction with the state of biodiversity (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011). However, due to climate warming, an additional 25.8 million people in the European Union may face water insecurity (< 1700 m^3 $capita^{-1}$ $year^{-1}$) by 2080 (Schröter *et al.*, 2005).

5.3.3.5 Global sustainable development

Overview: The *global sustainable development* scenario archetype has a focus on top-down governance and international cooperation to deliberately target long-term sustainability and improve quality of life. This results in impacts that are largely positive for most of the indicators of nature, of its contributions to people, and of quality of life (**Figure 5.10** and **Figure 5.11**). This scenario archetype mainly benefits regulating contributions and the nature indicators of most of the Europe and Central Asia regions. Other indicators such as material contributions and quality of life indicators are also positive overall, except in southern regions of Western Europe where negative impacts, such as a decline in water provisioning and non-material contributions, such as identity or psychological experiences, are projected.

Nature: The future of nature indicators under the *global sustainable development* archetype is generally positive for the north-western part of Western Europe, especially for marine ecosystems (**Figure 5.10** and **Figure 5.11**). The biomass of fish and shellfish populations are projected to increase and to develop enhanced traits (e.g. length, health), and to benefit from increased species diversity and greater intactness index (Hattam *et al.*, 2015). In northern, continental and Atlantic areas of Western and Central Europe, arable and forest species are expected to remain resilient to the changes associated with this archetype (Dunford, Smith, *et al.*, 2015b). However, biodiversity vulnerability is expected to be greater in southern and Alpine areas as well as in Germany, France and Greece (Brown *et al.*, 2014; Dunford *et al.*, 2015b; Harrison *et al.*, 2013; Schröter *et al.*, 2005). In the Mediterranean Sea, stable measures of ecosystem functioning such as net or gross primary production, and bacterial biomass suggest that the marine biodiversity of this region may not be impacted by this scenario archetype (Lazzari *et al.*, 2014).

Nature's regulating contributions to people: Nature's regulating contributions to people, such as disturbance mitigation (Palacios-Agundez *et al.*, 2013) and total organic carbon regulation (Hattam *et al.*, 2015) benefit from the environmental policies and the strong cooperation between countries under this scenario archetype (**Figure 5.10** and **Figure 5.11**). Carbon storage by agriculture, forests or marine waters is projected to be enhanced across Western and Central Europe (Dunford *et al.*, 2015b; Eggers *et al.*, 2008; Hattam *et al.*, 2015; Palacios-Agundez *et al.*, 2013; Schröter *et al.*, 2005). This estimated increase in carbon sequestration is particularly important in continental areas and may increase the tree carbon stocks of Western and Central Europe from 60 Mg ha^{-1}, as evaluated in 2000, to 131 Mg ha^{-1} in 2100 (IPCC SRES B1 storyline; Eggers *et al.*, 2008). Other authors also forecast an increase in soil fertility, air quality and climate regulation in the Doñana and Biscay regions and the Basque Country of Spain by 2035 - 2050 (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011), as well as an increase of erosion control provided by ecosystems by 2050 - 2080 (Lorencová *et al.*, 2013; Palacios-Agundez *et al.*, 2013). However, in line with the projected decrease in water availability, a growing number of forest fires is expected in the Mediterranean (Schröter *et al.*, 2005).

Nature's material contributions to people: Most of the nature's material contributions to people in Europe and Central Asia may benefit from the *global sustainable development* scenario archetype (**Figure 5.10** and **Figure 5.11**). In Western and Central Europe, food production is projected to be enhanced due to improved agriculture practices, higher land use diversity or increased arable land area (Brown *et al.*, 2015; Dunford *et al.*, 2015b; Harrison *et al.*, 2013). Similarly, forest area and timber production are projected to increase substantially in Western and Central Europe (+19 Mt wood $year^{-1}$ by 205 - Dunford *et al.*, 2015b; Eggers *et al.* 2008). There are, however, clear differences in the trends of material contributions between northern and southern countries of Western and Central Europe. Several studies highlight positive impacts in northern countries, such as increased biomass of fish and shellfish populations (Hattam *et al.*, 2015), increased forest products (by more than 19% - Eggers *et al.*, 2008; Forsius *et al.*, 2013) and increased agricultural yield (by more than 20% - Dunford *et al.*, 2015b), all of which benefit from increased temperature and from greater afforestation efforts. Southern countries may also benefit from greater fisheries and increased food production, but a decrease in water availability in this region may lead to an additional 44.3 million people facing water insecurity (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011; Schröter *et al.*, 2005). The future of forest production is less clear as some international studies project a decrease of this contribution of nature to people in southern countries of Western and Central Europe due to greater water stress (Dunford *et al.*, 2015b; Harrison *et al.*, 2013), while local studies from Spain project an increase (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011). In a lake system in Uzbekistan, both the water volume of the lake and the quantity of fish inhabiting it are projected to grow (Rodina & Mnatsakanian, 2012).

Quality of life: As with other contributions of nature to people, several studies conducted in the Europe and Central Asia region project an increase of various indicators of good quality of life under the *global sustainable development* scenario archetype (**Figure 5.10** and **Figure 5.11**). These positive projections include the number of species of recreational interest, aesthetic and spiritual value, nature and beach tourism and recreational activities (Hattam *et al.*, 2015; Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011; Rodina & Mnatsakanian, 2012). Some exceptions to these beneficial impacts were reported in a study of the Basque Country in Spain, such as a decrease in traditional knowledge or a decrease of local identity due to the global nature of the scenario archetype (Palacios-Agundez *et al.*, 2013).

5.3.3.6 Inequality

Overview: The results associated with the *inequality* scenario archetype are very limited because only two studies have been undertaken. Both studies were conducted in Western and Central Europe and their projections do not encompass nature's non-material contributions to people or good quality of life indicators. Overall, this archetype does not show a clear trend in the future of the nature indicators or material contributions. However, a clear decline is projected in regulating contributions such as habitat creation and maintenance, and natural hazard regulation.

Nature: The state of the nature indicators under the *inequality* archetype is stable overall, but is clearly area-dependent (**Figure 5.10** and **Figure 5.11**). Biodiversity is projected to be more vulnerable in the northern and western parts of Western Europe and more resilient in the eastern and southern parts of Western and Central Europe (Harrison *et al.*, 2013).

Nature's regulating contributions to people: Both studies using the *inequality* archetype agree on a general decrease in nature's regulating contributions to people in Western and Central Europe (**Figure 5.10** and **Figure 5.11**). For example, flood mitigation and the proportion of unmanaged lands are projected to decrease across these subregions (Harrison *et al.*, 2013). The trend is less clear for the index of land use intensity, with one study projecting a stable trend in this index (Brown *et al.*, 2015) and another projecting a decrease (Harrison *et al.*, 2013).

Nature's material contributions to people: As with the nature indicators, trends in nature's material contributions to people in Western and Central Europe depend on the areas considered (**Figure 5.10** and **Figure 5.11**). For the northern part of Western and Central Europe, material contributions are generally projected to increase (Harrison *et al.*, 2013). This is, for example, the case for intensive and extensive farming and forest area. In southern parts of Western and Central Europe, the *inequality* archetype is associated with a decrease in food and forestry-related contributions, but an increase in the water exploitation index as water demand exceeds supply.

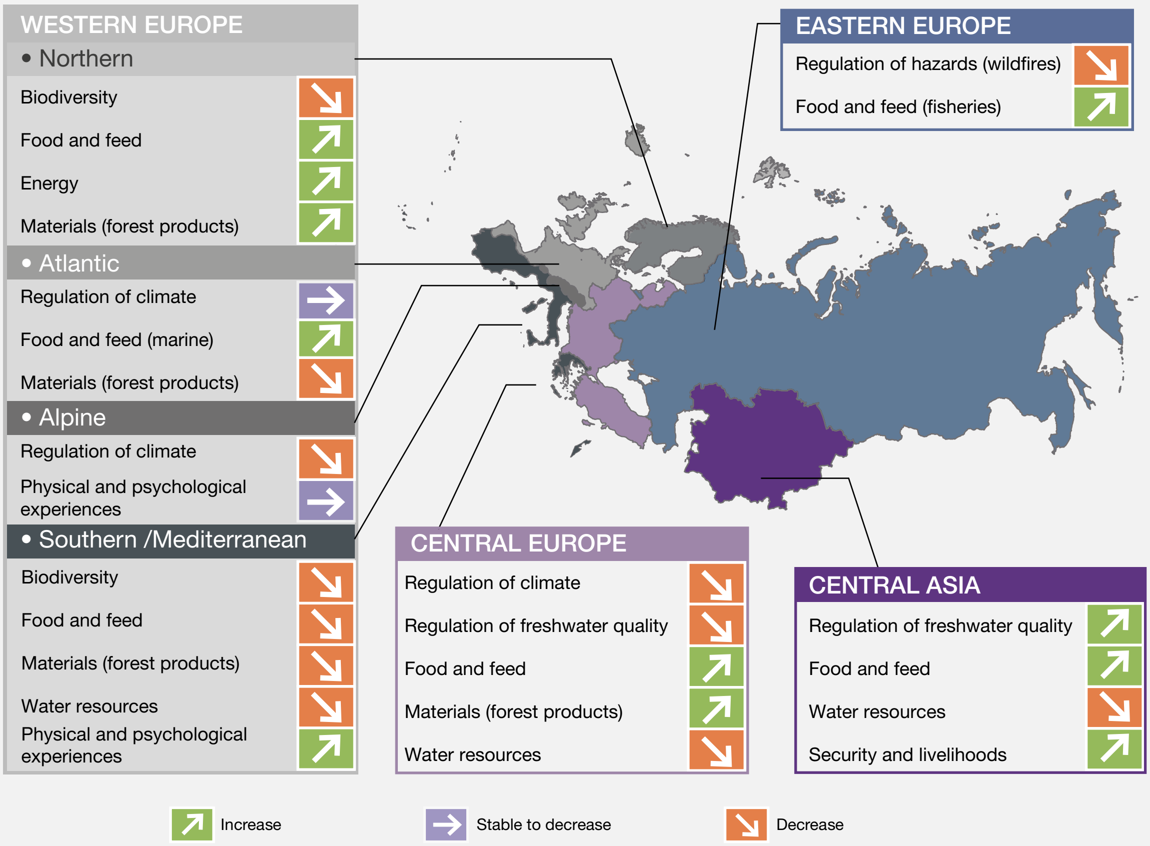
5.3.3.7 Comparing impacts across subregions

Despite clear differences between impacts in nature, its contributions to people, and quality of life indicators under the six scenario archetypes, some consistent trends within each of the subregions of Europe and Central Asia are apparent across all or most archetypes **(Figure 5.12)**. Note this figure and accompanying text focus on trends, which broadly agree on the direction of the impact across the scenario archetypes, sometimes with one exception. The reader is referred to the previous sections, **Figure 5.10** and **Figure 5.11** for detailed descriptions of impacts within each subregion of Europe and Central Asia for each individual scenario archetype. In **Figure 5.12** the Western Europe subregion has been sub-divided into five areas due to the larger number of studies for this subregion, which provide greater information on geographical variation in impacts.

Western Europe: In the northern part of Western Europe, most scenario archetypes project increases in agricultural production for bioenergy, food and feed (Brown *et al.*, 2015; Dunford *et al.*, 2015b; Forsius *et al.*, 2013; Harrison *et al.*, 2013; Schröter *et al.*, 2005) and increases in forest area and timber provision (Eggers *et al.*, 2008; Forsius *et al.*, 2013; Schröter *et al.*, 2005), with the exception of the *inequality* archetype, where it declines (Harrison *et al.*, 2013). However, such increases in agricultural areas may result in an overall increase in biodiversity vulnerability for both land and aquatic ecosystems across archetypes (Harrison *et al.*, 2013; Hattam *et al.*, 2015), with the exception of *global sustainable development*, where it is more resilient (Harrison *et al.*, 2013).

In the Atlantic region of Western Europe, forest area and yield is projected to decrease under all scenario archetypes (Dunford *et al.*, 2015b; Harrison *et al.*, 2013) except for *inequality*, which projects increases in forest area (Harrison *et al.*, 2013). This results in stable or decreasing carbon sequestration in most scenario archetypes (Dunford, *et al.*, 2015b; Lamarque *et al.*, 2014; Verkerk *et al.*, 2014), except *global sustainable development* where it increases (Eggers *et al.*, 2008). Enhanced growth and biomass of marine populations are projected for all archetypes (Blanchard *et al.*, 2012; Forsius *et al.*, 2013; Hattam *et al.*, 2015; Lazzari *et al.*, 2014; Merino *et al.*, 2012), but *regional competition* which shows decreases in the biomass and quality of fish communities (Hattam *et al.*, 2015). Adaptive marine management strategies aimed at reducing nutrient loads as

Figure 5 12 **Overview of consistent subregional impacts across scenario archetypes. Source: Own representation.**



well as sustainable fishery were suggested as being vitally important for the area in the future, as climate change is expected to intensify the challenges in the area (Meier *et al.*, 2012, 2014).

Southern parts of Western Europe and the Mediterranean region show decreases in agricultural production (Dunford *et al.*, 2015b; Harrison *et al.*, 2013) and timber production (Dunford *et al.*, 2015b; Harrison *et al.*, 2013) across scenario archetypes, as well as increases in water stress (Dunford *et al.*, 2015b; Eggers *et al.*, 2008; Schröter *et al.*, 2005). Greater biodiversity vulnerability in land ecosystems (Brown *et al.*, 2015; Dunford *et al.*, 2015b; Harrison *et al.*, 2013), stable or slight declines in bacterial and planktonic populations (Lazzari *et al.*, 2014) and decreases in the number of terrestrial species (Eggers *et al.*, 2008; Palacios-Agundez *et al.*, 2013; Schröter *et al.*, 2005) are also projected across all scenario archetypes. Some positive impacts are projected across most scenario archetypes. These include increases in air quality regulation (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011), with the exception of *economic optimism* (Palomo *et al.*, 2011), and greater recreational activities and tourism (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011), except in regional competition where beach tourism declines (Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011). Successful international and cross-sectoral coordination of adaptive measures, such as in *global sustainable development*, was projected to be crucial for dealing with these environmental challenges (Dunford *et al.*, 2015b).

Projections for Alpine areas of Western Europe show consistent decreases in climate regulation (Hirschi *et al.*, 2013) and stable or declining landscape beauty, tourism and recreational activities (Forsius *et al.*, 2013; Hirschi *et al.*, 2013; Schirpke *et al.*, 2013; Schröter *et al.*, 2005) across scenario archetypes. Studies found that the farmers' awareness of the values of nature's contributions to people can lead to more sustainable land use practices, with beneficial consequences in service provision levels (e.g. forage quantity and quality) and nature protection (Lamarque *et al.*, 2013). Synergetic relationships between carbon storage (regulation of climate) and forest protective functions (regulation of the natural hazards of avalanches and rockfalls) and nature indicators in Central and Western European mountain forests were identified under some scenarios (Mina *et al.*, 2017). Adaptive management practices were also projected to alter the vulnerability of the majority of nature's contributions to people, but no single management strategy was found to be beneficial for all areas. Rather each site has to be considered individually as adaptive management can create shifts in the synergies and trade-offs between contributions (Mina *et al.*, 2016).

Central Europe: In Central Europe, most scenario archetypes project increases in timber production, logging residues and forest increment (Dunford *et al.*, 2015b; Eggers *et al.*, 2008; Verkerk *et al.*, 2014), but decreases in carbon sequestration (Lorencová *et al.*, 2016; Lorencová *et al.*, 2013; Verkerk *et al.*, 2014). Predominantly decreasing impacts on contributions in agricultural systems were also projected for climate, erosion and water quality regulation, but increasing impacts for food provision in the Czech Republic (Lorencová *et al.*, 2016; Lorencová *et al.*, 2013). Biodiversity is also projected to be more resilient across scenario archetypes according to integrated modelling studies (Dunford *et al.*, 2015b; Kirchner *et al.*, 2015), although single sector studies reported in Chapter 3 show decreases in species abundance and diversity under the *business-as-usual* scenario. Ruijs *et al.* (2013) suggest that win-win solutions can be achieved for biodiversity and carbon sequestration on the one hand and agriculture on the other, if nature's contributions to people are improved in areas with low opportunity costs and agriculture is intensified in the areas with high opportunity costs.

Increases in water stress were projected under dystopian scenarios (similar to the economic optimism and *regional competition* scenario archetypes) (Dunford *et al.*, 2015b; Harrison *et al.*, 2015; Kara, 2014), leading to significant decreases in the contributions of wetlands (Okruszko *et al.*, 2011). The studies suggest that adaptive management is required to protect environmental flows, especially for reservoir operation rules. Best management practices, such as vegetation management, tillage practices, early crop sowing and erosion control in forest and agricultural fields, were also projected to regulate hydrological flows and reduce nutrient loads in lakes (Burek *et al.*, 2012; Erol & Randhir, 2013). Alternatively, Schröter *et al.* (2005) found that reforestation of mountainous areas in the Danube River catchment results in shifts in the seasonality of flows and increases in water stress. Similarly, Piniewski *et al.* (2014) showed that a sustainable "greening" scenario would lead to lower environmental flows[1] than a *business-as-usual* scenario. The authors suggest that this potentially counter-intuitive result can be interpreted as a trade-off whereby producing a "greener" environment in terms of larger percentages of forests and extensive grasslands is at the cost of surface water resources and potentially aquatic ecosystems.

Eastern Europe: There were only a few integrated modelling studies available for Eastern Europe, but these projected consistent impacts across scenario archetypes for increases in fisheries production in Russia (Merino *et al.*, 2012), showing that effective fisheries management coupled with technological advances would enable fish demand to be met. Studies also projected greater effects of wildfires on ecosystems (Chertov *et al.*, 2014; Shanin *et al.*, 2011) across scenario archetypes. However, the effects of forest management strategies on trade-offs between wood extraction and carbon sequestration varied by scenario archetype. Scenarios assuming natural forest development (i.e. no cuttings) resulted in the forest ecosystem becoming a carbon sink under the influence of climate change, whereas management scenarios focusing on wood harvesting resulted in the forest ecosystem becoming a carbon source (Shanin *et al.*, 2011; Zamolodchikov *et al.*, 2014). Reforestation of areas set aside from agricultural activities in Russia were also suggested to improve carbon accumulation in the future.

Central Asia: There were also only a few integrated modelling studies available for Central Asia. These projected increases in food and feed provisions in the short-term (2010-2040) leading to increases in farmer revenues (Bobojonov & Aw-Hassan, 2014) across archetypes. The authors suggest that farmers will face trade-offs between cash crop production and more extensive sustainable production as the profitability of different crops and resource scarcity change under climate change and different management regimes. Nitrogen retention is also projected to improve near agricultural fields due to increases in irrigation water reuse resulting from decreased water availability (Jarsjö *et al.*, 2017). This may also increase the amount of nitrogen in soils and dissolved in the groundwater aquifers next to agricultural fields.

The region is also projected to experience greater water stress and the drying out of lakes (Medeu *et al.*, 2015; Rodina & Mnatsakanian, 2012; Schlüter & Rüger, 2007). Sustainable integrated water and land management strategies, including water recycling, renovation of irrigation systems, installation of more efficient irrigational systems and improved restoration of pastures, were suggested as options to negate these negative effects. Capacity building (including providing farmers with access to technologies, such as improved irrigation systems) and cooperation between Central Asian countries was also considered to be crucial for tackling water stress and counteracting the negative effects of climate change on the volume of the lakes in the region.

1. Environmental flows describe the quantity, quality and timing of water flows that are required to maintain the components, functions, processes, and resilience of aquatic ecosystems.

5.3.3.8 Comparing impacts related to the different governance approaches in the scenario archetypes

Contrasting impacts are projected across the different plausible futures for Europe and Central Asia **(Figure 5.10)**. Generally, the indicators related to nature, its contributions to people, and good quality of life show more positive impacts under the *global sustainable development* and *regional sustainability* scenario archetypes than under the *economic optimism*, *regional competition*, *inequality* and *business-as-usual* scenario archetypes. This is particularly noticeable for the set of indicators of nature's contributions to people. These broad variations in impacts under different types of plausible futures have been discussed by various authors. For example, Palacios-Agundez *et al.* (2013), Palomo *et al.* (2011), and Schröter *et al.* (2005), showed that in general terms, nature's contributions to people are expected to be more negatively influenced under socio-economic scenarios which are associated with a reactive governance of environmental issues (e.g. *economic optimism* or *regional competition*) than under the proactive environmental policies that are found in sustainable scenarios (e.g. *global sustainable development* or *regional sustainability*).

Furthermore, the main objective of the "sustainability" archetypes is to promote a more holistic approach to managing human and environmental systems, which supports multifunctionality and many of nature's contributions to people. Alternatively, the *economic optimism, regional competition* and *inequality* scenario archetypes are motivated by economic growth or national security. These archetypes focus more on the self-interest of individuals or "elite" groups in society and tend to promote a more limited number of nature's contributions to people, particularly material contributions such as agricultural and timber production. This is supported by studies that examined trade-offs between nature's contributions to people and showed that increases in food provision (generally associated with the expansion of agricultural land or the intensification of livestock production and fish captures) were linked to decreasing provision of regulating contributions (e.g. prevention of soil erosion, regulation of water quality and quantity) and nature values (e.g. ecosystem functioning and compositional intactness indicators) (Briner *et al.*, 2013; Dunford *et al.*, 2015b; Harrison *et al.*, 2013; Palomo *et al.*, 2011; Posthumus *et al.* 2010). Similar trade-offs have also been identified between other material contributions (e.g. timber extraction) and regulating (e.g. carbon storage) and non-material contributions (e.g. aesthetic value). For example, Dunford *et al.* (2015b); Schirpke *et al.* (2013); Verkerk *et al.* (2014) found that increasing wood extraction reduces the value of forests as a carbon sink and ultimately leads to highly managed forest that are aesthetically unattractive (decreasing its cultural/recreation values) and/or biodiversity poor.

Box 5 5 A detailed example of the use of scenario archetypes in regional integrated assessment modelling: The CLIMSAVE Integrated Assessment Platform.

This box provides an illustrative example of scenario exploration within an integrated modelling study included in our literature review: the CLIMSAVE Integrated Assessment Platform (IAP) for Europe (defined as the European Union plus Norway and Switzerland). The CLIMSAVE IAP is an interactive, web-based, cross-sectoral modelling platform that uses a coupled-component modelling approach combining models for six sectors: urban, agriculture, water, forestry, fluvial/coastal flooding, and biodiversity **(Figure 5.13)**.

There are four socio-economic scenarios embedded within the CLIMSAVE IAP, which were developed with stakeholders. These scenarios include one utopian scenario of the *global sustainable development* archetype (*we are the world*); two dystopian scenarios of the *regional competition* archetype (*should I stay or should I go* and *Icarus*) and an *inequality* archetype (*riders on the storm*). These socio-economic scenarios are combined with a range of climate change scenarios representing different emissions pathways. This allows the influence of climate and socio-economic drivers to be explored independently or in combination to answer questions related to the limits of adaptation: What influence does a green society have in an extreme climate? What are the impacts of a dystopian society under moderate climate change?

The CLIMSAVE IAP produces outputs of nature's contributions to people including: food and timber provision, water availability, climate regulation and habitat for species (Dunford *et al.*, 2015a, 2015b). It also provides proxy indicators related to land use composition "land use experience", non-urban land not allocated to the production of food or timber, and "land use diversity" which reflects the variety of different land uses available and is seen as a proxy for ecosystem multifunctionality. Dunford *et al.* (2015b) modelled impacts on nature's contributions to people in the European Union as well as Norway and Switzerland for the *global sustainable development (we are the world*) and *regional competition* (*should I stay or should I go*) scenarios combined with both moderate and extreme climate change scenarios **(Figure 5.14)**.

Box 5 5

Figure 5 13 **An example of an integrated assessment model (the CLIMSAVE IAP) highlighting the interlinkages between models and the outputs of nature's contributions to people (NCP) produced. Source: Adapted from Dunford *et al.* (2015b).**

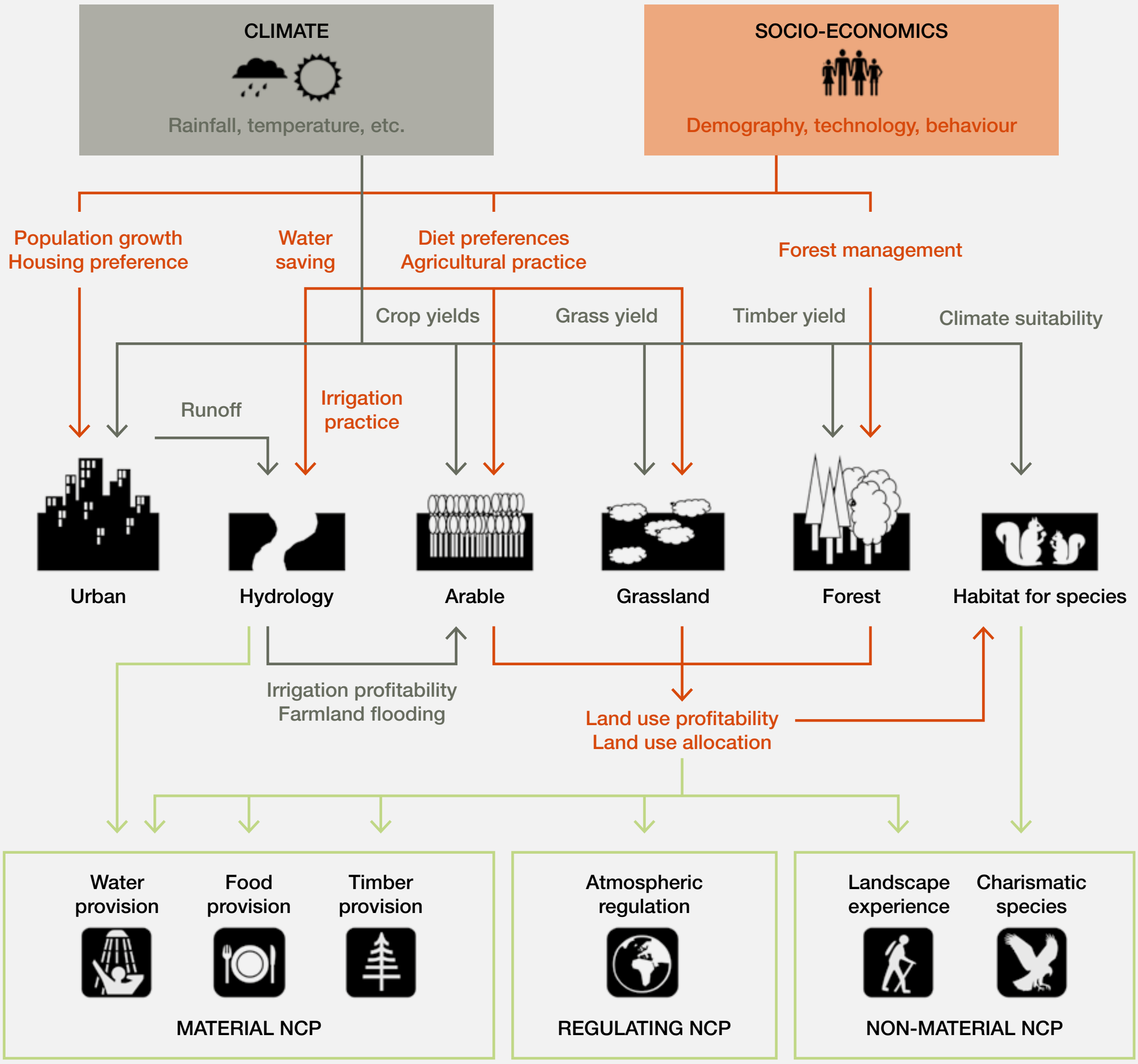
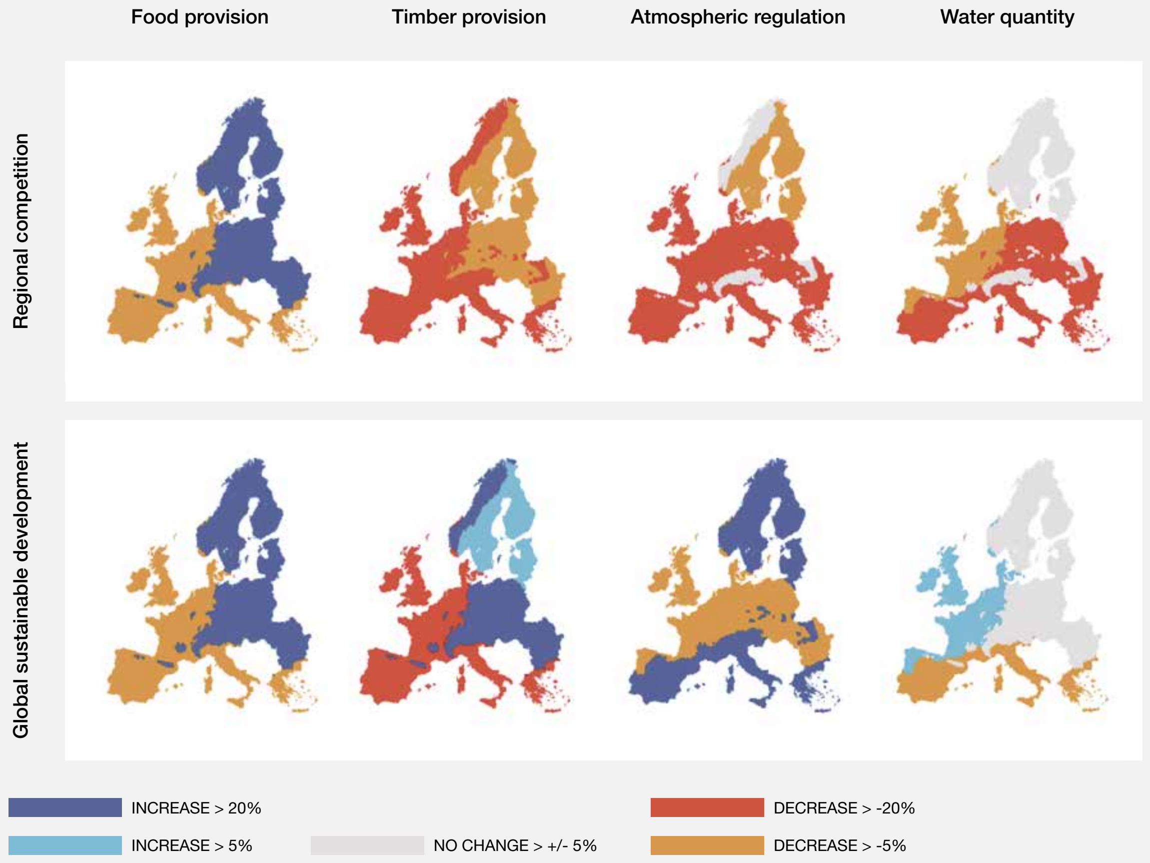


Figure 5.14 highlights the differences between plausible combinations of climate and socio-economic scenarios: the *regional competition* scenario with an extreme climate driven by high emissions and the *global sustainable development* scenario with a moderate climate driven by lower emissions. Within both scenarios food provision targets for the European Union plus Norway and Switzerland are projected to be met by increasing the provision of food in continental, northern and Alpine regions. However, within the *regional competition* scenario, the combined pressures of failed technological innovation and an expanding population lead to significant stress being put on the agricultural system to feed the population. Lack of technological development leads to limited options to increase food production in current agricultural areas. Instead, the model projects that it is more cost-effective to expand the agricultural area leading to significant land use change reducing forested land and, thus, nature's forest-based contributions to people. This is shown by a decline in timber provision and atmospheric regulation across these parts of Western and Central Europe **(Figure 5.14)**.

Box 5 5

Figure 5 14 **Impacts of climate and socio-economic scenarios on four indicators of nature's contributions to people simulated using the CLIMSAVE IAP.**

The *regional competition* scenario archetype (*should I stay or should I go*) has been combined with an extreme climate change scenario while the *global sustainable development* scenario archetype (*we are the world*) has been combined with a moderate climate change scenario. Source: Adapted from Dunford *et al.* (2015b).



The *global sustainable development* scenario shows quite different impacts. As with the *regional competition* scenario, the model projects an increase in food demand due to an increase in population (although more moderate). However, this does not lead to widespread land use change, due to a high level of technological development, which makes irrigation 26% more effective and agricultural yields 15% higher due to improvements in agronomy. As this allows more food to be produced in less space and without needing to change spatial patterns of land use, there is considerably less change in habitats and their associated contributions of nature to people than was seen in the *regional competition* scenario. Instead, timber provision increases in the northern, Alpine and continental parts of Europe (in this case the European Union plus Norway and Switzerland) while atmospheric regulation increases in the northern, Alpine and southern parts. In addition, the *global sustainable development* scenario leads to a reduced level of water exploitation relative to the impacts under climate change alone because of increases in water savings through technology and behaviour change.

Results show that trade-offs are projected between nature's contributions to people in both scenarios, particularly between southern and northern Europe with respect to agricultural- and forest-related contributions (Dunford *et al.*, 2015b). The authors show that southern Europe becomes less able to maintain competitive agriculture even under moderate climate change, while agriculture in northern Europe largely benefits from the warmer climate. In northern Europe, the scenarios result in trade-offs between projected increases in agricultural production to meet European food demand and decreases in forestry (due to agricultural competition for land) and the associated impacts on timber, recreation and cultural identify. Alternatively, in southern Europe, projected decreases in food production are shown to have considerable impacts on social, local and national heritage and tourism-related contributions of nature to people dependent on local food production.

Box 5 5

The analysis of Dunford *et al.* (2015b) also highlights that, while climate scenarios have a significant influence on nature's contributions to people, socio-economic scenarios (consisting of indirect drivers) have an equally if not more significant role in modifying these contributions. Sustainability-type scenarios, where technology and behavioural change focus on reduced water use, improved irrigation efficiency, improved crop yields and less red meat consumption, considerably reduce the pressure placed on the agricultural system and lead to less dramatic land use change with less knock-on impacts on nature's contributions to people.

Bateman *et al.* (2013) demonstrated that future changes in market (e.g. agricultural production) and non-market values (e.g. open-access recreation, urban green space and wild-species diversity) in the UK show opposite trends depending on the severity of the environmental regulations of the scenario considered, regardless of climate trends. The authors concluded that reactive scenarios with weaker environmental regulations, such as *economic optimism*, tend to promote high-intensity agriculture even at the expense of converting protected areas. This results in strong positive effects in market values and negative effects in non-market values. Alternatively, proactive scenarios with strong environmental regulations, such as *global sustainable development,* lead to strong positive effects in non-market values and losses in market values. This also highlights the importance of implementing integrated management approaches which aim to optimize both market and non-market values simultaneously, although the authors acknowledge the difficulty in developing such approaches given the clear trade-offs that exist between some indicators of nature and its contributions to people (e.g. agricultural yields and wild-species diversity).

A more detailed description of impacts on indicators of nature and its contributions to people across different scenario archetypes is provided in **Box 5.5** based on an integrated modelling study for Western and Central Europe which included multiple drivers, multiple sectors and was conducted as part of a participatory process involving inputs from different groups of relevant stakeholders.

5.3.4 Linking future impacts on nature, its contributions to people, and good quality of life, to policy goals and targets

The projections of impacts on nature, its contributions to people, and good quality of life indicators under the six scenario archetypes for Europe and Central Asia were compared with the Sustainable Development Goals and Aichi Biodiversity Targets using expert opinion to estimate the extent to which these policy goals and targets are likely to be achieved under the different scenario archetypes.

Results of this analysis show relative estimations of success (projected positive impacts) and failure (projected negative impacts) to reach individual Sustainable Development Goals and Aichi Biodiversity Targets under the different scenario archetypes **(Figure 5.15)**, recognizing the different time frame of the scenarios to those stated in the policy targets. As the analysis is based on expert opinion and a limited number of integrated studies, we do not interpret results for specific targets, but rather aim to provide a broad indication of the scenario archetypes which are likely to lead to success instead of failure across the full range of Sustainable Development Goals and Aichi Biodiversity Targets.

The analysis shows that the "sustainability" scenario archetypes (*regional sustainability* and *global sustainable development*) are estimated to achieve the majority of Sustainable Development Goals and Aichi Biodiversity Targets. Such scenarios attempt to provide various contributions of nature to people and aspects of a good quality of life. Thus, they represent a greater diversity of values, but often at the expense of lower, or less intensive, production of material contributions. In contrast, the fragmented world of *regional competition* is expected to lead to failure in the majority of the targets, while *economic optimism* is estimated to have a mixed level of success in achieving the Sustainable Development Goals, but would fail to achieve the majority of the Aichi Biodiversity Targets. This may be because such scenarios tend to lead to trade-offs between nature's material contributions to people and regulating and non-material contributions through prioritizing market values. Their focus on instrumental values and individualistic perspectives, with little acknowledgement of relational or intrinsic values, are unlikely to offer effective sustainable solutions to environmental and social challenges (Jacobs *et al.*, 2016).

The reliability of the results for *business-as-usual* and *inequality* is lower than for the other scenario archetypes due to the more limited number of modelling results for these types of scenarios. Bearing in mind this lower reliability, *business-as-usual* is estimated to lead to failure in most of the Sustainable Development Goals, but mixed to positive effects on the Aichi Biodiversity Targets. The *inequality* scenario archetype shows mixed results for those policy targets for which modelled indicators were available, with slightly more failure than success for the Aichi Biodiversity Targets.

These results are consistent with recently published research by Kubiszewski *et al.* (2017), who presented an assessment of the future total annual values of nature's contributions to people under four global scenarios: *market forces* (part of the *economic optimism* archetype); *fortress world* (part of the *regional competition* archetype); *policy reform* (part of the *global sustainable development* archetype); and great transitions (part of the *regional sustainability* archetype). The authors show that total annual values of nature's contributions to people decrease the most under the *fortress world* scenario, with an average reduction in the value of contributions of -29% across Europe and Central Asian countries (range from -87 to -4%). The *market forces* scenario also leads to reductions in values of these contributions, albeit slightly smaller than under *fortress world* (-19% average, -72 to +2% range). In contrast, the *policy reform* scenario results in only small changes from current 2011 values (+2% average, -10 to +9% range), while the great transitions scenario results in substantial improvements in values of nature's contributions to people of +24% on average across Europe and Central Asian countries (+19 to +44% range). The authors conclude that the *great transitions* scenario (and to a lesser extent the *policy reform* scenario) embodies many of the Sustainable Development Goals, and that, therefore, achieving the Goals would involve greatly enhanced contributions of nature to people, good quality of life and sustainability.

Figure 5 15 **Extent to which Sustainable Development Goals (SDGs) and Aichi Biodiversity Targets (ABTs) may be reached under the different scenario archetypes.**

Relative estimations of success (predicted positive impacts) and failure (predicted negative impacts) based on: (i) the review of integrated scenario and modelling studies (Figure 5.10); and (ii) the extent to which Sustainable Development Goals and Aichi Biodiversity Targets prioritize diverse values of nature, its contributions to people, and good quality of life. Grey bars indicate the reliability of the estimations based on the number and consistency of the reviewed model literature. Source: Own representation.

This section has highlighted that the choices made by decision-makers and society in Europe and Central Asia will likely lead to large differences in impacts on nature, its contributions to people, and good quality of life. Decisions related to resolving trade-offs are likely to be needed under all scenario archetypes, even sustainable futures. Such trade-offs would be more likely minimized if decision-making adopted a holistic (i.e. not siloed) approach that takes account of multiple drivers, diverse values and competing interests across sectors and regions. Approaches and actions that decision-makers can take to move society away from futures with undesirable trade-offs towards more sustainable outlooks are considered in Sections 5.4 and 5.5.

5.4 VISIONS OF SUSTAINABLE DEVELOPMENT

Sections 5.2 and 5.3 assessed what might happen in the future under different plausible, exploratory scenarios for Europe and Central Asia. The next two sections assess what society as a whole, or groups within the society, want to happen in the future, i.e. visions of desirable futures (Section 5.4, but see also 5.1.2) and pathways, which attempt to describe a course of actions to achieve such visions (Section 5.5). In particular, Sections 5.4 and 5.5 focus on visions and pathways for sustainable development that are similar to the scenario archetypes *regional sustainability* (Sections 5.2.3.4 and 5.3.3.4) and *global sustainable development* (Sections 5.2.3.5 and 5.3.3.5). Sustainable development, as conceptualized in the Sustainable Development Goals or Aichi Biodiversity Targets (see Sections 1.4.1 and 1.4.2), is a global priority, a goal shared by many countries and at the centre of the questions framing the IPBES regional assessments. Beyond this, we note that societal visions are diverse and some visions may aspire to futures not related to, or even conflicting with, sustainable development.

Visions have been developed by different stakeholder groups in Europe and Central Asia to guide and foster their perception of sustainable development and associated pathways to a sustainable future. We reviewed these visions to (i) analyze their framing of nature, its contributions to people, and good quality of life, and the linkages between these elements as described by the IPBES conceptual framework, and (ii) assess which areas for action are being given more importance (see also Section 5.1.2), based on their coverage of key sustainability and biodiversity conservation issues, as formulated by the Sustainable Development Goals and Aichi Biodiversity Targets. This analysis provides the basis for assessing the mainstreaming of goals and targets across sectors and the cross-scale coherence of the visions in Europe and Central Asia.

5.4.1 Review of Europe and Central Asia visioning and pathway exercises

Visions with associated pathways, and a minimum time frame of 15 years, were included in the review. To be inclusive, we accepted all documents stating to pursue sustainable development or, more particularly given the focus of IPBES, environmental sustainability. Individual corporate level visions for private companies were not considered. Relevant documents were identified using keyword searches in Google, Scopus and Web of Science covering both the scientific and grey literature focusing on visions, pathways, normative or target-seeking scenarios. This was supplemented by more targeted searches to fill gaps related to marine studies, wetlands, urban environments, conservation areas and indigenous and local knowledge. As accessible visions and pathways were rare for most of the Eastern Europe and Central Asia subregions, we additionally included governmental cross-sectoral development strategies and national biodiversity strategies and action plans (NBSAPs). These focus on biodiversity conservation targets and are often developed for time frames shorter than 15 years.

For our analysis of policy coherence across scales, we also searched for and reviewed 22 global visions (for the results of the cross-scale comparison see Section 5.1.2, **Figure 5.3** and **Figure 5.4**).

Information was systematically extracted from the vision documents on the vision developers (i.e., type of actors/ stakeholders), target region and geographic scale, activity sector, time frame and main goals. Furthermore, we examined the framing of nature, its contributions to people, and good quality of life in the construction of these visions, and how each vision captured the links between these elements. We also assessed visions' priority areas for action towards sustainable development and biodiversity conservation. Here, we used as a reference the list of Sustainable Development Goals and Aichi Biodiversity Targets, which were related to a dominant dimension of sustainability, that is, biophysical (Goals 6, 13-15), economic (Goals 8-10, 12), and social (Goals 1-5, 7, 11, 16) (Folke *et al.*, 2016). Aichi Biodiversity Targets are predominantly related to the biophysical dimension.

The review resulted in 18 visions for the three subregions of Europe in general, and four governmental development strategies and ten national biodiversity strategies and action plans covering countries in Eastern Europe and Central Asia. Details of the reviewed visions and their key features are summarized in supporting material Appendix 5.1[2]. A targeted search for national or local visions was not undertaken due to language constraints, but a few thematic exceptions were added to the review. Nevertheless, we acknowledge that such visions are potentially available and could provide relevant insights. Examples of visions for topics that are rarely covered are given in boxes, namely an example for indigenous and local knowledge and the Sami people **(Box 5.6)** and for a marine protected area **(Box 5.7)**. A box on visions related to bioeconomy **(Box 5.8)**, addresses the special request raised in the scoping report for the Regional Assessment for Europe and Central Asia.

5.4.2 Key characteristics of visions of sustainable development for Europe and Central Asia

Notwithstanding the limited number of retrieved regional visions, the findings from the review suggest that a broad range of sectors of relevance to nature (e.g. agriculture, forestry, environment, energy and fisheries), nature's contributions to people and good quality of life have already been included in visioning exercises (see supporting material Appendix 5.1[2]). Exceptions are sectors involved in the development of urban areas or transport, for which there were no sectoral visions at the broad Europe and Central Asia regional scale. However, several examples on how individual cities envision their future urban development, including transport, are available (e.g. UK - Eames *et al.*, 2013; Tight *et al.*, 2011). Sectoral visions were developed by multiple actor initiatives, international organizations, NGOs or business-oriented organizations.

The vast majority of visions were developed in a participatory way, including diverse stakeholder groups, for example through workshops, expert interviews and consultations. This shows that a diversity of perspectives has been incorporated in developing the visions and pathways, and indicates that deliberation of strategic planning and agenda setting is becoming mainstreamed. Consideration of indigenous and local knowledge was rarely covered explicitly in the development of visions and pathways. Most visions included stakeholder or local knowledge, but none explicitly included indigenous knowledge. However, it was not possible to determine with certainty whether the stakeholders involved in the participatory development processes were indigenous and local knowledge holders, nor whether there was a diversity of stakeholders involved (public, private, third sector stakeholders). Nevertheless, some visions explicitly including indigenous and local knowledge and practices were found at the national level and below (see **Box 5.6**). National biodiversity strategies and action plans and governmental development plans were drafted by governmental agencies, sometimes including other actors such as academic experts and NGOs, but no further stakeholder groups.

2. Available at https://www.ipbes.net/sites/default/files/eca_ch_5_appendix_5.1_list_of_reviewed_vision_studies.pdf

Most visions were developed with the aim of providing policy support, namely by proposing strategic areas for action and policy instruments as part of the associated pathways (Section 5.5). For the reviewed visions, specific goals were often qualitative, providing general guidance instead of clear end-targets. An exception is the Vision for 2030 of the European Forest-based Sector (where Europe is defined as 19 European Union countries, plus Norway, Switzerland and Russia), which envisions that "Recovery, reuse and recycling of forest-based products account for 70% of all recyclable material. The remaining is used for energy production" (The Forest-based Sector, 2013). Other visions, such as the EATIP (2012) vision for aquaculture, include quantitative goals for sectoral development and growth potential, but were less specific on measures of sustainability. The absence of clear end-goals (e.g. targets that are quantitative, spatially and temporally specific, and that integrate trade-offs with other targets) can be potentially problematic, as allocation of responsibilities when assessing levels of achievement or trade-offs between goals is difficult (see Chapter 6 for further discussion).

The interdependency between nature, its contributions to people, and good quality of life was best covered by environmental visions **(Table 5.4)**. Visions from the other reviewed sectors often show concern about the effects of environmental pressures, such as climate change, conversion of natural habitat to agriculture, or water pollution, and aim to reduce the impacts, but their goals often miss the underpinning role of nature in the delivery of nature's contributions to people and the maintenance of quality of life. This lack of focus on biodiversity and nature's contributions is also true for some cross-sectoral visions although they tend to consider both the need to reduce pressures from human activity and the need for proactive measures to enhance environmental conditions, partly also through protection and restoration (e.g., PBL & SRC, 2009).

The sectoral visions exhibit certain foci. The provision of food, fibre, water and energy (including biofuels), climate change mitigation, and transition to sustainable production modes and consumption were the prevalent goals among reviewed visions. In this respect, most visions focused on material and nature's regulating contributions to people, namely climate regulation, water regulation, natural hazard regulation and soil protection. Nature's non-material contributions to people often focused on physical and psychological experiences, such as recreation.

The development strategies for Kazakhstan, Uzbekistan, Russia and Belarus focus on economic and social sustainable development. Although these are cross-sectoral visions, the sectors are addressed independently from one another, masking potential trade-offs and synergies between different goals. Sectoral strategies focus on resource extraction and production, with an emphasis on mining,

Table 5 4 **Presence of elements related to nature, its contributions to people, and quality of life in Europe and Central Asia visions.**

Information is based on vision documents covering all three European subregions (Western Europe, Central Europe and Eastern Europe, labelled "Europe") or national biodiversity strategies and action plans and cross-sector development strategies for Eastern Europe and Central Asia (labelled "EE & CA"). The total number of visions per sector and region are indicated in each column, the number of visions including each of the elements is indicated with circles (red • – Europe, green • – EE & CA). Visions for the environment sector include national biodiversity strategies and action plans (n=10) for EE & CA, and visions on conservation areas (n = 1), biodiversity (n = 1) and environment in general (n = 1) for Europe.

	Cross-sector	Agriculture	Fisheries	Energy	Forestry	Environment	Number of visions
Number of visions	Europe: 5 EE & CA: 4	Europe: 5 EE & CA: 0	Europe: 1 EE & CA: 0	Europe: 1 EE & CA: 0	Europe: 3 EE & CA: 0	Europe: 3 EE & CA: 10	Europe: 18 EE & CA: 14
Nature	••• ••••	••••			•••	••• ••••••••••	Europe: 13 EE & CA: 14
Regulating contributions	••• ••	••••			•••	••• ••••••••••	Europe: 13 EE & CA: 12
Material contributions	••••• ••••	•••••	•		•••	••• ••••••••••	Europe: 17 EE & CA: 14
Non-material contributions	••• ••	••••			•••	••• •••••	Europe: 13 EE & CA: 7
Quality of life	•••• ••••	••••	•		••	••• ••••••••••	Europe: 14 EE & CA: 14

water and intensive agriculture and intensive forestry. Environmental aspects of the visions relate to the control of pollution and waste. The national biodiversity strategies and action plans for the countries of Eastern Europe and Central Asia provide extensive descriptive information on the status of biodiversity using Red List approaches as a baseline for their primary goal to stop biodiversity loss, mostly based on the rational of intrinsic values of biodiversity. The concept of ecosystem services (or nature's contributions to people) is hardly mentioned at all. Recent national biodiversity strategies and action plans are mostly aligned with the Aichi Biodiversity Targets and, in some cases, also with Sustainable Development Goals-relevant targets related to poverty alleviation; but not to vulnerable groups and gender, with the exception of Georgia. Most national biodiversity strategies and action plans express strong optimism towards achieving conservation as a side effect of economic development. At the same time, consequences of development such as extractive processes, e.g. mining, overexploitation, pollution or fragmentation, are named as some of the key drivers of biodiversity loss.

5.4.3 Key global sustainability goals and targets reflected in visions for Europe and Central Asia

Overall, Europe and Central Asia visions give priority to sustainable economic growth in tandem with sustainable industrialization, sustainable agriculture, forestry, aquaculture and management of natural resources in general (see **Figure 5.3** and **Figure 5.4** in Section 5.1.2). Climate action through land use management and the increased share of renewable energy is another priority for the region (see also **Box 5.8**). Also perceived as critical is changing people's behaviour towards more sustainable consumption patterns and lifestyles. All three dimensions of sustainability are present in Europe and Central Asia visions (see **Figure 5.3** and **Figure 5.4**), in particular the biophysical dimension linked to nature conservation and sustainable management of natural resources, and the economic dimension linked to sustainable production and consumption.

Biodiversity related goals, such as the Aichi Biodiversity Targets, are covered to a narrower extent in the visions than the Sustainable Development Goals (**Figure 5.3** and **Figure 5.4**). The overall narrowing of biodiversity dimensions towards the targets on indirect (Target 4) and direct drivers (Target 7) in visions for Europe and Central Asia, in particular market pressures from consumption patterns and direct pressures from agriculture, fisheries and forestry activity, suggests a strong regional priority on actions to mitigate the cause of environmental impacts (Strategic Goals A and B of the Strategic Plan for Biodiversity 2011-2020). Interestingly, when compared to the global visions **(Figure 5.4)**, the need to eliminate harmful subsidies (i.e. Target 3) appears to be of lower priority in visions for Europe and Central Asia. This could be due to a predisposal towards positive policy formulation in countries of the region, creating new measures and

Box 5 6 **Visions including indigenous and local knowledge: an example from the Sami people. Photo: Geir Rudolfsen**

A number of stakeholder reports and studies from Sweden (The Sami Parliament, 2009), Finland (e.g. Kitti *et al.*, 2006) and Norway (Norwegian Saami Association, 2008) reflect knowledge from the Sami people. The Sami Parliament's Living Environment Program (The Sami Parliament, 2009) for Sweden provides a vision, which focuses on both sustainable nature and culture: "We wish to live in a resilient Sápmi which is rooted in both healthy nature and a living (thriving) Sami culture. People and nature shall have a long-term capacity to renew themselves and to sustainably evolve even in times of significant changes. Both aspects – nature and culture – shall be experienced as enriching for the surrounding world".

The vision specifically mentions protection of habitats and ecosystems, and states that "All activities are conducted according to the precautionary principle. Use of natural resources is conducted sustainably and with a long-term perspective. Nature is kept clean from non-degradable waste and from materials which threaten biological diversity or human health". Sustainable use of forests is emphasized: "both the forest structure, biological diversity, supply of lichens and connectedness with other important grazing grounds shall be protected", but linked to the needs of the reindeer herding industries as found by Sandström *et al.* (2016). "Among other things this means that trees are left to grow old, there is no clear-felling and infrastructure such as roads and windmill-parks are scarce or adapted to the needs of the reindeer".

actions, and lower use or acceptance of formulations for "dismantling" or "disinvestment" or "phasing out" of existing policy measures (Sanderson, 2000).

In addition, the stronger coverage of the Sustainable Development Goals, when compared to the coverage of the Aichi Biodiversity Targets, in particular of goals directly related to elements of good quality of life and to drivers of environmental degradation, could in part be explained by the framing of several visions in the former set of the Millennium Development Goals, which relied more on indicators of quality of life and less on nature indicators than the Sustainable Development Goals. Moreover, the difference in the level of coverage of sustainability and biodiversity conservation issues, as formulated by the Sustainable Development Goals and Aichi Biodiversity Targets, also argues for the need to move beyond a focus on human needs and quality of life to a more comprehensive perspective that acknowledges not only socio-ecological systems and their dynamics, but also the primary role of biodiversity in sustainable development.

Box 5 7 Visions for marine protected areas in France. Photo: Anthony Caro

In France, including its overseas territories, the Ministry of Ecology, Sustainable development and Energy developed a national strategy for the creation and management of marine protected areas (Government of France, 2012). This strategy lays down the framework and principles to set up a national network of marine protected areas. Within each marine protected area belonging to this network, a visioning exercise engaging local stakeholders (e.g. fishermen, local administrations, tourism operators, energy companies) was undertaken to define the targets and sub-targets that should be reached within the next 15 years. The visions and associated targets pertain to natural heritage, water quality, natural resources, sustainable use and development, cultural heritage, education and governance. Targets can be specific to local contexts, but all marine protected area visions link and integrate the protection and management of marine natural resources and heritage, sustainable development and cultural heritage. The visions included targets for maintaining or improving habitats, species and communities to ensure that they achieve a good conservation status to maintain high levels of biodiversity and ecosystem functioning. Other biodiversity-related targets included ensuring terrestrial run-off is compatible with high standards of water quality, good conservation of marine resources, sustainable management of fisheries and the associated sector, and the promotion of economic activities which are respectful of the marine environment.

Box 5 8 Increasing demand for biological raw materials in a bioeconomy context.

In the scoping document for this chapter, a special request was included to "consider issues that include increasing demand for biological raw materials in a bioeconomy context (bioenergy, fibres and organic matter), and water availability." A number of definitions exist for the bioeconomy, e.g. the OECD "refers to the set of economic activities relating to the invention, development, production and use of biological products and processes." The European Commission (2012) (p.3) defines bioeconomy as "the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy. Its sectors and industries have strong innovation potential due to their use of science, enabling and industrial technologies, along with local and tacit knowledge." The underlying intention is, however, similar - namely the substitution of fossil fuel resources and to close material cycles in industrial processes by using renewable resources such as plant materials like wood, agricultural crops, animal by-products and waste (Hagemann *et al.*, 2016).

When looking, for example, at the European White Paper on the Bioeconomy (BECOTEPS, 2011), Sustainable Development Goals or Aichi Biodiversity Targets are not directly considered. However, according to a communiqué of the Global

Box 5 8

Bioeconomy Summit 2015 a sustainable bioeconomy could make essential contributions to achieving the Sustainable Development Goals as its potential is particularly geared to the Sustainable Development Goals related to food security and nutrition (Goal 2), healthy lives (Goal 3), water and sanitation (Goal 6), affordable and clean energy (Goal 7), sustainable consumption and production (Goal 12), climate change (Goal 13), oceans, seas and marine resources (Goal 14), and terrestrial ecosystems, forests, desertification, land and soil degradation, and biodiversity (Goal 15) (see El-Chichakli *et al.*, 2016, for more details). Anand (2016) also found that the development of the bioeconomy could potentially contribute to Goals 1 (no poverty), 2 (zero hunger), 7 (clean energy), 13 (climate action), 14 (life below water) and 15 (life on land), as it facilitates access to food, drinking water, cheap energy, effective health care and sustainable agriculture through intensive use of biomass and bioenergy, and the development of biotechnologies. However, there are a number of issues resulting from an increasing demand for biological raw materials in a bioeconomy context, such as:

- Inappropriate management of the available biomass resources. To date, one of the major obstacles in this respect is the lack of biomass utilization and management strategies that take into account the available regional resources as well as the regional technical and human capacities and infrastructures. To implement the bioeconomy while at the same time making use of the regional resources appropriately, there is a need to establish regional bioeconomy strategies (Bezama, 2016).

- This leads to the second issue, namely the current low involvement of national and regional stakeholders in the definition of regional strategies. There is a need to establish a "regional critical mass" that defines the key issues and development aspects that should be the basis for the regional strategies. This would not only allow the definition of the regional issues, but can also be the basis for improving social acceptance towards the issue of biomass utilization in the bioeconomy field (Thrän & Bezama, 2017).

- On the other hand, there are also issues regarding the development of the industrial sector associated with the bioeconomy. The implementation of the bioeconomy strategy will not be successful if the technological development process is carried out in the traditional way. A new, more integrative technological development process is needed, which is currently being promoted by the new circular economy strategy. Such a systems perspective for technological development will foster proper integration of the industrial sector and the biomass production sector, as discussed by Hildebrandt *et al.* (2017).

5.4.3.1 Key global sustainability goals and targets in sectoral visions

The main policy priorities identified in the different sectoral visions are matched to the Sustainable Development Goals and Aichi Biodiversity Targets in **Figure 5.16** and **Figure 5.17**. The sustainable use of terrestrial ecosystems (Goal 15) is pursued by all the reviewed agricultural visions, being therefore a key priority for this sector. Moreover, agricultural visions show a relatively balanced coverage of goals similar to the Sustainable Development Goals and their associated dimensions of sustainability **(Figure 5.16)**. However, visions goals related to Goals 3 to 5 on health, education and gender equity, which are associated with the social dimension of sustainability, and to Goal 10 on reducing inequalities between countries, are virtually absent. The reviewed environmental visions agree with the agricultural visions on the need to work towards goals similar to Goal 15 on protection and sustainable use of terrestrial ecosystems, and show a stronger emphasis on the biophysical dimension of sustainability. Cross-sectoral visions, on the other hand, appear to give lower priority to the management of nature and natural resources. All reviewed visions aim at sustainable cities (Goal 11), sustainable consumption habits and lifestyle (Goal 12) and sustainable industrialization (Goal 9).

Regarding the Aichi Biodiversity Targets, both agricultural and cross-sectoral visions focus on Targets 4 and 7, while environmental visions show a balanced coverage of all strategic goals, in particular Strategic Goal C that focuses on biodiversity condition **(Figure 5.17)**. The weak or even inexistent coverage of Aichi Biodiversity Targets addressing Strategic Goals C, D and E, especially by the agricultural and cross-sectoral visions, could reduce the efficiency in efforts to achieve sustainability. For example, actions related to Target 15 were only found in the visions for the environmental and forestry sectors and one cross-sectoral vision, despite the urgent need to restore degraded land in Europe and Central Asia and to enhance ecosystem resilience. This includes solutions both to restore ecosystems degraded by intensive agriculture and forestry, and to enhance the resilience of ecosystems affected by agricultural abandonment (Leadley *et al.*, 2013).

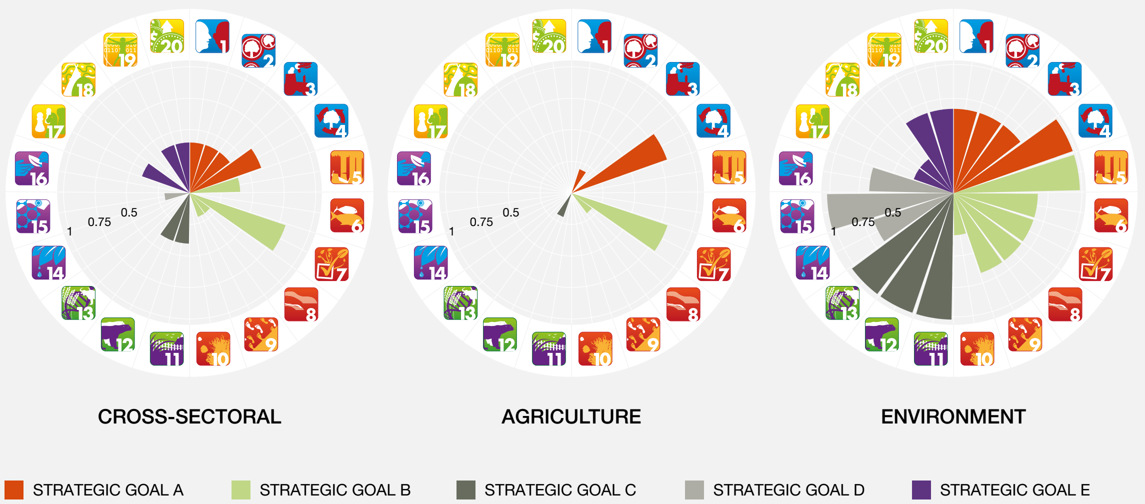
The distribution of sectoral priorities not only highlights how the different sectors could promote synergies for the attainment of global goals, but also reveals potential trade-off between the sectors. Sectoral actions to promote a particular goal or set of goals may obstruct efforts from other sectors towards other goals. For instance, the promotion of biofuels by the energy sector, or food production by the agricultural or fisheries sector, may conflict

Figure 5 16 **Coverage of goals similar to the Sustainable Development Goals by cross-sectoral visions (number of analyzed visions, n = 5), agricultural sector visions (n = 5) and environmental sector visions (n = 3) for the three European subregions.**

Dimensions of sustainability were assigned to Sustainable Development Goals based on their dominant character (Folke *et al.*, 2016); the size of the bar towards each Sustainable Development Goal shows the proportion of visions covering that goal, ranging from 0 (not mentioned) to 1 (covered by all visions). Note that the visions often concern a different (longer-term) timescale to the Sustainable Development Goals, often until 2050. Source: Own representation.

Figure 5 17 **Coverage of goals similar to the Aichi Biodiversity Targets by cross-sectoral visions (number of analyzed visions, n = 5), agricultural sector visions (n = 5) and environmental sector visions (n = 3) for Europe (covering all three European subregions).**

Aichi Biodiversity Targets are organized by strategic goal of the Strategic Plan for Biodiversity 2011-2020, each goal addressing an area for action (A - the underlying causes of biodiversity loss, B - the direct pressures on biodiversity, C - the status of biodiversity, D - the benefits from biodiversity and ecosystem services, and E - implementation of biodiversity strategies and action plans); the size of the bar towards each Aichi Biodiversity Target shows the proportion of visions covering that target, ranging from 0 (not mentioned) to 1 (covered by all visions). Note the visions often concern a different (longer-term) timescale to the targets, often until 2050. Source: Own representation.



with efforts to improve water savings and enhance water quality by the water sector and efforts to conserve nature when land- and seascapes are cultivated. Hence, while focusing on the most relevant goals for their sector, sectoral visions should anticipate cross-sectoral interactions and strive for smart solutions that reduce their impact on other sectors or even promote synergies with other sectors. Often these trade-offs become apparent only if the pathways, on how to achieve visions, are analyzed.

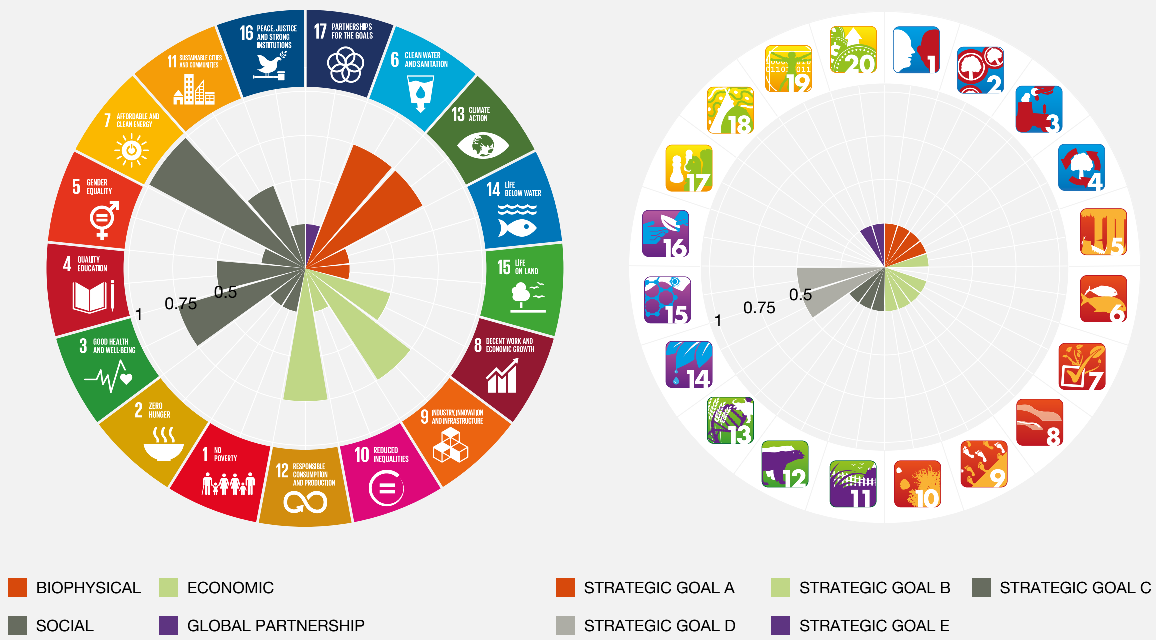
5.4.3.2 Key global sustainability goals and targets in regional visions

The main policy priorities identified in the different regional visions are matched to the Sustainable Development Goals and Aichi Biodiversity Targets in **Figure 5.3**, **Figure 5.4** and **Figure 5.18**. For example, the cross-sectoral strategies for Eastern Europe and Central Asia **(Figure 5.18)** show a more balanced coverage of dimensions of sustainability than cross-sectoral strategies for Europe and Central Asia in general (**Figure 5.3** and **Figure 5.4**), but also more diversification (or lower agreement) in the goals targeted by each document. Investment in clean energy (Goal 7) is the more consensual goal, pursued by all development strategies. Regarding biodiversity conservation targets, Strategic Goal D, related to nature's contributions to people and the maintenance or enhancement of key ecosystems, appears to be of higher priority than the other strategic goals **(Figure 5.19)**.

National biodiversity strategies and action plans focus inherently on biodiversity conservation and, therefore, are expected to address Aichi Biodiversity Targets more thoroughly. However, while most post-2010 national biodiversity strategies and action plans for Eastern European and Central Asian countries mention the Aichi Biodiversity Targets, and the Strategic Plan for Biodiversity 2011-2020 as an overarching goal, not all establish a direct link between national goals and the targets. Those that do explicitly address a direct link, tend to cover a diverse and almost complete range of Aichi Biodiversity Targets. A similar pattern was found for national biodiversity strategies and action plans from the other subregions of Europe and

Figure 5 18 **Coverage of goals similar to the Sustainable Development Goals (left) and the Aichi Biodiversity Targets (right) by cross-sectoral visions for Eastern Europe and Central Asia (number of analyzed visions = 4).**

Dimensions of sustainability were assigned to Sustainable Development Goals based on their dominant character (Folke *et al.*, 2016); Aichi Biodiversity Targets are organized by strategic goal of the Strategic Plan for Biodiversity 2011-2020, each goal addressing an area for action (A - the underlying causes of biodiversity loss, B - the direct pressures on biodiversity, C - the status of biodiversity, D - the benefits from biodiversity and ecosystem services, and E - implementation of biodiversity strategies and action plans). The size of the bar towards each goal or target shows the proportion of visions covering that goal or target, ranging from 0 (not mentioned) to 1 (covered by all visions). Note the visions often concern a different (longer-term) timescale to the Sustainable Development Goals or Aichi Biodiversity Targets. Source: Own representation.



Central Asia (data not shown, but available at https://www.cbd.int/nbsap/targets/default.shtml), which also cover a wider range of Aichi Biodiversity Targets in contrast to what was found in the visions analysis. This divergence between national biodiversity strategies and action plans, developed by governmental institutions, and societal visions suggests that more effort is required to mainstream biodiversity and its various dimensions into strategic planning and decision-making in Europe and Central Asia.

5.4.3.3 Mainstreaming interregional flows in regional visions

While there are some regional differences in visions, a similarity appears to be the disregard of Goal 10 of the Sustainable Development Goals to reduce inequalities within and among countries. This omission could have important implications in the future. For example, Kitzes *et al.* (2008) project that in a *business-as-usual* scenario we will require the biocapacity of two worlds to satisfy human demand for nature's contributions to people by 2050. As shown in Chapter 2, Section 2.2.4, the current ecological impact measured in global footprint is distributed unevenly among countries. *Business-as-usual* scenarios show that the spatial polarization between consuming high income countries (including Western Europe) and providing poorer countries (including Central and Eastern Europe) will further increase (Teixidó-Figueras & Duro, 2014). A more concrete example, is provided by Gerbens-Leenes *et al.* (2012), who use a scenario approach to analyze global water-use changes related to increasing biofuel use for road transport in 2030 and evaluate the potential contribution to water scarcity. The study finds that amongst the largest biofuel consuming countries, only Brazil will dispose of sufficient capacity within the country to provide the required water. France and Italy, with ongoing biofuel production, and Spain and Germany (even without biofuel production) will depend on flows of water from neighbouring countries.

Lenschow *et al.* (2015) suggest that the interregional connectedness created by the flows of nature's contributions to people between countries, and even continents, gives rise to specific sustainability challenges, which require new governance solutions. Using the example of soy trade between Brazil and Germany, Lenschow *et al.* (2015) show that global governance approaches are likely to result in unspecific and therefore ineffective policies. The authors suggest that collaboration between nations might offer more promising opportunities for developing specific solutions. Another policy option suggested in the literature is to decouple economic growth and ecological impact. By projecting the decoupling potential of different policy mixes in the European Union, Watkins *et al.* (2016) find that a technical policy approach will not be sufficient to reduce environmental impacts, for example on biodiversity, land use and other indicators. Instead, they suggest medium-term changes in culture and behavioural patterns to achieve sustainability. Working together towards mainstreaming Goal 10 of the Sustainable Development Goals further into visions and policies might reveal a way to deal with this sustainability challenge.

5.5 PATHWAYS FOR SUSTAINABLE DEVELOPMENT

Pathways consist of different strategies for moving from the current situation towards a desired future vision or set of specified targets. They are purposive courses of actions that build on each other, from short-term to long-term actions into broader transformation (Ferguson *et al.*, 2013; Frantzeskaki *et al.*, 2012; Wise *et al.*, 2014). As such, pathways (i) build or re-create favourable resilience and break down undesired resilience as well as reduce vulnerability through mitigation, adaptation and transformation actions that address drivers and impacts of system change; and (ii) build the system's capacities that establishes the conditions for the pathway trajectories (Poustie *et al.* 2016; Wise *et al.*, 2014). Pathways studies have only been recently developed in research on nature and its contributions to people (e.g. Brown *et al.*, 2016), building on experience from the energy sector, sustainability studies and climate adaptation. They provide information to policy- and decision-makers on which strategies and actions may be compatible with an identified vision. Such evidence can support the design of long-term policy, allowing for innovation and creativity in the development of solutions that enhance nature and its contributions to people, and foster a good quality of life.

This section reviews pathways that have been developed to realize the visions analyzed in Section 5.4 as well as goals and targets similar to the Sustainable Development Goals and Aichi Biodiversity Targets. Furthermore, it compares the consistency of the pathways with the scenario archetypes described in Sections 5.2 and 5.3 from the perspective of the Sustainable Development Goals and Aichi Biodiversity Targets.

5.5.1 Review of global, and Europe and Central Asian pathways

As detailed in Section 5.4.1, visions and pathways that target sustainable development were selected for this review. In addition to the studies analyzed for their visions

(Section 5.4), a specific review of the pathways literature was conducted focusing on local-scale studies, and especially on studies incorporating indigenous and local knowledge and societal transformations, such as no-GDP growth, lifestyle change or other societal transformations (supporting material Appendix 5.2[3]). Information extracted from the document sources included trade-offs addressed, actions related to land/sea use and management, nature, its contributions to people, good quality of life and/or anthropogenic assets. Furthermore, we analyzed pathways' coherence, and whether the actions suggested by the pathways could be considered transformational. We also checked whether the pathways took into account cross-sectoral integration, including the mainstreaming of environmental objectives into other sectors, or cross-scale interactions and related trade-offs, and which values were considered and how.

As mentioned in Section 5.4, no study explicitly included indigenous knowledge at the scale of Europe and Central Asia. Noteworthy exceptions are provided in local level case studies (Hanspach *et al.*, 2014; Oteros-Rozas *et al.*, 2013; Palomo *et al.*, 2011, see **Box 5.9** for further details) and a study on strategies to deal with frictions in transformation movements (Demeulenaere, 2014). Moreover, while indigenous and local knowledge does not explicitly feature in countries' development strategies or the national biodiversity strategies and action plans of Eastern Europe and Central Asia, some of them mention indigenous and local knowledge-related issues, for example, the importance of traditional crop varieties and breeds for adaptation to climate change.

More than two thirds of the pathways studies considered the concept of value. Among those considering values, this was explicit in about 80% of the cases, and implicit otherwise. Pathways studies included different dimensions of value: about 60% used the concept of value as good quality of life (anthropocentric relational values); about 30% as nature's contributions to people (i.e. anthropocentric instrumental values) and only about 10% as nature (non-anthropocentric or intrinsic values). Most studies focused primarily on values associated with non-material contributions to people (60%), followed by regulating contributions (20%), and finally material contributions (20%).

The majority of the pathways reviewed for Europe and Central Asia are open-ended storylines (without quantification) and mainly present orientations for strategic action to address a respective vision. Examples of pathways supported by quantification from exploratory scenarios are highlighted in Section 5.5.5. In line with the international agenda on sustainable development (e.g. FAO, 2014; IGBP, 2009; IPCC, 2012) and the Sustainable Development Goals, the pathways broadly aim to address several sustainability challenges, including: (i) food provision (Goal 2) while

3. Available at https://www.ipbes.net/sites/default/files/eca_ch_5_appendix_5.2_main_features_of_the_pathway_studies.pdf

Box 5 9 **Pathways including indigenous and local knowledge and practices (based on Oteros-Rozas *et al.*, 2013).**

This study focused on the agro-pastoral strategy of transhumance in south-central Spain as a traditional way of adapting to fluctuating and seasonal environmental factors for livestock production. This long-term practice rooted in prehistory has been shaping and maintaining biodiversity at all levels. Today this practice is declining or already abandoned because of the integration of animal production into the global market economy and the dominance of the global food system. In light of global environmental change, including climate and land use change, sustainable livestock production systems adapted to local environments have seen renewed interest. Against this background, participatory scenario planning was performed with 68 stakeholders including herders, administrators, NGOs and scientists. The aim was to envision plausible futures for transhumance and to enlighten policymaking on the maintenance of this practice along the "Consequence Drove Road", one of the largest transhumant social-ecological networks still in use in Spain. Among the specific goals was also to analyze trade-offs between different contributions of nature to people between different scenarios and their effect on a good quality of life.

Four plausible future scenarios were built, each showing clear trade-offs in the delivery of 19 studied contributions, such as food, fibre, soil fertility, fire prevention, cultural identity, local ecological knowledge and other dimensions of good quality of life. Nine management strategies for the maintenance of transhumance were identified by the stakeholders. Priority was given to implementation of payment schemes for nature's contributions to people, the enhancement of social capital among transhumants, the improvement of product marketing and the restoration of the drove roads. All the mentioned measures will enhance and make transhumance economically viable for younger generations. The results and recommendations of the participatory exercise were linked to the current reform of the European Union Common Agricultural Policy that aims for sustainable food production by strengthening links between food production and various contributions from nature to people. Thus, this study is an example of how to design pathways towards the goal/vision of sustainable livestock production by incorporating indigenous and local knowledge, a foundation in the transhumance practice, into a scenario exercise.

ensuring water availability and water quality (Goal 6) and minimizing biodiversity loss (Goal 15); (ii) mitigating climate change (Goal 13) while enhancing energy security (Goal 7), contributing to health (Goal 3) and offering practical and workable solutions for low carbon transport systems; and (iii) promoting economic wealth (Goals 8 and 9), relational values and equity (Goal 10). In line with these international priorities, Europe and Central Asia visions prioritize (Section 5.1.2; **Figure 5.3**):

- two Sustainable Development Goals relating to the biophysical dimension of sustainability: Goals 13 (climate action) and 15 (life on land);
- three Sustainable Development Goals relating to the economic dimension of sustainability: Goals 8 (decent work and economic growth), 9 (industry and innovation) and 12 (responsible consumption and production); and
- two Sustainable Development Goals relating to the social dimension of sustainability: Goals 7 (clean energy) and 11 (sustainable cities).

In addition to addressing the above challenges, the pathways also aim to mitigate trade-offs between different aspects of nature, its contributions to people and good quality of life. Major trade-offs relating to land, addressed by pathways studies and national biodiversity strategies and action plans alike, concern on the one hand food, fibre and energy provisioning, and on the other hand biodiversity and regulating contributions for the preservation of soils, water quantity and quality, and regulation of water-related hazards, climate and air quality.

In the European Union, Prins *et al.* (2017) and Van Zeijts *et al.* (2017) suggest that most future conflicts and synergies will potentially occur in urbanized and mountainous regions. For example, in urban and peri-urban regions, synergies may be found between cultural landscapes that are attractive for recreation and regulating services, such as pollination. Alternatively, conflicts could arise between the development of private landscape parks and free accessibility for recreation, and between intensive agriculture and the attractiveness of landscapes. In mountainous areas, regulating services, such as water retention and carbon sequestration, may be compatible with the large-scale development of wild nature and private parks for tourism. While the development of large nature areas with natural dynamics may conflict with the conservation of historically characteristic landscapes (Prins *et al.*, 2017; van Zeijts *et al.*, 2017).

In the Mediterranean region and Eastern Europe, pathways for land address additional trade-offs resulting from land abandonment regarding biodiversity, the regulation of fire hazards, and nature's non-material contributions to people associated with indigenous and local knowledge (e.g. Hanspach *et al.*, 2014; Oteros-Rozas *et al.*, 2013). In northern areas of Western Europe (Sami land) and Russia / Central Asia, trade-offs between exploitative land use, e.g. mining, and pastoral activities by indigenous herders are at the core of current conflicts and future pathways (Heikkinen *et al.*, 2012; Roué & Molnar, 2017).

In coastal areas, pathways address the tension between intensive food production (fisheries, aquaculture and intensive agriculture), nature's material contributions to people and non-material contributions associated with tourism on the one hand, and on the other hand biodiversity and regulating contributions for the preservation of freshwater quantity and quality, coastal and marine water quality, and for hazard regulation (Palomo *et al.*, 2011; Palacios-Agundez *et al.*, 2013).

In the following sections actions within pathways regarding nature, its contributions to people, and good quality of life are described in terms of four types of narratives (Section 5.5.2), including the policy instruments considered to support these actions (Section 5.5.3). The trade-offs observed within pathways are then reviewed (Sections 5.5.4 and 5.5.5), and how these may be mitigated by cross-scale integration and the mainstreaming of environmental goals across sectors (Section 5.5.6).

5.5.2 Narratives of pathways for nature, nature's contributions to people, and a good quality of life

Pathways can be clustered into internally consistent narratives based on the alternative system properties that they mobilize through their actions and strategies (in a similar manner to how scenarios are clustered into scenario archetypes in Section 5.2 based on the changes in drivers they represent). Luederitz *et al.* (2017) distinguish four groups of narratives describing pathways to sustainability according to the structural and societal transformations, and associated system properties, upon which they focus:

- The *green economy* narrative addresses transitions toward decreased environmental degradation and resource depletion through green growth supported by "policy instruments that incentivize and regulate specific economic activities" (Luederitz *et al.*, 2017).
- The *low carbon transformation* narrative encompasses all pathways focusing primarily on mitigating climate change and adapting to climate change impacts, whether at large geographic and governance scales through incentives and regulatory instruments or through local spatial planning and behavioural control.

Similar to the *green economy* narrative priority is given to the top-down governance of transitions to sustainability.

- The *ecotopian solutions* narrative addresses unsustainable development and associated environmental impacts through transitions toward "greater socio-ecological integrity". It does this by challenging current belief systems, lifestyles and living spaces with bottom-up, politically alternative initiatives of self-organization at the community or neighbourhood level to work towards local-scale, self-sufficiency.

- The *transition movements* narrative also focuses on fundamental individual and social changes to propose alternatives to economic growth and globalization, and their negative social and environmental impacts. Although also starting from local, bottom-up initiatives, in contrast to *ecotopian solutions*, *transition movements* aim to scale-up to whole system transformation.

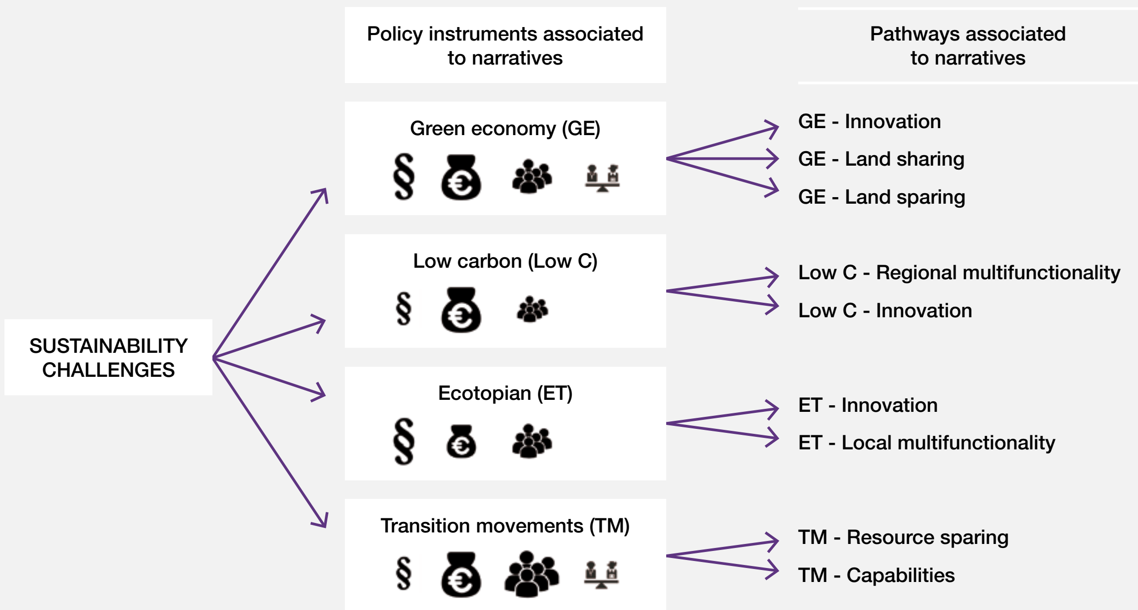
Importantly, these four narratives are complementary and non-exclusive, with specific themes such as innovation or multifunctional land use incorporated within multiple narratives.

The Europe and Central Asia pathways were classified according to the four narratives of Luederitz *et al.* (2017). For each narrative, alternative pathways could be identified, which vary in their sets of concrete actions and strategies **(Figure 5.19)**. Below we describe the main features of each narrative adapted for the Europe and Central Asia studies in terms of their component actions for land use and land management, nature, its contributions to people, and good quality of life.

5.5.2.1 Green economy and low carbon transformation pathways

The majority of pathways for Europe and Central Asia fit the *green economy* or *low carbon transformation* narratives. In the *green economy* narrative, pathways rely on diversification and sustainable intensification of all production activities (agriculture, forestry, fisheries) and increased protection and restoration of biodiversity. The pathways promote improved quality and diversity of forest, agricultural and marine production, supported by healthy soils and wetlands/water. Furthermore, they contribute to employment and improved food safety, nutrition and health. As a result, these pathways rely largely on relational values

Figure 5 19 **Four narratives, *green economy* (GE), *low carbon transformation* (Low C), *ecotopian solutions* (ET) and *transition movements* (TM), to address sustainability challenges for Europe and Central Asia. Each narrative is associated with different sets of policy instruments. Icons for policy instruments are defined in Table 5.5, and the size of each icon relates to the importance of each category of instruments in the narrative. Source: Own representation.**



(e.g. governance and justice, security and livelihoods, health and well-being) mentioned in around 50% of the studies, but they also consider instrumental values (e.g. nature's material and non-material contributions to people) (ca. 30%) followed by a no-values perspective about nature (ca. 20%). Intrinsic values (e.g. biodiversity, biophysical processes) were not explicitly mentioned in any of the studies associated with the *green economy* pathway.

Pathways from the *low carbon transformation* narrative may be considered as a subset of the *green economy* narratives, with a specific focus on biofuel production, reforestation and forest management. Based on a similar set of values to *green economy*, but with a much greater focus on instrumental values, they contribute to increased regulation of climate, energy access and security, improved health (regulation of air quality), and reduced risks from regulation of hazards and extreme events. Alternative pathways within the *green economy* and the *low carbon transformation* narratives focus on the following three different sets of actions:

- Innovation pathways within *green economy* and *low carbon transformation* narratives rely on technological innovation to address sustainability and resolve trade-offs. They do this by supporting more efficient land use allocation and management through, for example, agro-ecological practices, water-smart agriculture, precision farming, smart and sustainable forest use, increased fish farming, biofuels and biogas. These benefit nature by reducing land/sea area consumption, decreasing climate impacts, increasing climate change adaptation of production activities and supporting nature protection and restoration. While mostly focused on increasing nature's material contributions to people, and thereby employment, income and nutrition, they explicitly aim to reduce their trade-offs with regulating contributions and to improve health.

- Multifunctionality within *green economy* and *low carbon transformation* narratives can play out at different scales. The most common multifunctionality pathways rely on *land sharing* with lower management intensity and diversification of production of nature's contributions to people within individual land/sea/water uses and across uses at landscape to regional scale. Apart from decreasing intensification, such subregional scale multifunctionality, is often associated with the promotion of conservation, restoration and sustainable use of land and wetlands. Direct benefits of these land use actions are expected for agricultural, forest, soil, water and wetland biodiversity. The improvement of nature is in turn expected to support both quality production and nature's regulating contributions to people, especially in soils and water. Further benefits are expected for climate resilience and mitigation, and for recreation.

- Although less common, *green economy land sparing* pathways promote regional (Europe and Central Asia)-scale multifunctionality. These focus on concentrating production activities in the most favourable areas, while protecting, and in some cases abandoning, selected ecosystems or areas. According to such pathways, this land allocation and management strategy is suggested to benefit nature conservation and total provision of nature's contributions to people, at the regional scale, including in particular climate change mitigation and recreation or wilderness tourism, especially for urban dwellers. Implicit in this pathway is the assumption that the biodiversity of cultural landscapes has a lower value to society compared to the resumption of "wild" biodiversity.

Overall, for the *green economy* or *low carbon transformation* narratives, most actions in pathways at the Europe and Central Asia level focus on land-freshwater-sea use or management and nature and its contributions to people, with fewer actions directly targeting a good quality of life.

5.5.2.2 Transition movements pathways

In contrast to the *green economy* and *low carbon transformation* narratives, pathways of the *transition movements* narrative involve changes in relational values towards resource-sparing lifestyles, and in some cases, they emphasize explicitly non-GDP growth. They incorporate the development of innovative forms of agriculture combining indigenous and local knowledge with technological innovations (e.g. agroecology, agroforestry, organic agriculture, urban agriculture), and transport and energy models that limit impacts on nature, climate and water. Relational values are at the centre of proposed actions, including education, the incorporation of indigenous and local knowledge and cultural diversity. Enhancing quality of life, especially by supporting the Sustainable Development Goals, is complemented by a focus on reduced social inequities and full employment. These goals are enabled by new social models, which aim to reduce market globalization and interregional flows, and support cultural identities, knowledge sharing and transformative capabilities. Here, transformative capabilities are defined as individual and collective capacities to improve and enrich their quality of life by changing factors affecting their lives, of which the environment is central. Apart from education, they include for instance social capital, local leadership and empowerment, building trust and collaboration. All types of values are represented within *transitions movements* pathways, with relational values having the greatest emphasis (ca. 41%) followed by instrumental (ca. 18%) and intrinsic values (ca. 9%).

Specific pathways of *transition movements* narratives focus on resource-sparing lifestyles (including e.g. food and energy), or on transformative capabilities (including common actions), though these two categories are not mutually exclusive.

- Resource-sparing lifestyle pathways emphasize change in dietary and overall consumption patterns. These changes are associated with innovative land use or management such as agro-ecological methods, including organic agriculture, possibly also in coexistence with more intensive production regionally. Other changes suggest a radically reduced energy consumption and new urban spatial structure and planning. All these changes in lifestyles are intended to have beneficial effects for biodiversity at species, habitat and landscape levels. With explicit inclusion of intrinsic and relational values, these pathways invoke a strong reliance on nature's regulating contributions to people, as well as benefits from material and non-material contributions. Together these promote all aspects of a good quality of life, including continuous education, participatory transdisciplinary research and social capital, and the preservation of cultural diversity, indigenous and local knowledge and social equity.

- Transformation capabilities pathways mostly emphasize the role of local empowerment, deliberation and social cohesion for achieving diversified, sustainable land use and livelihood strategies at the subregional scale. As such, they do not target transformation of lifestyles or economic growth *per se*, but nevertheless share many actions of resource-sparing pathways regarding quality of life as a secondary effect of social changes.

5.5.2.3 Ecotopian solutions pathways

Ecotopian solutions pathways share many elements with *transition movements* in terms of lifestyles, land use or management types and innovations, and societal transformation. However, *ecotopian solutions* have an even stronger focus on bottom-up actions and politically alternative initiatives of self-organization than *transition movements* pathways. Similar to *transition movements*, they include all values: relational (ca. 60%), intrinsic (ca. 20%) and instrumental (ca. 20%). The inclusiveness and balance among different types of values in this pathway support sustainability efforts through changing social behaviour.

Local-scale multifunctionality is a cornerstone of *ecotopian solutions* pathways. For this, *ecotopian solutions* pathways rely on fine-grained landscape mosaics of diversified land uses with multifunctionality within individual land uses and connecting green infrastructure (e.g. corridors). They also highlight new production methods and new technologies, but in contrast to other pathway narratives, their focus is to achieve community-level food and energy self-sufficiency and the production of multiple contributions from nature to people. Two pathways can be distinguished within the *ecotopian solutions* narrative depending on whether they focus on innovation or local multifunctionality. Those pathways with a strong emphasis on innovation and associated instrumental values, often along with radical social innovation and shifts in worldviews, generally focus on urban design and food production.

Unlike *transition movements* pathways, *ecotopian solutions* pathways, and specific actions therein, focus solely on local scales and may therefore only be applicable at community, or even very local levels (e.g. wealthy neighbourhoods). Scaling-up to the regional level and beyond may not be easy, especially due to trade-offs and spill-over effects (Maestre Andrés *et al.*, 2012). For example, the pathway of local multifunctionality at the European scale (Western, Central and Eastern Europe) is not compatible with objectives of nature protection (e.g. connectivity, natural protected areas, forest biodiversity protection) or climate mitigation at the European Union level, and may ultimately increase net global trade in agricultural products (Verkerk *et al.*, 2016).

Overall, local level studies of pathways from *transition movements* and *ecotopian solutions* narratives, and some studies of visions of societal transformations towards sustainability (Capellán-Pérez *et al.*, 2015; Davies & Doyle, 2015; Fauré *et al.*, 2016; Robertson, 2016; Videira *et al.*, 2014) offer a rich set of actions focusing on good quality of life, anthropogenic assets and institutions. However, in a number of cases, specific actions on land use or management, nature and its contributions to people, are lacking. Nevertheless, such studies suggest a diversity of alternative transition pathways which may act as "seeds" for future sustainability (Bennett *et al.*, 2016), yet need to be further developed to incorporate explicit sets of actions related to land use or management, nature, and its contributions to people.

Box 5.10 summarizes a local *transition movements* pathway as a demonstration of a coherent pathway incorporating indigenous and local knowledge developed for southern Transylvania (Hanspach *et al.*, 2014).

5.5.3 Policy instruments associated with pathways to sustainability

The sets of actions and priorities in the pathways studies are supported by specific policy instruments. These have been analyzed using the following instrument categories

Box 5 10 Pathway to sustainability for southern Transylvania (based on Hanspach *et al.*, 2014).

Alternative target-seeking scenarios for the future of rural areas in southern Transylvania were developed using a participatory process. The *balance brings beauty* scenario offers a possible pathway towards regional and local sustainability based on a complete reorientation of European Union agricultural and rural policies towards sustainability and environmentally friendly land use. Subsidies and policies foster small- and medium-scale organic farming, low-intensity forestry and the discontinuation of previously common exploitation of resources (e.g. soil, forest). This major policy change is combined with a high ability of local people to capitalize on opportunities. This is supported by a fundamental change in the social fabric; from communities that were shaped by mistrust, corruption, ethnic conflicts and poor education to communities with high social capital, mutual learning and collaboration, equality and excellent education. Importantly, knowledge and practice of traditional land use, traditions and cultural and natural heritage are maintained and people are proud of their landscape.

The continuation of sustainable, small-scale farming based on indigenous and local knowledge is a keystone for this pathway. Due to pro-environmental policies, this is only organic farming, with an increase in intensity (abandoned land taken into use again). Farming is undertaken by local farmers who are well connected and collaborate. Thus, large or external farming companies have no influence on land use. Forest resources are maintained with only low-intensity harvesting. Land use and livelihood strategies are diversified (farming for crops, vineyards, orchards, hay-meadows, livestock grazing on (wood) pastures, tourism).

Small-scale farming maintains biodiversity at its current level overall, but the intensification of land use (less abandoned fields) leads to a slight decline, particularly of farmland biodiversity. Farming practices rely on, and ensure a balance between nature's regulating and material contributions to people, while the level of non-material contributions, especially in relation to indigenous and local knowledge is preserved. People are relatively happy in spite of limited economic growth. Ethnic conflicts are settled and there are few inequalities. Community spirit is high and people are proud of the cultural and natural heritage of their landscape.

in line with Chapter 6 and IPBES (2015b): (i) legal and regulatory instruments (e.g. laws); (ii) economic and financial instruments (e.g. taxes, subsidies); (iii) social and information-based instruments (e.g. education); and (iv) rights-based instruments and customary norms (e.g. strengthening collective rights).

In the *green economy* pathways, legal and regulatory instruments are included in almost all studies **(Table 5.5)**. These mostly involve the articulation and implementation of laws and regulations, but the setting of social and environmental standards and planning are also mentioned frequently. Legal and regulatory instruments are often combined with economic and financial instruments. An example of such a policy mix is the implementation of a regulation to deter illegal fishing accompanied by incentives for business models that embrace certification schemes and cooperative marketing in aquaculture (FAO, 2014). Another example is provided by Verkerk *et al.* (2016), where area protection is combined with incentives, e.g. payments for carbon sequestration and payments for recreation services.

A similar reliance on a mix of economic and financial instruments with legal and regulatory instruments was found for Eastern Europe and Central Asia, where mainly national documents such as national biodiversity strategies and action plans and strategies for sustainable development were analyzed. For example, in Ukraine, an increase in pollution taxes as an economic instrument was combined with a revision of the permitted pollution thresholds in

Table 5 5 **Policy instrument categories related to narratives of pathways (instruments mentioned: "+" = a few times, "++" = quite often, "+++" = very frequently, "no +" = not mentioned at all; n = number of pathways analyzed with respect to policy instruments). Source: Own representation.**

Pathway narratives	Policy instrument categories related to pathway narratives			
	Legal & regulatory §	Economic & financial	Social & information-based	Rights-based & customary
Green economy (n=42)	+ + +	+ +	+ +	+
Low carbon transformation (n=6)	+ +	+ +	+	
Transition movements (n=16)	+ +	+ +	+ + +	+
Ecotopian solutions (n=4)	+ + +	+	+ +	

surface waters as a regulatory instrument (Parliament of Ukraine, 2016). In Belarus, including sustainable biodiversity use in spatial planning documents was suggested together with the introduction of payments for ecosystem services in financing nature conservation (Council of Ministers of the Republic of Belarus, 2015).

Of similar importance to legal and regulatory instruments in *green economy* pathways, and again often mentioned as policy mixes, are social and information-based instruments. A wealth of instruments and tools are cited in the pathways related to the provision of information, e.g. via monitoring, valuation exercises and research. Environmental education and training are also important. For instance, the inclusion of "ecological trails" in tourist routes was proposed in Belarus (Council of Ministers of the Republic of Belarus, 2015). Participatory approaches are mentioned in a number of studies, but only a few of these are from Eastern Europe and Central Asia. Least important in the *green economy* pathways are rights-based instruments and customary norms. Here, strengthening of rights and local rights is mentioned occasionally.

Low carbon transformation pathways were particularly vague concerning policy instruments **(Table 5.5)**. Standards and targets are mentioned as legal and regulatory instruments, such as energy efficiency standards for all buildings combined with economic and financial instruments, such as energy taxation (WWF/Ecofys/OMA, 2011). Social and information-based instruments are almost exclusively associated with research and monitoring. As in the *green economy* pathways, rights-based instruments and customary norms played only a minor role.

The most important instruments in the *transition movements* pathways are social and information-based instruments **(Table 5.5)**. These instruments focus on community actions, participatory processes, shared visions and voluntary agreements. Examples from the Europe and Central Asia pathways include changing individual consumption patterns towards sharing coupled with an animal welfare and rights perspectives, and the inclusion of ecological knowledge and criteria in decision-making (Kirveennummi *et al.*, 2013). Rights-based instruments and customary norms are included in a few pathways, often in combination with social and information-based instruments. For example, in combination with increased participation, Palomo *et al.* (2011) highlight the importance of maintaining and including indigenous and local knowledge norms and customary rights perspectives to foster transformative capabilities and identity and conserve ecosystem qualities.

The importance of cross-scale integration and the mainstreaming of targets related to nature and its contributions to people into policymaking across a broad range of policy sectors, is also frequently considered in transition movement pathways in relation to social and information-based instruments. One pathway from the Food and Agriculture Organization of the United Nations suggests a combination of mainstreaming with other policy instruments for the governance of groundwater. In this study, the implementation of legal, regulatory and institutional frameworks for groundwater that establish public guardianship and collective responsibility, permanent engagement of stakeholders and beneficial integration with other sectors is coupled with assessments, monitoring, up-to-date information and communication techniques, capacity building and incentive frameworks and investment programmes to foster sustainable, efficient groundwater use and adequate groundwater resources protection (FAO, 2015). Other studies, dealing with sustainability transitions additionally highlight rules safeguarding access to resources for vulnerable groups (Videira *et al.*, 2014), trade barriers, and limits for energy use and CO_2 emissions (Capellán-Pérez *et al.*, 2015; Grabs *et al.*, 2016).

The few *ecotopian solutions* pathways all include legal and regulatory instruments, with planning playing a prominent role **(Table 5.5)**. Of similar importance are social and information-based instruments, with the provision of information receiving substantial attention. Economic and financial instruments such as incentives are also important, whereas rights-based instruments are not reflected in the studies.

In general, the pathways analyzed refer to very different levels of implementation and almost no pathway indicates directly how an instrument is supposed to be developed and implemented in order to produce a certain outcome or impact on the state of nature or its contributions to people. While the instruments mentioned in most studies can be interpreted as policy mixes, little information is given concerning the order of implementation of the different instrument types involved in the mixes. In particular, most of the studies from Eastern European and Central Asia envision only short time horizons and the instruments mentioned might be perceived as initial steps towards improved environmental governance. Overall, most studies remained rather vague on specific policy instruments, allowing for only a superficial analysis. However, this analysis might still provide some useful insights into future policy options when considered in combination with the analysis of current policy instruments provided in Chapter 6, Section 6.6.1.

While there are differences between the pathway narratives, there are also similarities in the level of individual instruments and strategies to support these instruments. Investments, and more specifically ensuring conditions to foster environmentally friendly investments, play a role in all the narratives. The investments are meant to support the implementation of instruments, for example, the regulation of investments in the context of delivering consistent and transparent business regulations (e.g. WEF, 2010), but also in the context of fostering renewable energy production (e.g. Greenpeace, 2009), sustainable groundwater management (e.g. FAO, 2015) and food production (UNEP, 2012). Investments in research and development are also important across pathway narratives (e.g. Forest Europe, 2011; WWF/Ecofys/OMA, 2011).

The most prominent policy instrument described across all pathway narratives is the use of awareness-raising tools and education. Participation is also frequently mentioned, although the specificities and intensities of participation vary across the narratives, e.g. in *transition movements* or *ecotopian solutions* narratives, collaborative participation including the delegation of power and control by citizens is given preference over consultative forms of participation.

The pathways studies often rely on known policy instruments and tools (see a discussion of these tools in Chapter 6, Section 6.6.2), despite the future visions often being radical. Most of the pathways across the four narratives strongly rely on cross-scale integration, especially in terms of governance, with the exception of some *ecotopian solutions* pathways. The pathways mention a diversity of planning approaches and integrated impact assessment tools for achieving cross-scale integration (see discussions of such instruments and tools in Chapter 6, Section 6.6.3). Finally, while rights-based and customary norms instruments are neglected in most studies, other categories of instruments are frequently combined in policy mixes (see discussions on policy mixes in Chapter 6, Section 6.6.4).

5.5.4 Analysis of synergies and trade-offs within pathways

The pathways for Europe and Central Asia involve alternative ways of mitigating trade-offs and capitalizing on synergies. Trade-offs within individual pathways may occur when the expected impact of actions within a pathway on nature, its contributions to people, and good quality of life compromise a given contribution in favour of another; this could result from sectoral trade-offs and spatial trade-offs. For example, several pathways focus on trade-offs and synergies between material contributions (food, timber, fish, water) and water quality regulation, global climate regulation and nature conservation. The four narratives propose different solutions for this: *green economy* and *low carbon transformation* narratives focus on technological innovation or land planning from the regional (Europe and Central Asia) to subregional scale; *ecotopian solutions* and to some degree *transition movement* narratives concentrate on resolving trade-offs locally through changing demand for nature's contributions to people, often along with innovation and multifunctional practices.

Analysis of such trade-offs is challenging because of the qualitative nature of the pathways, many of which were designed to guide the direction for action and change, rather than as comprehensive analyses. Furthermore, the studies strongly emphasize the synergies between nature's material and regulating nature's contributions to people afforded by the proposed pathways, but offer limited analysis, even qualitatively, of resulting trade-offs. Finally, limited information was available regarding non-material contributions (but see Brunner *et al.*, 2015; Hanspach *et al.*, 2014; Palacios-Agundez *et al.*, 2013; Palomo *et al.*, 2011), risk mitigation (but see Brunner *et al.*, 2015) or biotic regulation, such as pollination for which no explicit information was available.

In the following section we explore trade-offs within pathways first by summarizing the synergies and trade-offs between different contributions from nature to people, or between nature and different contributions found in the pathways studies. We then analyze trade-offs and synergies between the four different pathway narratives by considering their links to the Sustainable Development Goals and Aichi Biodiversity Targets.

5.5.4.1 Synergies and trade-offs between different contributions of nature to people and between nature and its contributions to people

Several trade-offs could be identified within the specific sets of actions suggested by the individual pathways. In general, management aimed at increasing nature's material contributions to people, associated with fish-farming, forest harvest, biofuels and agricultural products as depicted in *green economy* or *low carbon transformation* pathways implies an increase in land or water use or more intensified production. In these pathways, increased production of food and other natural resources might therefore imply a trade-off against alternative contributions from nature to people, and biodiversity associated with semi-natural or protected sea- or landscapes. Conversely, promoting nature conservation and some regulating contributions comes at a cost to production of food and other natural resources, in particular in *transition movements* and *ecotopian solutions* pathways. Nevertheless, some *transition movements* pathways promise to promote synergies between increased quantity and quality of food, regulating contributions and nature protection through agro-ecological practices based on combining indigenous and local knowledge and innovations.

Overall, many critical trade-offs revealed in pathways studies concern food production: (i) competition between food and biofuel (energy) production; (ii) trade-offs between food production and climate regulation, water provision and quality, soil quality or biodiversity; and (iii) trade-offs between biofuel (energy) production, soil quality and water provision and quality. In global level studies, such as the FAO (2014) vision, the two pathways on water and agriculture are argued to be so well integrated and in synergy that even the trade-off between water use for ecological functions and for food production is resolved, but this cannot be validated by the report itself.

Trade-offs with biodiversity are also mentioned with respect to energy infrastructure and forest products, while forest products themselves are cited as trading-off against water provision and soil quality. Lastly, trade-offs among components of nature associated with different ecosystems are also implicit in some pathways, especially in *regional multifunctionality* pathways that advocate land abandonment and rewilding at the expense of cultural biodiversity of extensively farmed areas (Pedroli *et al.*, 2015; Prins *et al.*, 2017; Sylvén & Widstrand, 2013). Even under *transition movements* pathways where land management relies on nature's contributions to people and synergies between nature and these contributions are fostered, some authors argue that tightly managing or engineering nature may ultimately not be ideal because it limits some natural processes (e.g. species dispersal and gene flow) (Heikkinen *et al.*, 2012). Thus, the studied pathways only partly succeed in mitigating the critical trade-offs around food, water, nature and climate, which they aim to resolve.

5.5.4.2 Relating pathways to the Aichi Biodiversity Targets

As outlined in Section 5.4, the Europe and Central Asia visions prioritize Aichi Biodiversity Targets 4 and 7. The actions within the different pathways targeting nature, its contributions to people, and good quality of life were examined to assess how they address the different strategic goals of the Strategic Plan for Biodiversity 2011-2020 (although not necessarily in line with their timeframe of 2020) (supporting material Appendix 5.2[4]). Insufficient evidence was available to undertake a reliable analysis of specific Aichi Biodiversity Targets due to uncertainties regarding the information in the pathways about specific actions, especially regarding indirect drivers.

Overall, targets within Strategic Goal A to address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society are covered weakly across all pathway narratives. Strategic Goal E to enhance implementation through participatory planning, knowledge management and capacity building is also poorly covered. Here, only the *transition movements* pathways offered sets of actions to change resource-intensive lifestyles, and foster education, good social relations and equity, for instance in urban or rural settings (see Section 5.5.2 for further details on the actions).

Consistent with the focus of the pathways on direct drivers, Strategic Goal B to reduce direct pressures on biodiversity and promote sustainable use and, more specifically, Target 7 (sustainable management of agriculture, aquaculture and forestry) is addressed by all pathways except for the *low carbon transformation* – innovation pathway, through their land planning and land management actions, for instance, targeting multifunctionality and biodiversity conservation either at local or regional scales. A similarly good coverage is found for Strategic Goal D to enhance the benefits to all from biodiversity and ecosystem services as nearly all pathways include actions targeting at least some of nature's contributions to people. Coverage of Strategic Goal C on the improvement of the status of biodiversity by safeguarding ecosystems, species and genetic diversity was mixed.

4. Available at https://www.ipbes.net/sites/default/files/eca_ch_5_appendix_5.2_main_features_of_the_pathway_studies.pdf

5.5.4.3 Relating pathways to the Sustainable Development Goals

Synergies and trade-offs within pathways were also assessed in terms of the Sustainable Development Goals. Here, we analyzed how the intended sets of actions within pathways could be helpful in achieving particular Sustainable Development Goals (although not necessarily in line with their timeframe of 2030). This involved using the expert opinion of the author team to combine information on how different indicators of nature, its contributions to people, and good quality of life relate to the Sustainable Development Goals, and how these indicators are likely to be affected by the actions in the pathways and the predominant dimensions of sustainability represented by each Sustainable Development Goal: biophysical (Goals 6, 13, 14, 15), economic (Goals 8, 9, 10, 12) and social (Goals 1, 2, 3, 4, 5, 7, 11, 16) **(Figure 5.20)**.

Of the Sustainable Development Goals which were found to be prominent across visions for Europe and

Figure 5 20 **Estimated ability of the pathway narratives to achieve the Sustainable Development Goals shown in three groups (A, B, C).**

For each pathway, the plot represents the relative score for each Goal according to actions on nature, its contributions to people, and good quality of life. Pathways are *green economy* (GE), *low carbon transformation* (Low C), *ecotopian solutions* (ET) and *transition movements* (TM). Sustainable Development Goals are clustered and coloured according to their predominant character: biophysical, economic, social dimensions of sustainability (Folke *et al.*, 2016); global partnership refers to Goal 17. The size of the bar towards each Goal shows the trends of actions within each pathway towards indicators of nature, its contributions to people, and good quality of life associated with that Goal, ranging from 0 (not mentioned) to 1 (increasing for all indicators). Note the pathways often concern timescales beyond 2030. Source: Own representation.

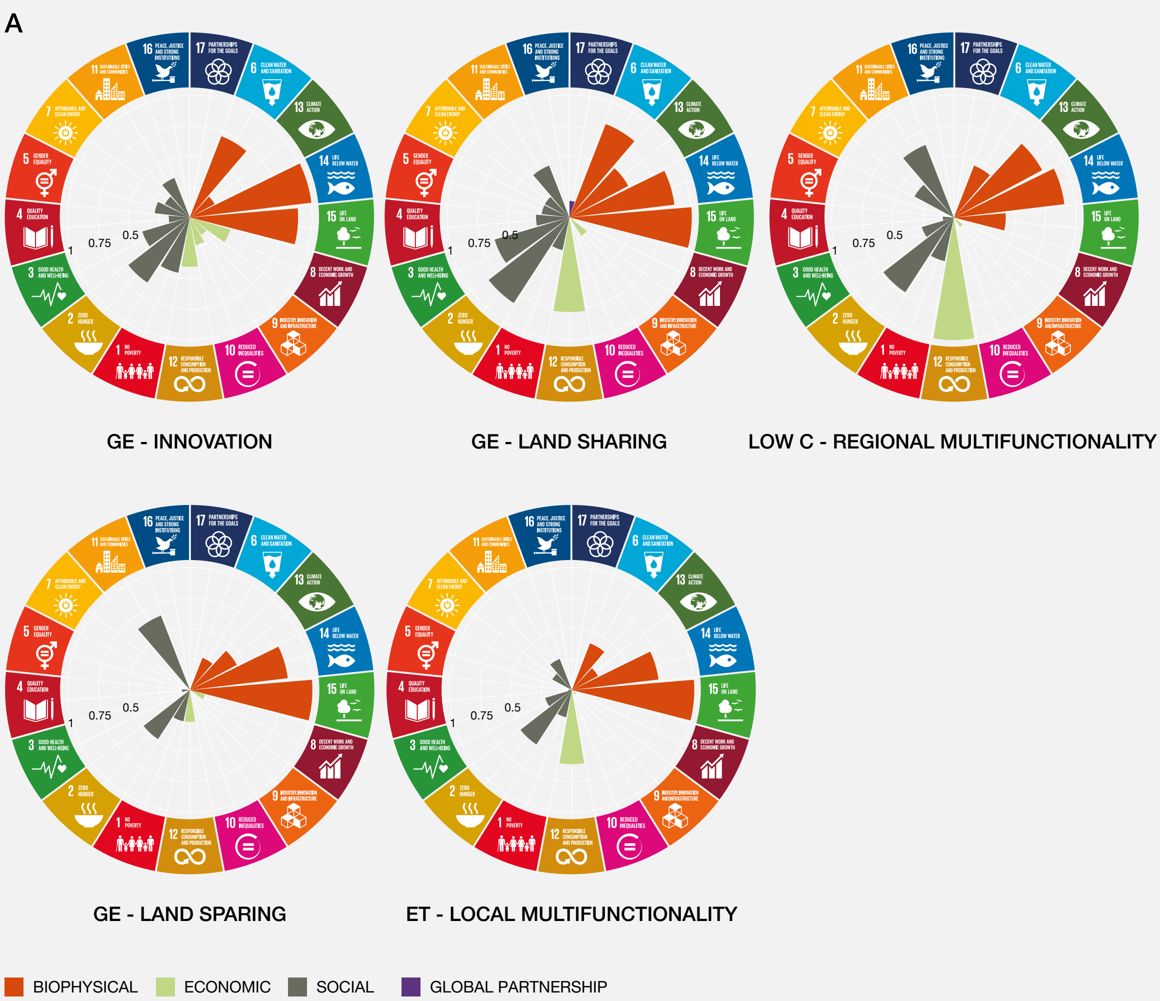
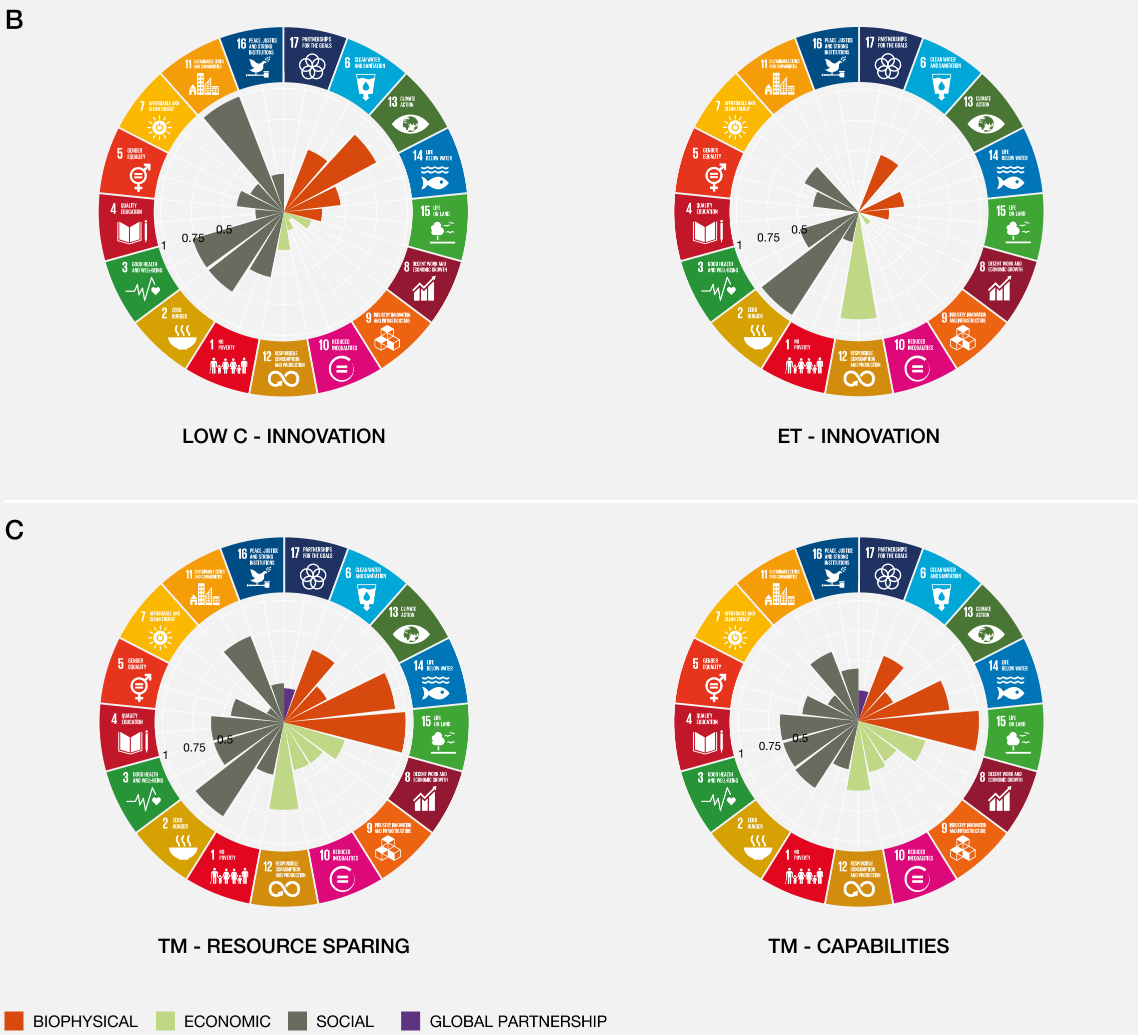


Figure 5 20



Central Asia (Section 5.1.2) the majority, that is Goals 13 (climate), 15 (life on land), 11 (sustainable cities) and 12 (responsible production and consumption), are addressed significantly by at least half of the pathways, and even by all of them in the case of Goal 15. Therefore, when aiming to achieve goals 11, 12, 13 and 15 different sets of actions from diverse pathways could be employed. In particular, multifunctionality based on the combination of traditional and innovative practices in agriculture and forest management is critical for achieving these goals, but can be operationalized at different scales depending on pathways, and across different regions of Europe and Central Asia.

However, the focus on the biophysical dimension associated with Goals 13 and 15 in some pathways, for example, in the *green economy* narrative, can come at a cost of ignoring other goals associated with the economic and social dimensions of sustainability, such as Goal 7 (clean energy), and especially Goals 8 (decent work) and 9 (industry and infrastructure). These were highlighted as important in the Europe and Central Asia visions, but are hardly addressed across pathways with the notable exception of *transition movements* pathways for Goals 8 and 9.

Low carbon transformation or *ecotopian solutions* pathways with a focus on innovation address biophysical objectives less strongly than other pathways, particularly for Goal 15 (except *ecotopian solutions - local multifunctionality*). There are also few actions associated with Goal 13 for *ecotopian solutions* pathways. In contrast, *transition movement* pathways address all of the Sustainable Development Goals identified as being important in the Europe and Central Asia visions, except Goal 7, because they offer the broadest set of actions targeting elements of nature, multiple contributions from nature to people (material, regulating and non-material) and multiple dimensions of a good quality of life.

Based on this analysis, the ability of the pathway narratives to address the Sustainable Development Goals was divided into three groups in terms of their representation of dimensions of sustainability as follows:

- First, the three *green economy* pathways and the *ecotopian solutions - local multifunctionality* pathway have a strong focus on the biophysical dimension, along with some on the social dimension, but fewer on the economic dimension. Within this group, the focus on the economic dimension is more developed in the *green economy – innovation* pathway, while it is absent in the *green economy – land sparing* pathway, and solely focused on Goal 12 (responsible production and consumption) in the *green economy – land sharing* and the *ecotopian solutions - local multifunctionality* pathways **(Figure 5.20 A)**.

- Second, pathways focusing primarily on climate action including the two *low carbon transformation* pathways and the *ecotopian solutions - innovation* pathway have a weaker focus on the biophysical dimension, but address the social dimension more than the first group. In particular, they include actions targeting Goals 2 (food) and 11 (sustainable cities and communities), along with a strong focus on Goal 12 (responsible production and consumption) for the economic dimension **(Figure 5.20 B)**.

- Third, the two *transition movements* pathways promise to address the greatest diversity of Sustainable Development Goals and thus cover biophysical, social and economic dimensions. As such, they best fulfil the three dimensions of sustainability articulated in visions for Europe and Central Asia **(Figure 5.20 C)**.

The analysis shows that the four pathway narratives lead to different trade-offs and synergies between Sustainable Development Goals and associated dimensions of sustainability. Nevertheless, a recurring trade-off was found between food provision and nature conservation goals on the one hand and some important social and economic goals on the other hand. This trade-off seems to be difficult to mitigate across all the pathways. More specifically, based on the actions they reported, none of the pathway narratives could

Box 5 11 **Assessing the impact of pathways using an integrated assessment model.**

Models can be applied to pathways to simulate the potential impacts resulting from their proposed actions, for example on biodiversity conservation, or trade-offs between nature and its contributions to people. Such information is needed to compare alternative pathways and to inform decision-making. A study by the Netherlands Environmental Assessment Agency (PBL, 2012) assessed the impacts of three alternative pathways on global biodiversity, analyzing the extent to which the pathways help to meet the 2050 Vision of the Strategic Plan for Biodiversity 2011-2020. The different pathways (consisting of combinations of biophysical and behavioural options) were designed to step-up and scale-up efforts within activity sectors towards biodiversity-friendly production. They included:

- A *global technology* pathway, which in line with the *green economy – innovation* narrative relies on large-scale technologically-optimal solutions and a high level of international coordination;

- A *decentralized solutions* pathway, which in line with the *green economy – land sharing* narrative focuses on regional solutions; and

- A *consumption change* pathway, which in line with the *transition movements – resource sparing* narrative prioritizes changes in human consumption patterns.

Model results show that the actions within the three pathways are able to prevent more than half of the loss of biodiversity that is projected to take place worldwide in the coming 35 years **(Figure 5.21)**.

The results highlight the importance of mainstreaming policy objectives concerning biodiversity across sectors and the need to take account of synergies and trade-offs between nature's contributions to people, in planning long-term solutions that lead to a halt in biodiversity loss while maintaining multiple contributions. For example, the agricultural sector was identified in all pathways as playing a critical role in contributing to biodiversity loss in forests, water bodies and coastal ecosystems. Increased use of bioenergy or hydropower resulting from climate change mitigation and adaptation policies may reduce the impacts of climate change on biodiversity in the coming decades, but is also projected to cause an expansion of agricultural lands and increased river fragmentation, which would in turn have detrimental impacts on biodiversity (PBL, 2012).

A further multi-model and expert assessment was carried out by Prins *et al.* (2017) for four pathways for the European Union plus Switzerland (28 countries) (van Zeijts *et al.*, 2017). These four pathways included:

- *Strengthening cultural identity*, closest to the *transition movements – resource sparing* pathway;

- *Allowing nature to find its way*, illustrating a *green economy – land sparing* pathway incorporating rewilding;

Box 5 11

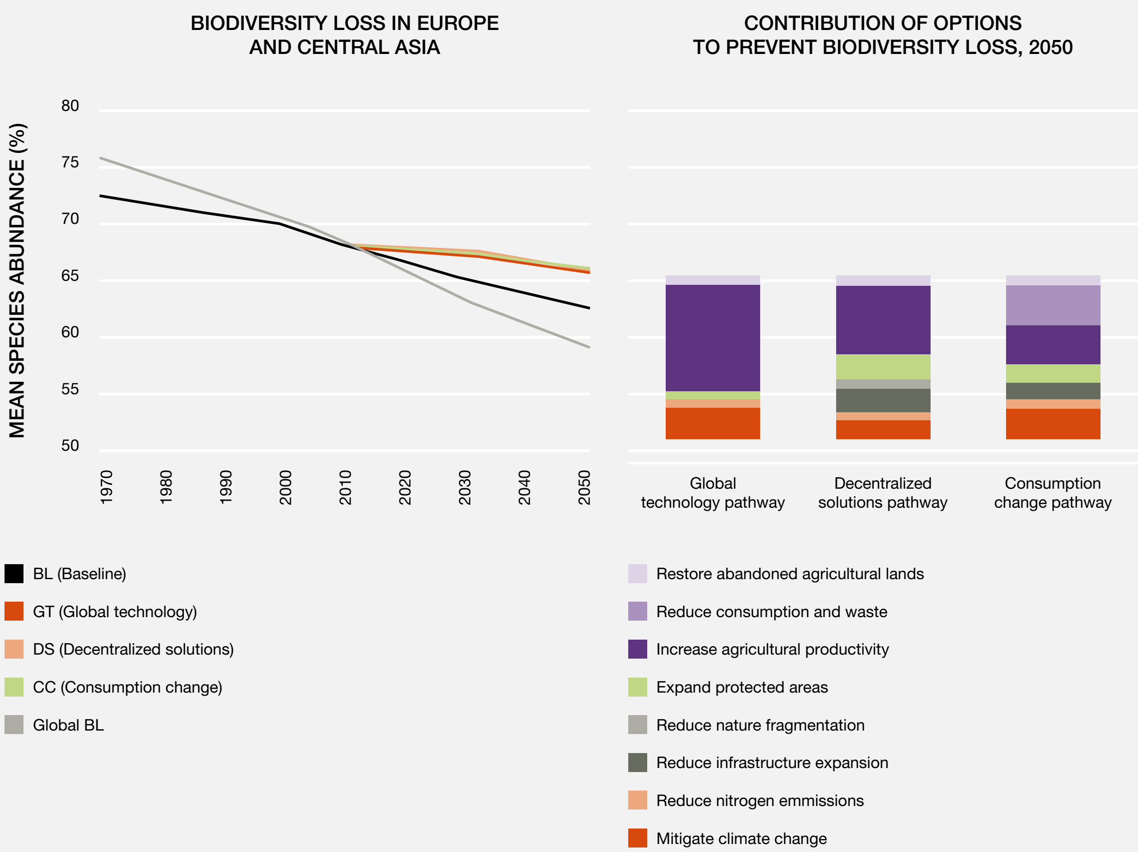
- *Going with the economic flow*, another *green economy – land sparing* pathway with a strong liberal component and elements of innovation; and

- *Working with nature*, a *green economy – land sharing* pathway, proposed as a possible means to bridge with and upscale *transition movements* pathways.

The analysis showed that some of the actions are fully compatible across pathways, particularly those associated with the conservation of cultural landscapes and the use of nature's regulating contributions to people in agriculture, which were included in *strengthening cultural identity, allowing nature to find its way* and *working with nature*. Conversely, some interventions were incompatible across pathways, such as the establishment of large dynamic nature areas in *allowing nature to find its way* with the land sharing approach of *strengthening cultural identity* and *working with nature*.

Nevertheless, some combinations of actions could lead to synergies given careful management. For example, agricultural abandonment of less productive land under *going with the economic flow* would provide the large nature areas envisioned in *allowing nature to find its way*, potentially resulting in a significant nature protection network given top-down planning and regulation. As another example, the private parks favoured in *going with the economic flow* could support cultural landscapes for *strengthening cultural identity* given negotiation on access and citizen participation. Overall, the exploration of these combinations using modelling and expert assessment highlighted how pathways reflecting different worldviews and objectives may be complementary across Europe and Central Asia.

Figure 5 21 **Ability of actions within three pathways (GT - *global technology*, DS - *decentralized solutions* and CC - *consumption change*) to prevent biodiversity loss in 2050 (as represented by mean species abundance) compared to a scenario of continuing trends (BL = baseline in Europe and Central Asia); Global BL = baseline for the globe and is included for comparison with the regional results for Europe and Central Asia. Source: PBL (2012).**



fully resolve the major trade-off between Goals 2 (food), 14 (oceans) and 15 (land) with Goals 7 (clean energy), 9 (industry and infrastructure), 10 (equity), 16 (justice) and 17 (global responsibility). Interestingly, the ability to achieve Goal 12 was found to vary independently of this trade-off, suggesting that pathways towards responsible production and consumption can be considered in combination with either the first (2, 14 and 15) or the second (7, 9, 10, 16 and 17) sets of goals.

Overall, *transition movements* pathways appear to be the most promising in achieving a wide range of Sustainable Development Goals and addressing trade-offs across biophysical, social and economic dimensions of sustainability. However, the actual effectiveness of the actions proposed by the different pathways in mitigating negative impacts and promoting positive impacts would need support from scenario and modelling studies (see next section and examples in **Box 5.11** and Kubiszewski *et al.*, 2017 described in Section 5.3.4).

5.5.5 Linking pathways to exploratory scenarios

An alternative method for assessing trade-offs within pathways is to link the pathways to one of the scenario archetypes introduced in Section 5.2, based on similar features in terms of the types of policy and management actions they represent. This allows the impacts on nature, its contributions to people and a good quality of life under the scenario archetypes (described in Section 5.3) to be related to the pathways. The synthesis is based on 15 pathways studies, which also used exploratory scenarios. Information from these 15 pathways studies was used to assign scenario archetypes to the four groups of pathway narratives.

The pathway narratives tended to be consistently associated with certain scenario archetypes. Overall, *innovation* or *land sparing* pathways from *low carbon transformation* and *green economy* narratives were associated with the *global sustainable development* scenario archetype (with a focus on behavioural and technological change or strong governments, see Section 5.3.3.5). Meanwhile, with few exceptions (Brunner *et al.*, 2015; Mont *et al.*, 2014), *green economy - land sharing*, *transition movements* or *ecotopian solutions* pathways were associated with the *regional sustainability* scenario archetype, with a strong predominance of collaborative solutions (see Section 5.3.3.4).

Impacts on nature, its contributions to people, and a good quality of life under the *global sustainable development* scenario archetype from Section 5.3.3.5 (and **Figure 5.10**) can be summarized as largely positive for all indicators of nature, its contributions to people, and quality of life. More specifically, nature indicators are projected to improve in all regions of Europe and Central Asia, except for some studies in southern and Alpine parts of Western Europe. In terms of nature's contributions to people, regulating (e.g. climate regulation, air quality regulation, erosion control and soil fertility) and material contributions (e.g. food and timber) are mainly projected to be enhanced, although negative impacts due to water stress may be experienced in southern parts of Western and Central Europe and in Central Asia. Similarly, most quality of life indicators improve, with the exception of traditional knowledge and local identity due to the global nature of this scenario archetype and the focus of actions on top-down regulatory instruments.

The *regional sustainability* scenario archetype is associated with similarly positive overall impacts for indicators of nature's contributions to people and quality of life, but impacts on nature are unclear with some studies showing improvements and others declines in biodiversity vulnerability. This may be because fewer modelling studies were found for this scenario archetype, with no studies from Central Asia. More specifically, all regulating contributions and quality of life indicators included in modelling studies showed improvements. Results for material contributions were more variable, with increases in forests/timber production and bioenergy, but mixed impacts for food production depending on the region and study.

To summarize, both scenario archetypes perform well in their likely achievement of many of the Aichi Biodiversity Targets and Sustainable Development Goals (Section 5.3.4; **Figure 5.15**). *Global sustainable development* (and hence the linked pathways of *green economy* and *low carbon transformation*) provide more consistent improvements in nature's material contributions to people, alongside regulating contributions, while *regional sustainability* (and hence the linked pathways of *transition movements*, *ecotopian solutions* and *green economy - land sharing*) provide more consistent improvement in quality of life indicators alongside regulating contributions, but sometimes through actions which result in lower material contributions.

5.5.6 Addressing trade-offs by mainstreaming and cross-scale integration

As discussed in Chapter 6, 20% of land- and seascapes are currently protected. Mainstreaming nature and its contributions to people across all sectors in private and public decision-making on the remaining 80% of land- and seascapes appears as one of the most important issues in the future (see also Bouwma *et al.*, 2018; Schleyer *et al.*, 2015). A need for mainstreaming was implicitly suggested by the pathways studies, as they were often developed for a single sector with a focus on a given narrative. Several alternative pathways often exist for the same sector. For example, for food and agriculture in Western, Central and Eastern Europe, three pathways were identified: *green economy - innovation* narrative (European Commission, 2015), *green economy - subregional land sharing* narrative (Food Drink Europe, 2012), and *transition movements* narrative (Barabanova *et al.*, 2015).

Likewise, *green economy* pathways for forestry at the scale of Western, Central and Eastern Europe may either be based primarily on innovation (Forest Europe, 2011) or on subregional multifunctionality (Forest Europe, 2011). The transition to sustainability of the water sector, a sector particularly critical for the Mediterranean or Eastern Europe and Central Asia, is also addressed by either global narratives of *green economy* with technical and governance innovation (Cosgrove & Rijsberman, 2014; UNESCO, 2015) or by a European *transition movements* narrative also relying on technical and governance innovation (van Vliet & Kok, 2015). Here, "Europe" refers to "Greater Europe reaching to the Caucasus and Ural Mountains, and including the Mediterranean rim countries of North Africa and the Near East".

A diversity of options from different pathways is seen as an asset for adaptation and sustainability transition (Wise *et al.*, 2014). Incorporating several alternative scenarios, which effectively represent alternative pathways to sustainability and specific Sustainable Development Goals, is considered essential for designing policy at the regional scale that considers alternatives depending on specific nations or biogeographic areas and on prevailing societal choices (Prins *et al.*, 2017).

For Western and Central Europe, the three alternative cross-sectoral pathways of the VOLANTE project (Brown *et al.*, 2016; Pedroli *et al.*, 2015) illustrate trade-offs across *green economy - land sparing* and *subregional land sharing* pathways, and a third ecotopian *local multifunctionality* narrative. For the food production sector, Barabanova *et al.* (2015) offer insights into policy and social trade-offs between a *green economy* narrative of technical innovation and a *transition movements* narrative of changed food and dietary patterns for implementing organic agriculture in the European Union. In particular, only the *transition movements* pathway fosters the integration of knowledge from different social and ethnic groups. As a local example, Palomo *et al.* (2011) also contrasted a *green economy* narrative of technical innovation with a *transition movements* narrative of transition capabilities in Spain. Both pathways enabled the reconciliation of food production, water management and tourism, but with contrasting approaches to whole landscape management (the protected area and the land surrounding it) and to the education and empowerment of local people.

Pathways may not need to be alternative, but could instead be sequenced over time. In sustainability transitions studies (Frantzeskaki *et al.*, 2012; Rotmans *et al.*, 2001), pathways usually start with incremental and often non-disruptive actions in the short-term, often tuned to adaptation rather than mitigation or transformation, such as those depicted in *green economy* and *low carbon transformation* narratives. These short-term actions do not challenge current worldviews or institutions but pave the way and condition the implementation of more radical, disruptive actions in the medium- and long-term (Butler *et al.*, 2014; Fazey *et al.*, 2015; Wise *et al.*, 2014), such as those imagined in *transition movements* or *ecotopian solutions* narratives, and in visions of societal transformations towards sustainability. This view is also consistent with the concept of "seeds" of transformation, where early local transformation may later be scaled-up to regions and globally (Bennett *et al.*, 2016).

Many of the trade-offs highlighted by this analysis straddle across socio-economic sectors. Cross-sectoral mainstreaming and cross-scale integration is seen as a means to mitigate trade-offs within pathways and across scales. Across the different regions of Europe and Central Asia, the overwhelming majority of pathways referred to at least potential, cross-sectoral interactions, irrespective of their initial sectoral focus. The concept of the food-water-energy nexus, that is the multiple interactions (synergies and trade-offs) between food, water and energy provisioning, demand and access, and their environmental and social determinants, is core to many pathways. Other critical cross-sectoral interactions concern integration across productive land uses, tourism, education, planning and nature conservation, or the consideration of how human activities affect freshwater and coastal waters. A specific idea found in the context of innovation pathways for the *green economy* narrative, is the notion of bioeconomy landscapes, which rely on cross-sectoral networks of scientific, technological and managerial excellence (van Zeijts *et al.*, 2017). Pathways within the *transition movements* narrative focus particularly strongly on the integration of multiple dimensions of governance, technology, economy and society. In addition to these cross-sectoral interactions within individual pathways, there is great scope for mainstreaming (not just interactions) by, in future steps, integrating pathways formulated for different sectors.

Likewise, cross-scale integration, whether across adjacent scales, or across the whole range of scales from local to subnational, national, regional and in some instances to global (e.g. for energy / climate or food systems), is a strong common feature of most proposed sustainability pathways, with the exception of some *ecotopian solutions*. Verkerk *et al.* (2016) found that, under the available policy options and modelling constraints, local multifunctionality was not feasible across the whole of the European Union, even if successful for some areas due to spatial trade-offs and spill-over effects, as highlighted in Section 5.5.2. In contrast, *transition movements* pathways aim at integration with larger scales, especially in terms of governance. For example, the global Greenpeace (2009) pathway includes both actions at the local scale (use of agroecology) and actions at the larger scale (protection of areas with high conservation value – globally and regionally), thus combining land sharing and land sparing approaches in a *transition movements* narrative. While mainstreaming from local "green pioneers" solutions to a green society as a whole remains a great challenge, pathways for such spatial integration (scaling-up) are now starting to be imagined (van Zeijts *et al.*, 2017). Bennett *et al.* (2016) suggest in particular to use combinations of exemplary transition movement "seeds" in large-scale (e.g. global) scenarios, as well as in local participatory scenarios.

5.6 CONCLUSIONS

5.6.1 Overall synthesis

Chapter 5 focuses on the future interdependencies between nature and society. It asks to what extent findings from reviewed literature can establish future interactions between indirect drivers (such as human population change, economic or foreign policy), direct drivers (such as land use patterns or climate change), nature, its contributions to people, and a good quality of life. Each of these interactions represents a complex set of interrelationships. Scenarios and models are useful tools for advancing understanding of these interrelationships and how they might change in the future.

Four linked assessments on exploratory scenarios, integrated assessment models, visions of sustainable development, and pathways or normative scenarios for achieving such visions were undertaken to better comprehend what might happen to nature, its contributions to people, and a good quality of life in the future, and the actions decision-makers can take to move away from undesirable futures towards more sustainable futures.

The assessment of exploratory scenarios revealed that existing scenario studies for Europe and Central Asia can be categorized into six broad scenario archetypes, which describe different plausible futures for the region:

- *Business-as-usual* assumes that the future will be characterized by a continuation of past and current trends in indirect and direct drivers.
- *Economic optimism* assumes that global developments are steered by economic growth resulting in a strong dominance of international markets with a small degree of regulation. Environmental problems are only dealt with when solutions are of economic interest.
- *Regional competition* assumes an increasingly fragmented world with a growing gap between rich and poor, and increasing problems with crime, violence and terrorism. This leads to a strong focus on national or regional security, increased trade and other barriers to cooperation, and often low concern for the environment.
- *Regional sustainability* assumes a shift towards local and regional decision-making, which is strongly influenced by environmentally aware citizens. A proactive attitude to environmental management prevails, but poor international collaboration obstructs coordination to solve global environmental issues.
- *Global sustainable development* assumes a globalized world with an increasingly proactive attitude of policymakers and the public at large towards environmental issues, which are dealt with using a high level of top-down regulation.
- *Inequality* assumes fundamental and growing economic, political and social inequalities with power becoming concentrated in a relatively small political and business elite that takes environmental responsibility, while keeping the large lower-class poor, but satisfied.

Impacts on nature, its contributions to people, and a good quality of life within each of these plausible futures, as simulated by integrated assessment models, are summarized in **Table 5.6**. This provides a broad indication of whether impacts, on average, are positive, negative or mixed. More positive impacts are projected under futures that assume proactive decision-making on environmental issues, such as the *global sustainable development* and *regional sustainability* scenario archetypes, than those that are reactive, such as *economic optimism*, *regional competition* and *business-as-usual*. The two *sustainability* scenario archetypes also promote a more holistic approach to managing human and environmental systems, which supports multifunctionality and multiple contributions from nature to people. Alternatively, the *economic optimism* scenario archetype tends to promote a more limited number of services, particularly material contributions such as agricultural and timber production resulting in strong positive effects in market values and negative effects in non-market values. Such scenarios are often associated with trade-offs between increases in food provision (generally associated with the expansion of agricultural land or the intensification of livestock production and fish captures) and decreases in the provision of regulating contributions (e.g. prevention of soil erosion, regulation of water quality and quantity) and nature values. Similar trade-offs were also identified between increases in timber provision and decreases in regulating (e.g. carbon sequestration) and non-material contributions (e.g. aesthetic value).

Trade-offs were also apparent under the sustainability scenario archetypes, particularly under *regional sustainability*, where society chooses to live less resource-intensive lifestyles and hence nature's material contributions to people, tend to decrease, while nature and regulating contributions increase. Most of the trade-offs projected in the sustainability scenarios relate to the use of land and water. These included: (i) agricultural extensification leading to increases in agricultural areas and consequent decreases in other land uses, such as forests, to maintain food production levels and not to create displacement effects to other regions; (ii) expansion of bioenergy croplands at the expense of food production or biodiversity-rich forests; (iii) and reforestation or afforestation to improve climate regulation or natural hazard regulation resulting in reductions in surface water resources, leading to water stress and potentially detrimental effects on aquatic ecosystems (although it is also recognized that in some circumstances reafforestation can lead to improved water resources). In tackling such trade-offs to develop sustainable land and water management strategies, cooperation between sectors and countries to foster strategic planning was considered crucial, as characterized as part of the *global sustainable development* scenario archetype.

Interpretation of these broad findings for decision-making should bear in mind that scenario and modelling studies are projections of the future and involve different sources of uncertainties. These include uncertainties arising from scenario assumptions, model structure, model inputs and the propagation of uncertainties across the integrated components of the systems, amongst others.

The reviews of visions and pathways of sustainable development aimed to synthesize knowledge on the actions decision-makers can take to move away from undesirable futures, such as *regional competition*, towards more sustainable futures, such as *regional sustainability*. Many visions, and the pathways to achieve them, have been developed for policy support and can be linked to the Millennium Development Goals, Sustainable Development Goals or Aichi Biodiversity Targets. However, the Sustainable Development Goals tend to be more consistently covered, relative to the Aichi Biodiversity Targets, suggesting that the strong focus on elements of good quality of life in visions is not sufficiently supported by goals related to the nature and ecosystems that underpin nature's contributions to people and a good quality of life. This implies a need to further mainstream biodiversity in its various dimensions into strategic planning and decision-making.

Multiple pathways were found at global, regional and local scales that offer the means to devise courses of actions towards visions of sustainable development. The pathways could be grouped into four distinctive sustainability narratives: *green economy*, *low carbon transformation*, *transition movements* and *ecotopian solutions*. The *green economy* and *low carbon transformation* narratives, which dominate at global and regional scales, build towards sustainability without challenging the economic growth paradigm. They share three alternative pathways: *technological innovation*, *land sparing* with strong nature protection in designated areas, or *land sharing* with lower use intensity and diversification of production of nature's contributions to people. Combinations of top-down legal and regulatory instruments mixed with economic and financial instruments designed at regional (European Union) or national levels (Eastern Europe and Central Asia) are essential to support pathways of *green economy* and *low carbon transformation*. Such pathways are often formulated

Table 5 6 **Traffic light summary of projected impacts on nature, its contributions to people, and good quality of life indicators (green = positive, red = negative, amber = mixed). Source: Own representation.**

Note: interpretation is based on the detailed description of model results in Section 5.3.3. Only two studies are available for the inequality scenario archetype, so results are highly uncertain and missing for non-material contributions and good quality of life indicators.

Scenario archetype	Nature	Nature's contributions to people			Good quality of life
		Regulating	Material	Non-material	
Business-as-usual					
Economic optimism					
Regional competition					
Regional sustainability					
Global sustainable development					
Inequality					

at a sectoral level, and integration across sectoral pathways is critical. However, because *green economy* and *low carbon transformation* pathways do not fully mitigate trade-offs between production activities and the conservation of nature and regulating and non-material contributions, as well as with important aspects of good quality of life, such as equity and indigenous and local knowledge, they may not be sufficient alone to achieve sustainability.

Instead, they may pave the way for the first steps of *transition movements* pathways towards future transformation to meet ambitious goals for nature and its contributions to people, to support better quality of life. At the same time, nurturing of diverse local, bottom-up *transition movements* or *ecotopian solutions* pathways is suggested. Such pathways reconsider fundamental values and lifestyles through sets of actions focusing on less resource intensive lifestyles, education, good social relations and equity (e.g. food and dietary patterns, transport, energy and consumption patterns). *Transition movements* pathways also develop bottom-up transformative capabilities by combining rights-based instruments and customary norms (including indigenous and local knowledge) and social and cultural instruments. So far, innovative thinking for bridging scientifically and institutionally from these local, bottom-up and sectoral options, to systemic, regional and global solutions remains limited. The incorporation of combinations of exemplary transition pathways into large-scale scenario exercises and into participatory scenario development has been suggested as a way forward.

The last step in this synthesis section presents a combined analysis of the results from the scenario archetypes and pathways assessments. The extent to which policy goals and targets, such as the Sustainable Development Goals and Aichi Biodiversity Targets, are likely to be achieved under the different scenario archetypes, and the extent to which the pathway narratives are likely to influence the achievement of the Sustainable Development Goals (although not necessarily in line with their timeframe of 2030) is summarized in **Table 5.7**. *Regional competition* is estimated to lead to failure in the majority of the targets. *Economic optimism* is estimated to have a mixed level of success in achieving the Sustainable Development Goals, but fails to achieve the majority of the Aichi Biodiversity Targets, while *business-as-usual* shows the opposite effect. These scenarios focus on instrumental values and individualistic perspectives, with a more limited acknowledgement of relational or intrinsic values, and hence are unlikely to offer effective sustainable solutions. Alternatively, *regional sustainability* and *global sustainable development* are estimated to achieve the majority of Sustainable Development Goals and Aichi Biodiversity Targets due to their focus on value diversity across multiple contributions from nature to people, and aspects of a good quality of life.

Table 5 7 **Traffic light summary of the estimated extent to which the Aichi Biodiversity Targets (ABTs) and Sustainable Development Goals (SDGs) are likely to be met under the six scenario archetypes for Europe and Central Asia (based on Section 5.3.4), and the relative effect of the actions in the pathway narratives on helping to reach the Goals (based on Section 5.5.4). Source: Own representation.**

Left: red = widespread failure in the achievement of policy targets; green = widespread achievement of targets; amber = mixed achievement of targets. Right: darker shades of green indicate a greater degree of influence of actions within pathways on achieving the Sustainable Development Goals (note that here all three dimensions of sustainability, biophysical, economic and social are given equal weights, i.e. the balance across dimensions addressed in Section 5.5.4.3 is not considered). Linkages between the scenario archetypes and pathway narratives are indicated through colour coding of text (see Section 5.5.5). Note: the scenarios and pathways concern different time frames to the Aichi Biodiversity Targets and Sustainable Development Goals.

Scenario archetype	ABTs	SDGs
Regional competition		
Business-as-usual		
Inequality		
Economic optimism		
Global sustainable development		
Regional sustainability		

Pathway narratives	SDGs
Transition movements – resource sparing	
Transition movements – collaboration	
Green economy – land sharing	
Low carbon – innovation	
Green economy – innovation	
Low carbon – regional multifunctionality	
Ecotopian – innovation	
Ecotopian – local multifunctionality	
Green Economy – land sparing	

Transition movement pathways address all of the Sustainable Development Goals identified as being important in the Europe and Central Asia visions (Section 5.1.2 and 5.5.4), except one, because they offer the broadest set of actions targeting elements of nature, multiple contributions from nature to people (material, regulating and non-material) and multiple dimensions of a good quality of life. The other pathways include actions that focus on specific Sustainable Development Goals more than others. For example, the *green economy – land sharing* and the *ecotopian solutions - local multifunctionality* pathways have a strong focus on nature and intrinsic values, the *green economy – innovation* pathway has a greater focus on instrumental values, while the two *low carbon transformation* pathways and the *ecotopian solutions - innovation* pathway have a weaker focus on intrinsic values, but address relational values to a greater extent than other pathways (albeit with a similar level to the *transition movements* pathways).

In summary, the different pathway narratives offer alternative sets of actions for decision-makers (see Section 5.5.2) that can be tailored according to regional needs and societal preferences. The pathways are non-exclusive and the actions within them can be sequenced over time to address environmental and social challenges, including cross-sector and cross-scale interactions and trade-offs, and to move society towards a sustainable future. Chapter 6, and more specifically Section 6.6, provides further detailed information on policy options to realize the sustainable futures laid out in Chapter 5.

5.6.2 Knowledge gaps and uncertainties

In this section, the knowledge gaps and uncertainties that appeared across all the sections of Chapter 5 are first listed followed by knowledge gaps specific to the assessments undertaken within each section.

Knowledge gaps and uncertainties across all sections of the chapter:

- The assessment of how findings from the different reviews related to policy goals or targets similar to the Sustainable Development Goals and Aichi Biodiversity Targets was mostly based on the expert judgement of the author team, as most documents reviewed did not explicitly include links to these goals or targets. The absence of direct links to these international goals in reviewed documents is related, on the one hand, to the fact that scenarios usually deal with time horizons going beyond 2020 and even 2030. Furthermore, most studies were published before the Sustainable Development Goals were adopted and naturally did not include the goals. Moreover, the partial coverage of the full set of these international goals is related to their regional prioritization and reflects the dominant regional values. Lastly, our primary focus on studies targeting at least nature and its contributions to people meant that other strategic documents focusing on good quality of life with only loose links to nature were not considered.

- All reviews reveal knowledge and information gaps for Central Asia and, to a lesser extent, for Eastern Europe. In general, higher uncertainties in outcomes are expected from regions where evidence is based on very few studies. There is a high diversity in the complexity and degree of integration reflected in the four reviews, which is explored further below.

- Studies which explicitly covered indigenous and local knowledge were largely unrepresented in all the reviews. This is related to the focus of some of the reviews on the national scale or higher. Yet, while indigenous and local knowledge was often not included explicitly, a range of studies, particularly in the visions and pathways review, were developed together with stakeholders and revealed valuable insights into nature's non-material contributions to people and relational values. This confirms the suggestion made by the IPBES "Guide on the production and integration of assessments from and across all scales" (IPBES/4/INF/9) as well as in the IPBES Methodological Assessment of Scenarios and Models of Biodiversity and Ecosystem Services (IPBES, 2016b), where participatory scenario development and modelling are recommended as powerful approaches for knowledge co-production and the inclusion of indigenous and local knowledge. The development of new scenarios for IPBES (Rosa *et al.*, 2017) will open up opportunities for such approaches and work towards the appropriate inclusion of indigenous and local knowledge in future assessments.

- The coverage of nature's non-material contributions to people, and quality of life indicators was poor in most scenario and modelling studies and they were absent from, or limited to, recreational benefits in most visions and pathways studies.

- Studies covering the marine realm were poorly represented, and almost absent from visions and pathways. Consequently, very few results and conclusions on associated ecosystems can be provided.

- The analysis of how values were included in the exploratory scenario and normative scenario (or pathways) literature showed that some dimensions of value (i.e. intrinsic values) were not considered by the majority of futures studies. This highlights a significant gap in the current literature in recognizing the diversity of values where most studies predominantly focus on anthropocentric values (i.e. instrumental). Furthermore, socio-cultural approaches to valuation were used to a much lesser extent than biophysical or economic methods.

In the following, knowledge gaps and uncertainties for each of the individual reviews are highlighted:

The review on exploratory scenarios revealed that the indirect drivers of institutional change, cultural change and technology were rarely explicitly included within scenario analyses, but frequently subsumed within common socio-economic storylines (i.e. IPCC SRES, SSPs). Only limited aspects of these driver categories were addressed by the studies, for example efficiency of governance, level of international collaboration and proactivity of environmental management among institutional drivers; diet, material and meat consumption and environmental awareness among cultural drivers; and agricultural efficiency among technological drivers. Given the frequent presence of technology, cultural and governance drivers within qualitative storylines, we hypothesize that the relative absence of explicitly quantified technology and governance drivers is due to the complexities involved in parameterizing such uncertain drivers for inclusion in models. Economic drivers were frequently parametrized through increasingly questioned indicators, such as GDP.

The direct drivers of pollution and invasive alien species also had limited coverage in exploratory scenarios compared to other direct drivers, such as climate change and land use change. Among pollution drivers, only nutrient emissions from agriculture were covered more frequently. Biological invasions were addressed only generally in most cases, assuming high or low levels of invasive alien species, without specific assumptions regarding individual species.

The review of integrated models revealed that integrated studies which attempt to capture some of the complex interdependencies between human and environmental systems under multiple drivers of change are rare, particularly for Eastern Europe and Central Asia. Furthermore, they are often limited in the different social and ecological components that are coupled and the feedbacks between them that are represented. Few studies specifically focus on nature and its contributions to people, although such aspects can be included as part of a model chain or by linking the output of integrated models to biodiversity or ecosystem service models. This is a key priority for future work to quantify impacts on nature, its contributions to people, and good quality of life indicators under both exploratory and normative scenarios (or pathways), including the uncertainties associated with such model projections. Moreover, integrated models that accounted for nature's non-material contributions and aspects of a good quality of life were rare, and the few that were found used simplified expert-based approaches for representing the interrelationships. Few integrated modelling approaches have been benchmarked or inter-compared to fully capture and quantify uncertainties from different approaches. There is a significant gap in integrated assessments in terms of exploring the full range of synergies and trade-offs between the multiple aspects of nature, its contributions to people, and a good quality of life under different scenario archetypes and across different scales.

Furthermore, nature is not a simple unit. Rather, any change in drivers will likely favour some dimension of biodiversity (i.e. some species, variants, combinations of species that produce a given ecological function) at the expense of others. As a result, nature is rarely included as a dependent variable in scenarios. However, according to the IPBES conceptual framework, knowledge on the responses of various facets of nature to various direct and indirect drivers, and on the effects of changes in nature on changes in its contributions to people, would be crucial. Moreover, the multifaceted character of biodiversity may also explain why integrated models struggle to capture detailed impacts on biodiversity (many use simple indicators, such as mean species abundance or biodiversity vulnerability indices). Coupling more sophisticated (process-based rather than statistical) models of biodiversity and ecosystem functioning with models of human processes within integrated assessment models would provide a more realistic assessment of the trade-offs between nature and other indicators of socio-ecological systems. Despite these drawbacks, integrated modelling approaches offer great promise in capturing some of the important interrelationships in complex systems which are key to understanding the impacts of drivers on nature, its contributions to people, and a good quality of life.

The visions literature search yielded only a limited number of regional visions, with a small number of visions from the scientific literature. For Western, Central and Eastern Europe, visions have already been developed by different stakeholder groups and for several activity sectors. In Central Asia, however, future planning is only covered by the strategic plans developed by governmental agencies. Thematic gaps, for which societal visions have not been found, include marine ecosystems and urban systems at the broad regional scale. The level of development of visions was very heterogeneous (from a single paragraph to detailed descriptions of vision components), and most lacked quantitative goals providing only qualitative orientating goals. Moreover, reviewed visions did not explicitly include a diverse range of values in their narratives. Visions can also be "stakeholder-specific" with different societal groups having different (and potentially conflicting) visions of the future. Visioning processes which rationalize or accommodate these different viewpoints in their analysis are rare, although cross-sectoral visions involving multiple stakeholders were found.

Environmental goals within visions were mostly related to the need to reduce or avoid environmental impacts derived from human activity or in the context of nature's contributions to people. The underpinning role of nature and ecosystems in the delivery of these contributions and the maintenance of good quality of life was often missed. Finally, the analysis of visions content suggests that interregional flows are being overlooked, which could result in an aggravation of global inequalities.

The pathways review found that there are very few fully developed pathways studies that go beyond narrative presentations of pathways and are supported by quantitative modelling. Nevertheless, well-developed narrative approaches may be just as valuable (if sometimes not more so) for empowering decision-makers and stakeholders, but this makes results more difficult to link with exploratory scenarios and formal analyses of specific drivers (i.e. analytical approaches) using quantitative modelling approaches. In addition, this lack of quantitative analysis means that pathway narratives express intent rather than feasibility, and that some trade-offs may be underestimated. Many pathways studies addressed trade-offs between nature's material contributions to people (food, timber, fisheries) and water provisioning and quality, global climate regulation and biodiversity conservation. However, consideration of biotic regulation services (e.g. pollination, pest control), natural hazard protection and non-material contributions were largely absent from trade-off analyses. Detailed descriptions and sequencing of actions within pathways was rare, as was information on combinations of policy instruments for implementing specific actions. With the notable exception of *transition movements* narratives, pathways to sustainability focused on very few dimensions of a good quality of life. The incorporation of combinations of exemplary *transition movements* pathways into large-scale scenario exercises and into participatory scenario development is suggested as a way forward for better resolving trade-offs and for scaling-up local or sectoral solutions. Furthermore, while investments were mentioned in a number of studies across the chapter, none of them provided systematic research to appropriately respond to the role of investments in the protection of ecosystems.

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CHAPTER 6

OPTIONS FOR GOVERNANCE AND DECISION-MAKING ACROSS SCALES AND SECTORS

Coordinating Lead Authors:

Irene Ring (Germany), Camilla Sandström (Sweden)

Lead Authors:

Sevil Acar (Turkey), Malkhaz Adeishvili (Georgia), Christian Albert (Germany), Christina Allard (Sweden), Yaakov Anker (Israel), Raphaël Arlettaz (Switzerland), Györgyi Bela (Hungary), Ben ten Brink (The Netherlands), Anke Fischer (Germany/United Kingdom of Great Britain and Northern Ireland), Christine Fürst (Germany), Bella Galil (Israel), Stephen Hynes (Ireland), Ulan Kasymov (Kyrgyzstan), Cristina Marta-Pedroso (Portugal), Ana Mendes (Portugal), Ulf Molau (Sweden), Roland Olschewski (Germany/Switzerland), Jan Pergl (Czech Republic), Riccardo Simoncini (Italy)

Fellow:

Luca Coscieme (Italy/Ireland)

Contributing Authors:

Çiğdem Adem (Turkey), Kirsty Blackstock (United Kingdom of Great Britain and Northern Ireland), Jennifer Hauck (Germany), Johanna Johansson (Sweden), Caroline Lasson (Germany), Natalya Minchenko (Belarus), Elsa Reimerson (Sweden), Martin Schläpfer (Switzerland), Eugene A. Simonov (Russian Federation), Mark Snethlage (The Netherlands/Switzerland), Johanna Söderasp (Sweden)

Review Editors:

Susan Baker (Ireland/United Kingdom of Great Britain and Northern Ireland), Piotr Matczak (Poland), Eeva Primmer (Finland)

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EXECUTIVE SUMMARY

Mainstreaming the conservation and sustainable use of biodiversity and the sustained provision of nature's contributions to people into all sectoral policies, plans, programmes, strategies and practices could be achieved with more proactive, focused and goal-oriented approaches to environmental action (*well established*) (6.1, 6.3, 6.4, 6.5, 6.6). Key steps of mainstreaming include awareness raising, defining policy objectives as well as designing appropriate policy instruments and policy mixes (6.6, Table 6.11). Mainstreaming of biodiversity is one of the major goals of international, regional and national biodiversity strategies through clear and measurable objectives such as the Aichi Biodiversity Targets and relevant Sustainable Development Goals (6.1, 6.3, 6.4.1). Partial progress has been made towards mainstreaming biodiversity, and nature's contributions to people as well as tackling the underlying drivers of biodiversity loss, by setting up, reviewing and updating biodiversity strategies and action plans at multiple levels. Nevertheless, substantial efforts to effectively implement existing legislation, and additional commitments to improve on the current situation, are required to halt biodiversity loss and further ecosystem degradation (6.3, 6.4.1). Mainstreaming biodiversity is essential for environmental policies (6.4.2), but even more so for economic sectors and business actors depending on, or influencing, biodiversity (6.4.1, 6.5, 6.6, **Table 6.10**, **Table 6.11**), such as agriculture (6.5.1), forestry (6.5.2), fisheries (6.5.3), energy and mining, manufacturing (6.5.4) and services sectors (6.5.5). Opportunities to more successfully mainstream biodiversity and nature's contributions to people, in public as well as private policy and decision-making, can be harnessed through three key steps (6.6, 6.6.1, **Figure 6.13**, **Table 6.11**): first, raising awareness of the dependence of good quality of life on nature, enhancing capacity-building and strengthening participation of affected actors in decision processes; second, defining policy objectives concerning the ecological, economic and socio-cultural needs for achieving sustainable living, taking account of the diverse values of nature for different stakeholder groups; and third, designing instruments and policy mixes to support the implementation of effective, efficient and equitable policy- and decision-making for nature and a good quality of life.

Developing integrated approaches across sectors would enable more systematic consideration of biodiversity and nature´s contribution to people by public and private decision-makers (*well established*) (6.1, 6.2, 6.4, 6.5, 6.6, 6.6.4.1, Figure 6.2). This includes further options to measure national welfare beyond current economic indicators, taking account of the diverse values of nature (6.6.3.1). Ecological fiscal reforms would provide an integrated set of incentives to support the shift to sustainable development (*established but incomplete*) (6.4.1, 6.4.2, 6.6.2). Conventional sectoral approaches are insufficient to tackle interlinked environmental, economic and social challenges. Actions in one sector may affect other sectors because policy design, instrument choice, or policy implementation rarely consider trade-offs (6.2, 6.4.1, 6.4.2, 6.6, 6.6.4.1, 6.6.4.2, **Box 6.1**, **Box 6.9**). Without coordination between, and sustainable management practices within, sectors, there is evidence that agriculture, forestry, fisheries, mining, energy, manufacturing and the services sector may exert negative impacts on biodiversity, on nature's contributions to people and on the livelihoods of indigenous peoples and local communities (6.4.2, 6.5.1-6.5.5, 6.6.4.1, **Table 6.6**). Taking individual sectors as an example, a mismatch has been detected between the low degree of forest sector integration with other policy sectors on the one hand, and on the other its high potential to contribute to policy integration (6.5.2.3). In Western Europe, multiple formal and informal institutions work against a societal transition to a low carbon economy in the European Union (6.4.2). Similarly, in Central Asia, the combination of harmful subsidies and low energy and water prices that do not take into account the "polluter-pays" principle, and environmental standards based on outdated technology, may counteract general government priorities such as resource efficiency and promotion of renewable energy (6.6.4). Policies only targeting supply security and growth in the manufacturing, mining and energy sectors may come at the expense of biodiversity and nature's contributions to people, if they lack sufficient integration in wider policy agendas (6.5.4). With regard to economy-wide policy integration, reflecting the real

changes in the diverse values of nature's contributions to people in national income accounts is one option to provide better information and help to mitigate trade-offs (6.6.3.1). Another option would be complementing national income accounts with satellite accounts containing information on the costs of ecosystem degradation. Ecological fiscal reform that creates an integrated set of incentives by redirecting taxation from labour to environment, including ecological indicators in intergovernmental fiscal relations and by greening public expenditure programmes, could support the shift to sustainable development (6.4.1, 6.4.2, 6.6.2). While recognizing and promoting synergies and solutions to the extent possible through policy integration, dealing with trade-off decisions will probably remain the rule rather than the exception (6.6.4). Conflicting policy goals between different sectors may lead to conflicting roles of instruments, and thus to trade-offs between biodiversity and the delivery of nature's contributions to people. Designing, implementing and assessing instruments in relation to their role in the overall policy mix would help to mitigate conflicting policy goals and trade-offs (6.2, 6.4.1, 6.5.5, 6.6.1, 6.6.2, 6.6.4.1, 6.6.5.5, **Box 6.1**). The use of proactive strategies, tools and methodologies to account for diverse values and criteria, and of participatory processes can support trade-off analyses and facilitate policy integration (6.4.1, 6.4.2, 6.6.4, 6.6.5).

Legal and regulatory instruments are the backbone of policy mixes and are necessary to promote the conservation, restoration and sustainable use of biodiversity as well as fair ecosystem governance for the long-term maintenance of ecosystems and for good quality of life (*well established*) (6.2, 6.3, 6.4, 6.5, 6.6, 6.6.5.1, Table 6.5, Table 6.11). Formal instruments such as laws, regulations, standards and planning instruments usually set the basic framework for other policy instruments to function (6.2, 6.3, 6.4.1, 6.4.2, 6.6.5, **Table 6.2**, **Table 6.6**, **Table 6.9**). They work through command and control, representing binding rules for governments, businesses, land users and citizens. These formal instruments are increasingly complemented by informal instruments. Ratifying and implementing international treaties and transboundary agreements provides a strong impetus for improving national and subnational policies in all sectors (6.3). For example, effective implementation of the Natura 2000 network in the European Union, as well as the Emerald Network as its extension to non-European Union countries and the Pan-European Ecological Network, help considerably to meet conservation objectives under international law. Marine protected areas, however, need more attention (6.4.1). For freshwater ecosystems, the European Union Water Framework Directive is of particular importance for achieving a good status for surface and groundwater (6.3.2.3, 6.4.2, 6.5.1, 6.5.2, 6.5.3, 6.5.4, 6.6.3, 6.6.5.5), although integration and implementation of such novel governance approaches often remain incomplete, and ineffective when member States retain existing structures and procedures without transferring responsibilities and power to the river basin authorities (6.4.2). Similar structures have been developed in non-European Union countries, such as Ukraine, which share river basins with European Union countries (6.4.2). Targeted spatial and urban planning integrated across sectors and scales can support the conservation of biodiversity and nature's contributions to people. Such planning helps to safeguard sensitive areas, improve the state of ecosystems, minimize current and potential future impacts, as well as to identify synergistic land-use options. Urban planning has particular responsibility in ensuring biodiversity conservation and the delivery of nature's contributions to people today and in the future, and in enhancing the quality of life of an increasing number of urban dwellers (6.6.4.2). Planning informed by biodiversity and nature's contributions to people can facilitate public participation and stewardship and provide the basis for targeted investments in nature's contributions to people, for example by designating specific areas for results-oriented agri-environmental measures (6.6.4.2). Although regulatory instruments are the backbone of policy mixes, one key factor constraining the effectiveness of existing environmental governance arrangements is limited enforcement due, for example, to lack of institutional capacities and financial means, or corruption (6.3.1, 6.4.1, 6.4.2).

Economic and financial instruments complement regulatory and other policy instruments by balancing conservation benefits and costs between actors and regions (*well established*) (6.2, 6.3, 6.4, 6.5, 6.6). Improving existing policies and developing and implementing new policies could help to avoid biodiversity loss and ecosystem degradation (*established but incomplete*) (6.2, 6.4.1, 6.4.2, 6.5, 6.6.2, 6.6.5.2, Table 6.5, Table 6.6, Table 6.11). Economic and financial instruments include a wide range of designs and implementation approaches, both traditional and new **(Table 6.2)**. Since markets undervalue nature's contributions to people, economic and financial instruments aim to change the behaviour of businesses, land users, citizens and public-sector actors, through incentives and disincentives to correct price signals. Environmental taxes, charges and fees make environmental pollution and habitat degradation more expensive, thereby making the polluter pay, whereas payments for ecosystem services or compensation payments reward conservation-friendly behaviour that is otherwise not profitable or affordable (6.4.1, 6.4.2, 6.6.5.2). Reforming environmentally harmful subsidies in sectors that negatively affect ecosystems (e.g., agriculture, fisheries, energy) would support more cost-effective use of public funds in reaching conservation objectives. Innovative economic and financial instruments include biodiversity offsets and habitat banking, tax reliefs, ecological fiscal transfers and integrated funding for biodiversity and climate change adaptation (6.4.1, 6.4.2, 6.5.1-6.5.5, 6.6.2, 6.6.3.2, 6.6.5.2). However, economic and financial instruments are context dependent and sometimes contested, as different actors hold different norms and values towards monetary incentives and towards using markets to achieve environmental and conservation goals (6.2, 6.4.1, 6.4.2, 6.6.2, 6.6.5.2). Economic and financial instruments are more effective if customized to relevant scales, from global to national and local conditions in achieving conservation targets, while considering social impacts (6.2, 6.4, 6.6.2, 6.6.5). These instruments need, therefore, to be implemented with caution as they can have unintended social consequences and can also be detrimental to efforts to maintain and restore biodiversity and nature's contributions to people, for example when promoting intensification of agricultural and forest land use.

Social and information-based policy instruments have attracted significant interest in many policy sectors due to their capacity to integrate environmental concerns and trigger behavioural change at the local, national and international levels, and to include consumers and producers in policy development (*established but incomplete*) (6.2, 6.3, 6.4, 6.5, 6.6.5.3, Table 6.5, Table 6.11). If social and information-based instruments, such as voluntary market standards or social and environmental reporting, are to operate effectively as tools for conservation of biodiversity, sustained delivery of nature's contributions to people and poverty reduction, they have to be paired with the development of capacity-building and compliance mechanisms (6.4.2). Enhanced consumer awareness, media coverage, business commitment and sustainable government procurement have increased the market shares of certified products (6.6.5.3). Progress with certification is more advanced in countries with developed market economies and less so in countries in economic transition **(Table 6.11)**. Owing to the lack of compliance mechanisms and clearly assigned responsibilities, there is a trade-off between the effectiveness of certification schemes and their accountability and impact. Efforts to change social norms through education and information-based campaigns promoting pro-environment behaviour have also been important (6.2, 6.4.1, 6.4.2.3, 6.5.1.2, 6.5.2-6.5.5, 6.6.5.3).

Rights-based instruments and customary norms are increasingly supported and promoted by a wide range of multilateral environmental agreements, human rights and rights of indigenous peoples and local communities (*established but incomplete*) (6.2, 6.3, 6.3.2.5, 6.3.2.6, 6.4, 6.5, 6.6, 6.6.5.4, Table 6.11). Those instruments integrate rights, norms, standards, and principles into policy, planning, implementation and evaluation, and offer ways to reconcile biodiversity conservation and human rights standards (6.2, **Table 6.2**). While decisions by multilateral environmental agreements are implemented at the national level, the recognition of human rights, and in particular indigenous rights, in relation to conservation varies considerably between countries in Europe and Central Asia **(Table 6.11)**. Further efforts would be needed, therefore, to develop better rights-based approaches to fully integrate the fundamental principles of good governance, equalizing power relations, and facilitating capacity building. Examples of such development can be seen in the governance trend emerging within the mining sector where traditional governance modes to mining are no longer sufficient for indigenous peoples and local communities. The demand for a greater share of income and participation has opened up for mining companies to gain a "social license to operate" from local communities, to avoid conflicts (6.5.4.3).

A wide range of actors and stakeholders is increasingly integrated into governance processes. This can have a positive effect on biodiversity and nature's contributions to people if the effectiveness, efficiency and equity implications of such integration are carefully monitored, evaluated and improved (*well established*) (6.2, 6.4, 6.5, 6.6). The role of multi-actor environmental governance is recognized in Western and Central Europe, and increasingly also in Eastern Europe and Central Asia. In parallel to top-down governance, decision-making concerning biodiversity and nature's contributions to people is increasingly devolved to public-private partnerships, co-management arrangements or even private governance, involving many stakeholders (6.2, 6.4, 6.5, 6.6, **Table 6.1**, **Table 6.8**). Promising developments include the establishment of new protected areas, and the protection of cultural landscapes through the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Convention, the European Landscape Convention, and the International Union for Conservation of Nature (IUCN) protected landscape approach, where various forms of knowledge are integrated into management. These policies promote the protection, management, planning, and governance of cultural landscapes and voluntary forms of land management, such as through biosphere reserves or model forests. This development is driven by the importance of integrating various forms of knowledge, and the need to increase collective learning and adaptive management of natural resources. The evolution of governance, which includes changing responsibilities of public authorities, and how sectors are organized, varies substantially between sectors due to specific sector characteristics such as property rights, stakeholder commitments, transparency and degree of multi-functionality. Assessing the effectiveness, efficiency and equity of promising governance arrangements and taking power relationships and asymmetries into consideration require careful evaluation and monitoring (6.2, 6.4.2.2, 6.5.1.2, 6.5.1.5, 6.5.1.6, 6.6.2.2, **Table 6.8**, **Box 6.7**, **Box 6.11**). This holds especially true for environmental governance in Central Europe, Eastern Europe and Central Asia with their rapid transformation processes since the early 1990s, moving from hierarchical, state-dominated processes to more collaborative governance processes (6.4.2, 6.5.1.4).

Improving biodiversity conservation and nature's contributions to people across administrative boundaries is limited without coordination, cohesiveness and sufficient mobilization of financial resources (*well established*) (6.3.2, 6.3.3, 6.4.1, 6.5.4, 6.6.2, 6.6.4). Increasing coordination between governance scales and levels and developing cohesive strategies and policy objectives among multilateral environmental agreement with the capacity to address problems related to biodiversity and nature´s contribution to people could improve the current multilevel governance system. This also holds for the uneven distribution of benefits and costs across space, actors, and time. Coordinated, multilevel approaches are especially important when ecosystems cut across administrative jurisdictions between and within countries, and for addressing large-scale transboundary problems such as invasive alien species (6.3, 6.6). Furthermore, a key challenge for policy success consists in sufficient mobilization of financial resources (6.3.2, 6.3.3, 6.4.1, 6.5.4, 6.6.2, 6.6.4). Lack of adequate financing is a major constraint on efforts to achieve biodiversity conservation and ecosystem restoration (6.4.1). While a number of Western and some Central European countries of the European Union already provide substantial biodiversity-related financial development assistance to countries all over the world, there is still a need to mobilize more financial resources in Western Europe, but even more so in Central and Eastern Europe and Central Asia. Increased funding from public as well as private sources, together with innovative financing mechanisms, such as ecological fiscal transfers, would help to strengthen institutional capacities; to invest in research, training, capacity-building and education; to employ necessary staff; and to secure monitoring activities (6.3.2, 6.3.3, 6.4.1, 6.5.4, 6.6.2, 6.6.4).

There is no "one size fits all" for sustainable governance of biodiversity and nature's contributions to people in a region as vast and ecologically, socially, politically and economically diverse as Europe and Central Asia (*well established*) (6.2, 6.3, 6.4, 6.5, 6.6). There are difficulties in transferring policies across regions, nations and sectors. Governance schemes and policies that are not designed and adapted to different economic, policy and societal sectors run the risk of not achieving their purpose. However, the role of learning, between different countries within Europe and Central Asia or from other world regions, should not be underestimated. On the contrary, it is important to create opportunities for accelerated development of learning and innovation processes if sustainable governance of biodiversity and nature's contributions to people is to be achieved. Developing and improving governance systems to promote adaptive or transition management is therefore essential, if public and private actors are to achieve the overarching objective of safeguarding biodiversity, nature's contributions to people, and good quality of life (6.6.6). Furthermore, learning and policy diffusion could be reinforced by improved coordination among international and transboundary institutions and across decision-making levels, taking due account of regional, national and subnational requirements; scientific as well as indigenous and local knowledge; and different socio-cultural contexts and related values (6.2, 6.3.1, 6.3.3, 6.4.2.2, 6.5, 6.6).

Dealing with change is a matter of societal choice. The way in which we choose to organize our societies and institutions, in both public and private spheres, is key to the realization of pathways towards the sustainable future envisioned by a diverse range of actors in Europe and Central Asia (*well established*) (6.6.6). The design of promising governance options and smart institutional arrangements supports the effective involvement of different actors in policy and decision-making with the aim of promoting shared responsibility for our common future. Governing direct and indirect drivers in complex adaptive systems, a process which often includes various forms of incomplete knowledge, would benefit from limiting institutional failures and promoting policy processes that stimulate adaptation and learning. Hence, policies, programmes and strategies may be seen as experiments that require governance and management for – rather than against – change, and systematic monitoring and evaluation. This can be achieved incrementally through adaptive governance and management and the systematic improvement of policy implementation, or via transition governance and management, and the organization of evolutionary processes of societal change (6.2, 6.4.2, 6.6, 6.6.6).

6.1 INTRODUCTION

This chapter explores governance options and institutional arrangements for better consideration of biodiversity and nature's contributions to people (NCP) in public and private decision-making in Europe and Central Asia. Biodiversity, nature's contributions to people, and good quality of life are relevant to a wide range of sectors and actors. Addressing the underlying causes of biodiversity loss and ecosystem degradation requires a critical assessment of primary economic sectors such as agriculture, forestry and fisheries as well as energy and mining (PBL, 2014; UNEP, 2011a). Their management practices, and the way in which these impact on nature, call for implementing existing policies more effectively and improving the current situation through additional commitments (UNEP & UNECE, 2016). There is considerable potential for more biodiversity-friendly land-use practices, production methods and healthier consumer choices, for example through improved awareness raising, accounting tools, education and information-based instruments. This potential is also available to industries, manufacturing and the service sectors (TEEB, 2012). However, mainstreaming biodiversity across economic sectors and different stakeholder groups requires joint efforts by public and private actors and strong public policies to enable implementation of appropriate strategies (PBL, 2014; CBD, 2011, 2014). Strengthening political support for environmental improvement is as necessary as building competent and effective environmental institutions, mobilizing finance for environmental and conservation priorities, monitoring progress and readjusting targets and integrating environmental policies into sectoral policies. This is highlighted by the regular Environmental Performance Reviews that cover the countries of Central Asia, Eastern Europe and the Balkan countries of Central Europe. Environmental governance and financing as well as integration of environmental considerations with economic sector policies are core elements of these reviews (UNECE, 2007, 2017c).

Previous ecosystem assessments at global, regional and national levels such as the Millennium Ecosystem Assessment (MEA) or the UK National Ecosystem Assessment (UK NEA) have shown that policy integration across sectors and scales remains a crucial task (MEA, 2005a, 2005b; UK NEA, 2011). Countries' 5th national reports to the Convention on Biological Diversity (CBD, 2016b) confirm that these challenges persist. As the interim assessment of national biodiversity strategies and action plans (NBSAPs) (Pisupati & Prip, 2015: 2) states, there is generally a poor correlation between these strategies and action plans and poverty alleviation, on the one hand, and strategies related to the Millennium Development Goals (MDGs), on the other, as well as between national biodiversity strategies and action plans and sectoral policies. The close link between human rights, ecosystem services and biodiversity is an important topic at the Human Rights Council, with the United Nations Special Rapporteur on human rights and the environment calling for more action from States to respect and protect the rights especially of those who are most vulnerable to the degradation and loss of biodiversity (HRC, 2017). However, with the recently adopted 2030 Agenda for Sustainable Development, the strengthening of human rights in relation to environmental issues has been improved as part of the 17 Sustainable Development Goals (SDGs) (United Nations, 2015). The Sustainable Development Goals are an integrated international policy agenda for the coming years; they are universal and apply to all countries in Europe and Central Asia. In this way, the 2030 Agenda for Sustainable Development is an overarching theme for the region (UNEP & UNECE, 2016).

"Mainstreaming" biodiversity involves "*the integration of the conservation and sustainable use of biodiversity in both cross-sectoral plans such as sustainable development, poverty reduction, climate change adaptation/mitigation, trade and international cooperation, and in sector-specific plans such as agriculture, fisheries, forestry, mining, energy, tourism, transport and others. It implies changes in development models, strategies and paradigms*" (CBD, 2011, p. 5). Mainstreaming biodiversity and nature's contributions to people across sectors in private and public decision-making, and simultaneously addressing challenges at various spatial and temporal scales, remains an important and continuous task. As the recently published GEO-6 assessment for the pan-European region (UNEP & UNECE, 2016, p. 8) has put it: "*Living within planetary boundaries will require fundamental transitions in energy, food, mobility and urban systems and entails profound changes in predominant institutions, practices, technologies, policies and lifestyles. New governance coalitions involving national and subnational levels of government, businesses and citizens are urgently needed.*" A wide range of policy support tools and methodologies as well as different policy instruments are needed to realize these transitions (IPBES, 2015b). These tools and instruments address different actors in relevant sectors. Together they form policy mixes, with each of the instruments having a specific role in the overall policy mix for biodiversity conservation and the sustained provision of nature's contributions to people (Ring & Schröter-Schlaack, 2015).

Section 6.2 provides a framework for assessing governance options, institutional arrangements and policies in the context of the IPBES Regional Assessment for Europe and Central Asia, highlighting linkages between actors, sectors and instruments at different spatial scales. Section 6.3 provides an assessment of international, regional and transboundary environmental governance relevant to Europe and Central Asia. Sections 6.4 on biodiversity conservation and environmental policies and 6.5 on major economic sectors affecting biodiversity and nature's contributions to people, adopt a sectoral perspective: What are the major policy objectives, predominant governance modes and instruments currently governing these sectors? What are key constraints or opportunities within these sectors regarding biodiversity and nature's contributions to people? Which existing and novel options have been proposed in the scientific literature for better governance of biodiversity and nature's contributions to people in these sectors and to what extent have these options and opportunities been implemented or initiated by different actors? Finally, Section 6.6 synthesizes major insights for mainstreaming and integrating biodiversity and nature's contributions to people within and across different sectors; highlights areas for successful integration such as environmental accounting, spatial planning or progress in sustainable consumption and production; and assesses major categories of policy instruments.

6.2 FRAMING INSTITUTIONS AND POLICY OPTIONS FOR BIODIVERSITY AND ECOSYSTEM GOVERNANCE

Smart governance options and institutional arrangements are essential for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development (Meadowcroft *et al.*, 2012). Institutions and governance and other indirect drivers affecting biodiversity and nature's contributions to people have deliberately been placed at the centre of the IPBES conceptual framework (Díaz *et al.*, 2015), and this has been highlighted as an improvement on the Millennium Ecosystem Assessment (Borie & Hulme, 2015; MEA, 2005a). The way in which people and societies organize themselves and their interactions with nature at different scales indirectly drives biodiversity and ecosystem change (Díaz *et al.*, 2015). Governance and institutions thus influence all aspects of relationships between people and nature. Formal and informal institutions determine values and the ways in which responsibilities, costs and benefits of biodiversity conservation are distributed across society. Formal institutions include written constitutions, laws, policies, rights and regulations enforced by official authorities. Informal institutions are mostly unwritten social norms and rules, customs and traditions such as those related to collective action (North, 1990; Ostrom, 1990).

Biodiversity and ecosystem governance benefits from involving the full range of public and private actors, and drawing on a variety of coordination and interaction mechanisms. In contrast to public policies pursued by *governments* at various administrative levels, biodiversity and ecosystem *governance* promotes societal transformation by a number of different actors, including governments, business and civil society (Paavola *et al.*, 2009; Ring, 2008a). Governance processes occur at various spatial (local to international) and temporal scales, and affect different societal, economic and policy sectors (Lange *et al.*, 2013). Different modes of governance are typically viewed along a continuum between state intervention and societal autonomy **(Table 6.1)**.

At one end of the continuum, hierarchical decision-making by governments has traditionally shaped environmental and biodiversity conservation policies through standards and other regulatory measures. Decentralized governance is still top-down in its approach, yet subsidiarity allows lower governmental levels to take decisions autonomously. These publicly determined governance modes have increasingly been complemented by other approaches. These range from institutionalized public-private relations, that leave market actors more freedom to choose their actions within predetermined boundaries (e.g., incentive-based instruments such as environmental taxes or payments for environmental services), to public-private partnerships with negotiated agreements, to modes of self-governance at the other end of the continuum (e.g., by private-social partnerships). With the centre of power no longer only involving the state, but different spheres in society (State, market actors, and civil society), polycentric governance has become increasingly important (Driessen *et al.*, 2012; Muradian & Rival, 2012; Primmer *et al.*, 2015), transcending the above-mentioned continuum in combining different modes of governance with various actors, from public to private.

The European Union (EU), for instance, combines hierarchical governance with decentralized governance and public-private partnerships. It provides a legal and institutional framework in almost all policy sectors for European Union member States in Western and Central Europe. Yet, the European Union's "subsidiarity principle" as set out in Article 5(3) of the Treaty on European Union states that the European Union "*shall act only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States, either at central level or at regional and local level, but can rather, by reason of the scale or effects of the proposed action, be better achieved at Union level*" (European Union, 2016b). In addition, the European Union has developed new experimental modes of governance, such as the open method of coordination that is based on soft law mechanisms such as guidelines and indicators (EUR-lex, 2017). The open method of coordination has increased the competence of the European Union to regulate areas where the traditional Community legislative processes are weak, or where new areas require coordination of member state policy.

Table 6 1 **Governance modes, public and private actors and their interaction. Source: Adapted from Driessen *et al.* (2012) and Lange *et al.* (2013).**

	Hierarchical governance (centralized)	Decentralized governance	Public-private governance	Self-governance/ Private governance
Actors	Mainly central governmental (or supranational) bodies	Governmental actors at lower levels (subsidiarity)	Central government agencies; private sector – market actors (business, consumers)	Mainly non-governmental: Private sector or civil society (NGOs, indigenous peoples and local communities, citizens)
Power	Coercion	Coercion	Competitiveness (prices); contracts; agreements	Autonomy
Representation	Pluralist ((supra)national elections)	Pluralist (local elections)	Corporatist (formalized public-private arrangements) as well as public-private partnerships	Partnerships (participatory private-private governing arrangements)
Mechanisms of social interaction	Top-down; command and control	Sub-national governments decide autonomously within top-down determined boundaries	Private actors decide autonomously about collaborations within top-down determined boundaries or based on negotiations	Mainly bottom up; social learning, deliberation, negotiation

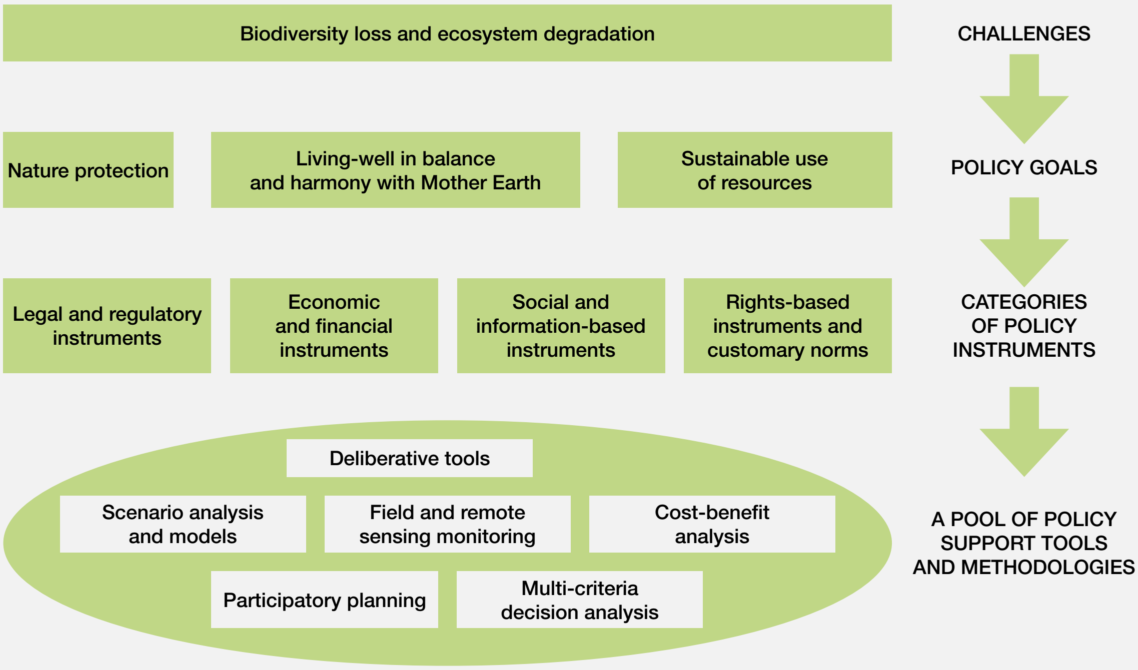
For Eastern Europe and Central Asia, most of the literature still focuses on centralized approaches to governance, but the role of multi-actor governance is also increasingly recognized (OECD, 2005, 2012a). Civil society actors such as NGOs play an important role and can be influential in the design of relevant legislation and programmes over time (Yamin, 2001). The European Platform for Biodiversity Research Strategy is an example of cooperation between researchers, policymakers and other stakeholders, a science-policy interface and forum aiming to promote knowledge for sustainability, with a focus on the conservation and sustainable use of biodiversity and ecosystem services science and policy (EPBRS, 2016). The BioNET network is a regional network of biodiversity-related civil society organizations in the Balkan countries in Central Europe. The network promotes democratic development and strengthening cooperation and dialogue between local authorities, national governments, civil society, private sector and international governmental and non-governmental organizations conducive to nature conservation as one key element of sustainable development (GIZ, 2016). Civil society networks such as the River without Boundaries Coalition, founded by several NGOs from Russia, China, Mongolia and USA, is uniting citizens from transboundary regions in one movement to campaign for the protection of the Amur River basin, which is the largest free-flowing transboundary river system in Asia (Rivers without Boundaries Coalition, 2017).

Despite improvements in governance in Europe and Central Asia, biodiversity loss and ecosystem degradation are still exacerbated by various institutional failures. These are often catalogued as: (i) law and policy failures (e.g., environmentally harmful subsidies); (ii) market failures (externalities in the use of public goods and services); (iii) organizational failure (e.g., lack of transparency and political legitimacy in decision-making, and implementation deficits); and (iv) informal institutional failures (e.g., breakdown in collective action norms such as free-riding or crowding out intrinsic motivations for biodiversity conservation due to erosion of trust) (IPBES, 2015a, 2015b; Ostrom, 1990; Rode *et al.*, 2015). To counteract these failures, strategies are formulated and concrete policy goals are set, which aim at designing and implementing policy instruments that avoid negative impacts on biodiversity and ecosystems services or support and promote environmentally-friendly behaviour **(Figure 6.1)** (IPBES, 2015b). Finally, a pool of policy support tools and methodologies is available to inform instrument design or stakeholders' activities for better biodiversity and ecosystem governance.

Biodiversity and ecosystem governance can build on a wide range of policy instruments as well as supporting tools and methodologies. In the context of IPBES, policy instruments have been placed into four main categories (IPBES, 2015a, for more detail on these categories see IPBES, 2015b):

- legal and regulatory instruments;
- economic and financial instruments;

Figure 6 1 **Schematic representation of the interrelation of policy formulation, policy instruments and policy support tools and methodologies. Source: Adapted from IPBES (2015b).**



- social and information-based instruments; and
- rights-based instruments and customary norms.

Legal and regulatory instruments, or so-called "command and control" measures have long been applied to deal with environmental degradation (Harring, 2014). Schröter-Schlaack & Blumentrath (2011) refer to "direct regulation" as environmental and technical standards as well as spatial planning. They provide three reasons why direct regulation is often the first choice for policymakers when faced with an environmental problem: (i) it is supposed to permit a fast and direct response; (ii) policymakers are experienced in using this type of instrument; and (iii) established legal institutions are often an important prerequisite for implementing economic and financial instruments.

Economic and financial instruments comprise (i) price-based mechanisms (e.g., subsidies, taxes, fees, payments, fiscal transfers), and (ii) quantity-based mechanisms (e.g., tradable permits, land-development rights, habitat banking) (Schröter-Schlaack & Ring, 2011). They are intended to change private and public actors' behaviour through incentives or disincentives towards desired policy objectives. Typically, they comprise a wide range of designs and implementation approaches, and are able to support manifold strategies concerning biodiversity and ecosystem services. They can be used to correct for policy and market failures, and aim at reflecting monetary costs or benefits of the conservation and use of biodiversity and ecosystem services (IPBES, 2015b). Thus, environmental fiscal reforms are important to change relative prices in the whole economy. Furthermore, Aichi Biodiversity Target 3 highlights the importance of reducing negative impacts of harmful subsidies and increasing positive incentives for conservation. However, until now substantial reforms have not taken place. Several countries in Eastern Europe and Central Asia have taken steps towards environmental fiscal reforms with mixed results (CBD, 2017a). The suitability of specific fiscal instruments for individual countries depends among others on the country's stage of development, level of resource endowment and institutional capacity (The World Bank, 2005).

Social and information-based instruments consider the interdependence of ecosystems and sociocultural dynamics for successful environmental management at the local, national or regional level. They comprise: (i) information-related instruments such as environmental education, eco-labelling, certification, and awareness raising; (ii) self-regulation, voluntary agreements and corporate social responsibility; (iii) participation; and (iv) enhancement of collective action of indigenous peoples, local communities, and local resource users (IPBES, 2015b).

Table 6 2 **Policy instrument categories. Source: Own representation.**

Legal and regulatory instruments	Economic and financial instruments	Social and information-based instruments	Rights-based instruments and customary norms
- Legislation - Standards - Environmental quality objectives - Planning - Threshold values - Liability rules - Impact regulations - Long-term agreements - Environmental classification - Technology requirements - Supervision	- Taxes - Tax reliefs - Charges - Fees - Allowances - Offsets - Emissions trading - Habitat trading - Ecological fiscal transfers - Subsidies - Compensation payments - Payments for environmental services	- Information - Pollutant release and transfer registers - Biodiversity registers - Ecolabelling - Certification - Counselling - Education/Training - Opinion forming - Corporate Social Responsibility - Self-regulation - Voluntary agreements - Cooperation and consultation - Networks	- International and national human rights instruments - Strengthening of collective rights - Customary norms and institutions of indigenous peoples and local communities - Equitable and fair management of natural resources - Heritage sites: e.g., sacred sites, peace parks, indigenous and community-conserved areas

The rights-based approach is often defined as a way of "*integrating rights, norms, standards, and principles into policy, planning, implementation, and outcomes assessment to help ensure that conservation practice respects rights in all cases, and supports their further realization where possible*" (Campese *et al.*, 2009). Thus, the rights-based approach offers a range of instruments to reconcile conflicts primarily through the improvement of governance procedures of biodiversity and ecosystem services. This includes elements that to a large extent overlap with the principles of good governance, such as participation, transparency; accountability (Biermann & Gupta, 2011; Ratner *et al.*, 2013), and empowerment (Ensor *et al.*, 2015). Rights-based instruments and customary norms are increasingly gaining interest in the field of natural resource conservation and management (Campese *et al.*, 2009; Jodoin, 2014). The instruments included in the rights-based approach may offer ways to reconcile conservation and human rights standards, and foster complementarity with human well-being (IPBES, 2015b). However, the practical implications of conserving biodiversity and, at the same time, protecting human rights are still rather unclear and therefore subject to much debate in particular when it comes to the rights of indigenous peoples (Reimerson, 2013).

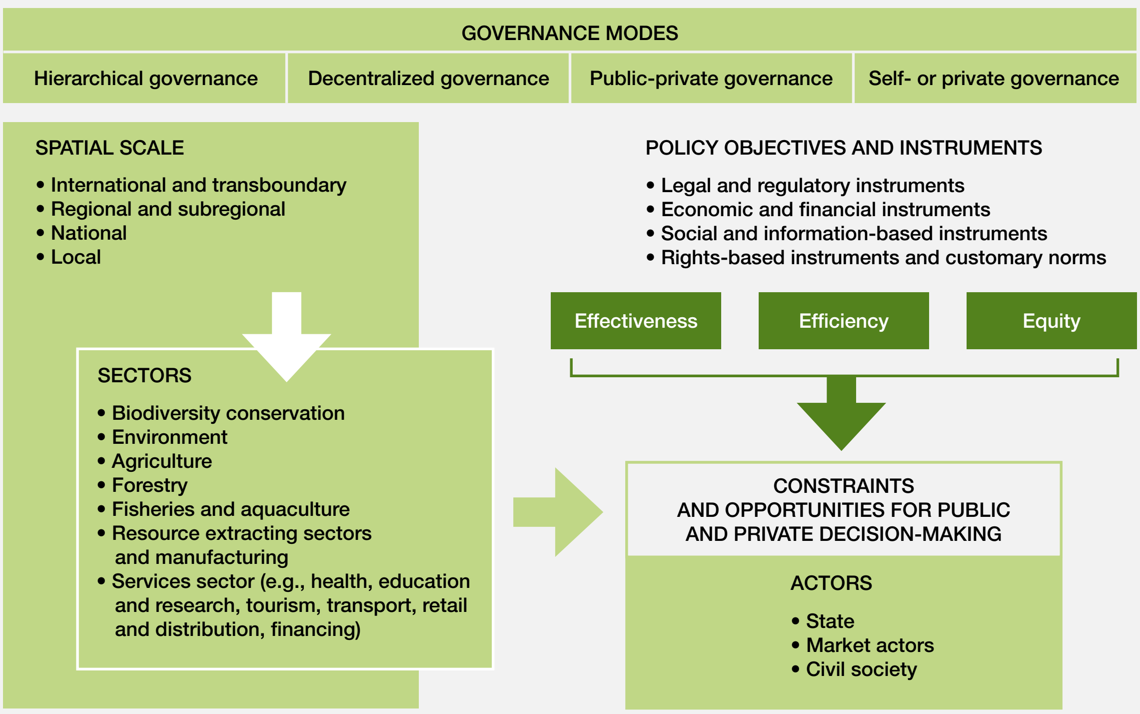
Examples of instruments belonging to the various instrument categories are provided in **Table 6.2**. It is difficult to connect value types (anthropocentric and non-anthropocentric) to specific policy instruments or governance modes. Legal and regulatory instruments can capture a wide range of values, including economic ones, for example through fines, and not all economic and financial instruments relate exclusively to monetary values derived by economic valuation methodologies.

Although the design and evaluation of policy instruments has mostly focused on individual instruments, in practice, policy instruments are used in combination, as a policy mix, which "*has evolved to influence the quantity and quality of biodiversity conservation and ecosystem service provision in public and private sectors*" (Ring & Schröter-Schlaack, 2015). Specific policy outcomes may, therefore, be due to individual policy instruments, but there may be cases where other instruments create synergies towards achieving objectives or cause conflicts that impede achievement of the envisaged outcomes. Possible interactions of instruments comprise co-existence (incl. complementarity, redundancy and overlap), synergies, competition and conflict, and sequential interaction (e.g. implement enabling legal and regulatory instruments before economic instruments that may require well-defined property rights) and replacement (Jordan *et al.*, 2013; Santos *et al.*, 2015b). Therefore, policy mix analysis and highlighting the role of instruments in a policy mix have increasingly gained attention in research and policy practice (Gunningham & Young, 1997; Lehmann, 2012; OECD, 2007; Ring & Barton, 2015; Ring & Schröter-Schlaack, 2011). Further concepts highlighting the coordination and integration of instruments include on the one hand the spatial fit to avoid mismatches between ecological and social processes or boundaries, and on the other hand the interplay and interconnections between regimes (Kim, 2004; Moss, 2012; Vatn & Vedeld, 2012).

The different conceptualizations of the diverse values of biodiversity and nature's contributions to people are important for choosing the most appropriate instruments and further options in any context (see Chapters 2 and 3; Chan *et al.*, 2012; IPBES, 2016a; Kenter *et al.*, 2015, 2016). The choice of policy instruments often implies altering the distribution of responsibilities for the conservation and use of biodiversity that goes along with changing the advantages and disadvantages for different actor groups. Different actors also hold competing norms and values that influence the type of policies they support, and this relates to the choice and design of policy instruments to achieve certain objectives. Whereas some stakeholders prefer regulatory instruments, others favour economic and financial instruments. However, any policy instrument can only be effective if the supporting formal and informal institutions are in place. Legal and regulatory instruments such as laws, regulation and plans usually set the boundaries within which economic instruments are then applied to incentivize public and private actors towards more environmentally-friendly behaviour (Vatn, 2015). Local communities and indigenous peoples often build on traditional knowledge for land-use practices. They may have developed customary norms in relation to special places in nature, respected as sacred sites or community-conserved areas, but these may not be recognized in formal conservation policies or regulatory developments at distant national, regional and international levels (Babai *et al.*, 2015; Borrini-Feyerabend *et al.*, 2004a; Samakov & Berkes, 2016). Granted concessions to business companies for the exploration and extraction of natural resources and minerals may thus, for instance, not recognize or may even violate indigenous and local peoples' access to and traditional use of local resources and ecosystem services (Bogoslovskaya, 2015; Fondahl & Sirina, 2006; Stammler & Forbes, 2006), as well as disregard their spiritual relationship with nature (Lavrillier, 2013).

Considering the mix of instruments is especially important in an ecosystem service perspective where trade-offs and synergies may occur between biodiversity and ecosystem services or among different ecosystem services (Elmqvist *et al.*, 2010; Ring & Schröter-Schlaack, 2015). Policy-mix analysis is also essential where policies in one sector, e.g., climate, fisheries, energy or agriculture, may jeopardize policies in another such as nature conservation. Terrestrial, freshwater, coastal and marine systems in Europe and Central Asia are exposed to manifold threats. Indirect drivers as assessed in Chapter 4 include institutional, economic, demographic, cultural and religious as well as scientific and technological drivers. The most important direct drivers of change are natural resource extraction, land-use change, pollution, climate change and invasive alien species (see Chapter 4). Relevant sectors, their

Figure 6 2 **Assessing governance options and policy instruments in key sectors. Source: Own representation.**



governance modes, policies and instruments and the coherence between them have to be assessed at different spatial levels if the aim is to identify promising policy options and opportunities for public and private actors, to promote positive and mitigate negative impacts on biodiversity and nature's contributions to people, and hence on good quality of life **(Figure 6.2)**.

Policy instruments are often analyzed regarding their effectiveness and efficiency (including cost-effectiveness) in reaching an environmental objective. Effectiveness comprises the assessment of the outcomes achieved with respect to different policy approaches, while efficiency deals with the (economic) comparison of inputs and outputs. Further policy assessment criteria include equity, social and distributive impacts, policy coherence, administrative feasibility, relevance and institutional requirements, among others (OECD, 1997; Ring & Schröter-Schlaack, 2011; Sterner, 2003; Turner & Opschoor, 1994). Equity touches upon raising social awareness and enhancing participation as well as legitimacy and transparency in the decision-making process, thereby improving the distribution of benefits and reducing social conflicts (Bagnoli *et al.*, 2008; Felipe-Lucia *et al.*, 2015; Grieg-Gran *et al.*, 2013; Martín-López *et al.*, 2012; McDermott *et al.*, 2013; Wilson & Howarth, 2002) (see also Chapter 2, Section 2.3.4). However, it should be acknowledged that it is extremely difficult to assess and to draw general conclusions on the effectiveness, efficiency or equity of any given instrument category or a mix of instruments as, ultimately, their success largely depends on instrument design and the coordination and integration between different policy fields.

6.3 INTERNATIONAL, REGIONAL AND TRANSBOUNDARY ENVIRONMENTAL GOVERNANCE

6.3.1 Intergovernmental and non-governmental organizations

In Europe and Central Asia environmental governance at the international level is based on a network of intergovernmental organizations and international non-governmental organizations, which plays an increasingly significant role (Esty & Ivanova, 2002) and also advocates for specific policies at the international as well as national and subnational levels (Eilstrup-Sangiovanni & Bondaroff, 2014; Esty & Ivanova, 2002). Membership of intergovernmental organizations may comprise sovereign states or of other intergovernmental organizations with the main aim of creating a mechanism for countries to work more successfully together in, for example, the areas of biodiversity, nature's contributions to people, and good quality of life. International non-governmental organizations are generally private, voluntary organizations, whose members are individuals or associations that come together to achieve a common purpose.

6.3.1.1 Intergovernmental organizations

Intergovernmental organizations are bodies based on a formal instrument of agreement such as a treaty or charter and possessing a permanent secretariat performing ongoing tasks (Oberthür & Gehring, 2006; Speth & Haas, 2006). At the global level, intergovernmental organizations relevant to biodiversity and nature's contributions to people include the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP), and other specialized United Nations agencies and commissions such as the Food and Agriculture Organization of the United Nations (FAO). A variety of other international organizations plays an important role in coordinating environmental policy. The World Bank influences policy directly through its environmental strategy, and indirectly through development activities for the environment. The Global Environment Facility (GEF) sets priorities and processes for funding many environmental projects and the World Trade Organization (WTO) influences environmental policies through trade agreements. The Organisation for Economic Co-operation and Development (OECD) addresses the economic, social and governance challenges of globalization and aims to exploit its opportunities (Oberthür & Gehring, 2006).

Within Europe and Central Asia specific intergovernmental organizations, such as the Council of Europe and the European Union (EU) have prominent roles in environmental policymaking. The European Union is commonly described as an international organization *sui generis* due to its uniqueness with regard to supranational features and strong elements of legal integration (Tömmel, 2011). The European Union is founded on the rule of law and on the principle of conferral (European Union, 2016b, Articles 2 and 5.2). This means that it only has the competences that have been voluntarily and democratically transferred to it from the member States in the founding Treaties. As described in Section 6.3.2.3 below, the European Union has developed a significant amount of environmental legislation and policy decisions over the years, and is party to several multilateral environmental agreements.

In addition to these intergovernmental organizations there are also a number of organizations or treaties related to specific geographical areas within Europe and Central Asia, for example the Arctic, the Barents, the Mediterranean and the Alpine areas. In the absence of a treaty, an intergovernmental organization does not exist in a legal sense. For example, the G8 is not an intergovernmental organization, but a group of eight nations that have annual economic and political summits. Intergovernmental organizations that are formed by treaties and thereby subject to international law are more advantageous to more informal groups since they have the ability to enter into enforceable agreements among themselves or with states (Speth & Haas, 2006). However, this does not mean that one should underestimate the impact of informal groups such as the G8 on the governance of biodiversity and nature's contributions to people, since such groups may, based purely on the collective influence of their members, be able to play a prominent role in global environmental governance (Speth & Haas, 2006).

Although intergovernmental organizations have come to play a significant role due to increasing globalization and interdependence of nations, their activities and objectives often overlap, resulting in a complex network; or they may have difficulty integrating competing objectives, as in the following case of global trade and the environment. The World Trade Organization still lacks a special agreement on the environment, but most agreements formalized within its domain include environmental regulations that require member States to ensure that the environment is duly protected. However, it has been challenging to recognize the ecological impacts of trade, such as biodiversity losses and destruction of ecosystems; and to develop an environmental policy framework that complements trade policies (Santarius *et al.*, 2004). Another challenge lies in the policy conflicts between multilateral environmental agreements and the World Trade Organization trade policy. These conflicts arise because environmental agreements often aim to internalize negative external costs, i.e. to reduce environmentally harmful economic activities, while this is often ignored in free trade policies. Hence, international trade policies have significant impact on the environment and potential to trump international environmental policies when they come into conflict (Santarius *et al.*, 2004).

In sum, intergovernmental organizations contribute to and develop habits of environmental cooperation, and regular interactions among nation States. While some intergovernmental organizations establish regularized processes of information gathering, analysis, and monitoring, others develop procedures to make rules, to settle disputes, and to punish those who do not comply to the rules. However, the multitude of intergovernmental organizations also gives rise to fragmented, sometimes overlapping and occasionally conflicting legal and policy mandates, which may complicate the ability of countries in Europe and Central Asia, and beyond, to achieve established goals.

6.3.1.2 International non-governmental organizations and hybrid organizations

International non-governmental organizations are generally voluntary organizations, often politically independent, that may participate at all political levels from the global to the local. From an environmental governance perspective, they are increasingly significant, especially in Europe and Central Asia. They may be funded solely through private sources or rely on partial government funds. Currently there are 4,189 international non-governmental organizations and non-governmental organizations that enjoy active consultative status with the United Nations Economic and Social Council (UN DESA, 2017).

As advocates for specific policies, they may offer alternative channels of political participation, and play a role in collecting, disseminating, and analyzing information; provide input into agenda-setting and policy development processes; perform operational functions; assess environmental conditions and monitor compliance with environmental agreements; and advocate environmental justice (Bernauer *et al.*, 2013; Eilstrup-Sangiovanni & Bondaroff, 2014; Esty & Ivanova, 2002). International non-governmental organizations may also be major operators of conservation initiatives in practice at various levels (Redford *et al.*, 2003). In contrast to intergovernmental organizations, international non-governmental organizations rely on soft power, i.e. information, expertise, and moral authority to attract the support of Governments and the public (Turner, 2010). However, at the national level, non-governmental organizations have also occasionally taken the place of a state when the state has not been able to perform as intended in protecting the environment (Borrini-Feyerabend *et al.*, 2013), for example in the case of political or military conflicts or corruption.

In general, very little is known about the degree of attention that government representatives pay to the input of non-governmental organizations in international negotiations, or which strategies are effective when employed to make an impact, such as activism, lobbyism or expert-influence. International non-governmental organizations also have to evaluate their respective strategies to make an impact in relation to the risk of being co-opted by Governments. Many non-governmental organizations address this challenge by specializing in either activist strategies (e.g., Greenpeace) or hybrid strategies with closer ties to governments, including partnerships (e.g., World Wide Fund for Nature). This attracts different groups of supporters and will also influence the funding structures ranging from public grants (e.g. European Commission and national grants), to membership contributions, donations, or crowd funding (Rietig, 2016).

A sharp distinction is often made between intergovernmental organizations and international non-governmental organizations. In practice, however, governments do not always strictly maintain the separation. There is an increasing number of hybrid organizations involving both intergovernmental organizations and international non-governmental organizations. One of the most prominent in environmental governance is the International Union for Conservation of Nature. The International Union for Conservation of Nature has observer status at the United Nations and consultative status with the United Nations Economic and Social Council, Food and Agricultural Organization, and United Nations Educational, Scientific and Cultural Organization. The International Union for Conservation of Nature has played an important role in the management and conservation of biodiversity, globally as well as in Europe and Central Asia. Two of their instruments have played particularly important roles: the Red List of Threatened Species, and the framework for governance models of protected areas. The latter has opened up for a larger variation of governance and management of protected areas also including indigenous peoples and local communities, as well as privately managed areas. Despite this development, most protected areas in Europe and Central Asia still have hierarchical modes of governance (Borrini-Feyerabend *et al.*, 2013; Holmgren *et al.*, 2016; Reimerson, 2013).

Another example where intergovernmental organizations and international non-governmental organizations come together is the "Environment for Europe" process. This process is a public-private partnership including 54 countries in Europe and Central Asia partnering with international organizations as well as regional environmental centres, non-governmental organizations and the private sector. The objective is to harmonize environmental policies and enhance the quality of the environment across Europe, but also to help countries of Eastern Europe, Central Europe and Central Asia to improve their environmental standards (UNECE, 2017a).

In sum, international non-governmental organizations play an important role in pushing for sustainable development at the international level, in particular in transition countries (Bernauer *et al.*, 2013). They are key drivers in intergovernmental negotiations on environmental governance. International non-governmental organizations also increasingly pay attention to social and environmental externalities of business activity. Multinational brands may be pressured by international non-governmental organizations challenging their labour, environmental or human rights record, for example through "naming and shaming" activities (Keskitalo *et al.*, 2009). International non-governmental organizations thus play an important role in relation to both public and private activities related to biodiversity and nature's contributions to people, given that they are afforded freedom to play a vital role and that they can find funding for their activities.

Some critics are, however, concerned that they may contribute to the fragmentation and weakening of political action. There are, for example, often competing international non-governmental organizations in the same policy field and their mutual contest for influence risks undercutting political effectiveness. Supporting and incentivizing coordination and collaboration among international non-governmental organizations is thus an important opportunity among actors at multiple levels in Europe and Central Asia in relation to the increasing influence of civil society in environmental governance at the global level (Esty & Ivanova, 2002).

6.3.2 Responses to global environmental challenges

Since many natural resources are shared and many environmental problems have a global or transboundary nature, they can only be addressed effectively through different forms of international or regional cooperation among States (Sands *et al.*, 2012). To understand and assess how the international level impacts on countries within Europe and Central Asia with respect to biodiversity and nature's contributions to people, one needs to comprehend the strengths and weaknesses of the international system, especially of the international environmental law. In the international arena, States are the primary legal subjects and the bearers of rights and obligations (Cassese, 2005). International law, or law of nations, consists of rules for the legal relations between and among States, international organizations and non-state actors. All international cooperation is voluntary, since all States are sovereign and equal (Sands *et al.*, 2012). However, ensuring compliance with international law is often problematic, since international agreements seldom include direct reprisals or sanctions (Beyerlin & Marauhn, 2011). Implementation and enforcement of international law in general, and environmental law in particular, rest on States' political standing and good will to comply (Sands *et al.*, 2012), and their ability to establish effective international cooperation. International environmental law provides a meta-framework for international relations, thereby providing rules and regulations that for example determine the legality of State actions with respect to ecosystem services that cross national boundaries. International law is thus important in providing a platform for identifying, integrating and implementing legal, scientific, and policy issues at national level relevant to the conservation and use of biodiversity, and nature's contributions to people, that cross political or administrative boundaries.

In contrast to the four categories of policy instruments adapted from IPBES (IPBES, 2015a, 2015b) and introduced in Section 6.2, international law is broadly divided into two main categories: 1) legally binding international law (hard law); and 2) non-legally binding international law (soft law). The Statute of the International Court of Justice, in its Article 38, declares that there are three main sources of binding international law: a) international treaties, conventions and protocols (binding only on the parties to the agreement); b) international custom, built on established practice and considered to be binding on all States; and c) general principles of law recognized by civilized nations (Thirlway, 2014).

Today there has been an increasing use of non-binding normative instruments in the international arena (Shelton, 2014). Such soft law instruments, international resolutions and declarations, or informal supervisory organs to international agreements, are commonly described as including hortatory, i.e. incentivizing or encouraging means, rather than legal obligations (Guzman & Meyer, 2010). New governance mechanisms and increasing interactions between governance levels are established today at the international level (Derkx & Glasbergen, 2014; Glasbergen *et al.*, 2007; Visseren-Hamakers *et al.*, 2012).

Over time, a vast number of international and regional environmental governance arrangements, containing both hard law and soft law instruments, have been developed. Globally, there are more than 1,100 formal, legally binding and multilaterally negotiated "multilateral environmental agreements". Many of these multilateral environmental agreements are also represented in Europe and Central Asia (Widerberg & Pattberg, 2015).

6.3.2.1 Global binding instruments

Even though measuring the effectiveness of binding international environmental law, i.e. treaty law, is difficult, the general trend seems to be toward greater compliance and better implementation among States over the past thirty years (Bodansky, 2015). This trend has been strengthened within Europe and Central Asia, especially in Central and Eastern Europe where "open regional funds" support a transition (GIZ, 2017). States that opt for accession to the European Union, such as Serbia, are encouraged to take necessary steps to achieve the highest levels of environmental protection and response to climate change (Heinrich-Böll-Stiftung, 2017). Potential and existing member States to the European Union need to comply with the body of European Union laws, rules and policies, including international agreements.

In general, the binding character of an international agreement seems to promote compliance, not least since States take legal commitments more seriously than political ones and therefore are more careful in negotiating and accepting them (Bodansky, 2015). However, international environmental law has been weakest when it comes to resolving major environmental challenges, such as loss of biodiversity and climate change (Bodansky, 2015; Leadley *et al.*, 2014). Despite good examples such as the Vienna Convention for the Protection of the Ozone Layer (and the follow-up Montreal Protocol) which, through the banning of stratospheric ozone–depleting chlorofluorocarbons (CFCs), contributed to a reduction of emissions into the atmosphere (Canan *et al.*, 2015; Gonzalez *et al.*, 2015), there are numerous examples in which treaties have failed to achieve their stated purpose (Adam, 2010; Harrop, 2011).

This applies, unfortunately, not least to the issue of biodiversity conservation, despite efforts in the framework of the Convention on Biological Diversity (Bodansky, 2015). The Aichi Biodiversity Targets, under the Strategic Plan for Biodiversity 2011-2020 that was adopted by Parties to the Convention on Biological Diversity and recognized or supported by the governing bodies of other biodiversity-related conventions will most likely not be fulfilled in 2020 (O'Connor *et al.*, 2015; Tittensor *et al.*, 2014). This is considered to be a consequence of having inadequate institutional structures and governance in place, and applies equally to Europe and Central Asia.

According to the literature several reasons for protection and conservation failures can be identified (Young, 2011), where overlaps and fragmentation among the treaties are problematic. In the case of biodiversity there are, for example, seven global conventions with somewhat similar aims although with different foci; the Convention on Biodiversity, the Convention on Conservation of Migratory Species, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the International Treaty on Plant Genetic Resources for Food and Agriculture, the Ramsar Convention on Wetlands, the World Heritage Convention, and the International Plant Protection Convention (see supporting material Appendix 6.1[1] Table 6.1.1). Although each of these "biodiversity-related conventions" has developed complementary approaches and operational tools, the treaty system remains fragmented and when considering various contributions from nature to people, often compartmentalized. Other examples are sustainable forest management and the protection of marine and water resources, which also are covered in separate treaties or agreements, with sometimes complementary and sometimes competing objectives to those of the biodiversity-related conventions (e.g. sustainable use vs protection) (Susskind, 2008; Susskind & Ali, 2015).

Another problem characterizing the global environmental treaty-making system is the level of ratification of treaties by States (Bodansky, 2015; Koivurova, 2014). This is not a major problem within Europe and Central Asia, where almost all countries have ratified, for example, the seven global biodiversity-related conventions. A larger problem,

1. Available at: https://www.ipbes.net/sites/default/files/eca_ch_6_appendix_6.1_responses_to_global_environmental_challenges.pdf

however, concerns the fragmentation of the treaty system. The implementation of treaties in the domestic legal systems may be slow due to, for example, lack of political will or financial resources at the national level, or due to the lack of proper enforcement mechanisms (Susskind & Ali, 2015). Seventeen Sustainable Development Goals were adopted by the United Nations General Assembly as part of the "2030 Agenda for Sustainable Development" (see Chapter 5 Section 5.4.3), embracing the so-called "triple bottom line" approach to human well-being (i.e. the combination of economic development, environmental sustainability, and social inclusion). Although non-binding, they have the potential to contribute to the reduction of the current fragmentation of the international law system by enabling synergistic interactions between existing legal instruments, the mainstreaming of biodiversity into the goals, and consistency between targets within goals at multiple levels (Oberthür & Gehring, 2006; Yoshida & Zusman, 2015).

Binding instruments at the international level are important for Europe and Central Asia as they define many of the objectives and means to protect and conserve, for instance, biodiversity. The advantages and problems related to international cooperation, such as compliance with, and enforcement of, international environmental law, apply also to the countries of Europe and Central Asia.

6.3.2.2 Regional binding instruments

Regional binding instruments are, by contrast to global treaties, limited in their geographical scope to certain regions, e.g. Europe, the Nordic countries, the Mediterranean or Central Asia. Such instruments address certain shared focal areas and objectives with respect to environmental protection, and function much in the same way that global binding instruments do, forming part of international law. For relevant agreements in Europe and Central Asia see supporting material Appendix 6.1[2] Table 6.1.2. See also Section 6.3.3 where regional environmental instruments are addressed by theme (transboundary challenges). A significant proportion of regional binding instruments in Europe and Central Asia stems from the European Union, see further Section 6.3.2.3. As an organization, the European Union is partner to several international environmental agreements regarding the protection of the environment and biodiversity. Importantly for their enforcement, these agreements have been transformed into binding European Union law through the adoption of regulations and directives.

Although not formally a partner, the European Union coordination of sustainable spatial development is anchored by the Council of Europe Landscape Convention (Council of Europe, 2000) and applied through the Committee of Ministers of the Council of Europe, and is a convention to which many states in Europe and Central Asia are party. There are several other regional agreements, for instance concerning watercourses: the Convention on the Protection and Use of Transboundary Watercourses and International Lakes from 1992, and more detailed rules on specific water courses or lakes, have been negotiated, for example for the rivers Rhine, Elbe, Mosel and Danube as well as the water courses between Norway and Finland and between Sweden and Finland.

The Arctic Council, established by the Ottawa Declaration in 1996 (Arctic Council, 1996), includes the following countries from Europe and Central Asia: Russia, Finland, Sweden, Norway, Iceland and Denmark (note that Greenland, although Danish territory, is assessed under the IPBES Regional Assessment for the Americas). It is distinguished by the six main indigenous people's organizations in the Arctic (two of which pertain to Europe and Central Asia, the Saami Council and the Russian Association of Indigenous Peoples of the North) that have permanent representation at the Council. The first binding agreement from the Arctic Council is the Arctic Search and Rescue Agreement from 2011, encompassing an observatory function for accidental oil spills that could impact on Arctic coastal biodiversity and fisheries. On the basis of major societal and environmental changes confronting the Arctic there is a knowledge gap with respect to what types of institutions work best to improve the well-being of Arctic residents, including what roles formal and informal institutions will play in meeting future needs (Larsen & Fondahl, 2015).

Although the bulk of regional environmental agreements in Europe and Central Asia exist in Western and Central Europe, including the environmental legislation of the European Union, the same implementation and enforcement gaps are present as seen with global international treaties (Susskind & Ali, 2015). An exception to some extent is the European Union, which has stronger enforcement mechanisms for obliging member States to comply with legislation.

6.3.2.3 The European Union and European Union environmental law

European Union law for the governance of biodiversity and nature's contributions to people is immensely important and is a role model for non-European Union countries in Europe and Central Asia. Hence, it is discussed in detail here. The key European Union institutions are the European Commission, the European Council, the Council of the European Union (the Council), the European Parliament, and the Court of Justice of the European Union (European Union, 2016c, Articles 14-19). The European Union founding

2. Available at: https://www.ipbes.net/sites/default/files/eca_ch_6_appendix_6.1_responses_to_global_environmental_challenges.pdf

treaties are the primary source of law, regulating the policy areas where the European Union can adopt secondary legislation (i.e. regulations and directives).

Implementation and enforcement are key factors for the effective application of European Union environmental law and policy (European Union, 2013a). While implementation lies foremost with the member States, the responsibility for enforcement is shared between the member States and the European Commission. While the member States are primarily responsible for providing adequate and appropriate sanctions for environmental offences, the European Commission ensures that European Union law is sufficiently implemented and applied throughout the member States. For this purpose, the European Commission may bring legal action against a member State before the Court of Justice of the European Union, where the member State risks being condemned for infringement of the obligations under the treaties (European Union, 2016b, Articles 258 and 260). The Court of Justice of the European Union therefore forms an essential part of the enforcement of the European Union legislation. There is also an informal European Union network created especially to improve enforcement, called Implementation and Enforcement of Environmental Law.

European Union environment policy under the treaties rests on the principle of integrating environmental concerns into other policy areas (European Union, 2016c, Article 11), a high level of environmental protection, the polluter pays principle, and on the principles of precaution, prevention and rectifying pollution at source (European Union, 2016c, Article 191-193). In addition, the following environmental objectives guide Union action on the environment:

- to preserve, to protect and to improve environmental quality;
- to protect human health;
- to utilize natural resources prudently and rationally; and
- to promote measures at international level to deal with regional or worldwide environmental problems, and in particular combating climate change (European Union, 2016c, Article 191.1).

Together, the objectives and principles of the treaties lay the foundation for more substantial environmental law and policy within the Union (Krämer, 2011). In the environmental field, the treaties authorize European Union institutions to act in all sectors of European Union environmental policy (see **Table 6.3**), i.e. climate change; protection of air, water and biodiversity; waste management; and sustainable consumption (European Union, 2016c, Articles 191-193; Krämer, 2011). Policy decisions, such as multiannual environment action programmes or policy decisions covering a specific sector of European Union environment policy (e.g. the 2020 Biodiversity Strategy), provide priority objectives and strategic guidance for more concrete environmental actions in the forthcoming years (Jans & Vedder, 2012). The European Union has developed several horizontal strategies for the conservation of biodiversity and restoration of ecosystems over the years, the latest being the 2020 Biodiversity Strategy from 2011 (European Commission, 2011a). Protection, conservation and enhancement of natural capital within the European Union is also one of the priority objectives in the 7th and latest European Action Programme entitled "living well, within the limits of our planet" (European Union, 2013a).

Binding environmental actions take the form primarily of regulations, and of directives, which create specific legal obligations for European Union member States. The aim of regulations is to totally harmonize member States' legislation in a certain field, to promote integration and the proper function of the internal market (Jans & Vedder, 2012). A directive is, instead, legally binding in terms of results to be achieved within a prescribed time, but leaves the form and method for implementation to the member States (European Union, 2016c, Article 288). The member States are expected to loyally implement, interpret and apply European Union law under the principle of sincere cooperation (European Union, 2016b, Article 4.3). The principles of subsidiarity and proportionality applied to the environmental field mean that Union action normally is justified for environmental matters that have transboundary effects, and that framework directives leaving implementation responsibilities to the member States are preferred over detailed, harmonizing regulations (European Union, 2016b, Article 193, 2016c, Article 5; Jans & Vedder, 2012).

Despite many institutional initiatives and strong enforcement mechanisms, also within the European Union, poor implementation remains a fact even if compliance may vary across different policy areas as well as within and between member States (Falkner & Treib, 2008; Jordan, 1999; Nicolaides & Oberg, 2006). The Court of Justice of the European Union has also, on numerous occasions, disallowed member State's attempts to transpose a directive into national law for reasons of being too unclear and vague (Krämer, 2011).

6.3.2.4 Soft law instruments and capacity building

As indicated above (see 6.3.2), there is an increasing use of non-binding normative instruments instead of, or as a complement to, legally binding international law. Soft law instruments, such as charters, resolutions, declarations or recommendations or guidelines by the world community, have thus come to play an important role in the growth of international norms in environmental protection. The impact of non-binding soft law instruments should not be

Table 6 3 **Key European Union strategies and related directives. Source: EEA (2015e).**

Topic	Overarching strategies	Related directives
Biodiversity	Biodiversity Strategy to 2020	Birds Directive Habitats Directive Invasive Alien Species Regulation
Land and soil	Thematic Strategy on Soil Roadmap to a Resource-Efficient Europe	
Water	Blueprint to Safeguard Europe's Water Resources	Water Framework Directive Flood Risk Directive Urban Waste Water Treatment Directive Priority Substances Directive Drinking Water Directive Groundwater Directive Nitrates Directive
Marine	Integrated Maritime Policy including the Common Fisheries Policy and Blue Growth Strategy	Marine Strategy Framework Directive Maritime Spatial Planning Directive
Air	Thematic Strategy on air pollution	Ambient Air Quality Directive National Emission Ceilings Directive
Climate	European Union Strategy on Adaptation to Climate Change 2020 Climate and energy package	Renewable Energy Directive Biomass Directive Energy Efficiency Directive

underestimated since they can be effective by working indirectly, through persuasion and not coercion. Soft law often develops into a binding treaty or by being recognized as customary law (Ahmed & Mustofa, 2016).

Instead of creating rules and obligations that must be strictly followed, soft law creates goals and aspirations that States can strive to achieve. If a State fails to achieve the environmental objectives encompassed in a soft law document there is no recourse available or enforcement mechanism to force compliance. Despite these weaknesses there are certain advantages compared to hard law. While creating binding rules is often time-consuming and tends to undermine national sovereignty, soft law instruments provide alternative means to establish relationships and partnerships. These include more flexible solutions, which allows states to tailor their commitment to their particular situation and find compromises which can be more easily adapted to national contexts and under scenarios of uncertainty (Abbott & Snidal, 2000; Guzman & Meyer, 2010).

Soft law is, however, dependent on effective monitoring schemes for the fulfilment of the aim of adoption of such instruments, as well as improved financial incentives (Ahmed & Mustofa, 2016). There is an urgent need to develop financing opportunities and mechanisms for capacity building to support the implementation of soft as well as hard law. Currently general mechanisms such as voluntary contributions fund United Nations agencies, while multilateral development banks such as the Global Environment Facility provide more specific funding. Capacity building can also come in the form of programmes such as the Environmental Performance Review programme that assists countries in the improvement of their environmental management and performance (e.g. by way of the Global Environment Facility Trust Fund; UNECE, 2017d). Within the Arctic region the Arctic Council initiates assessments through its six permanent working groups, all of which are more or less relevant for biodiversity and ecosystem services, such as the Sustainable Development Working Group, the Arctic Monitoring and Assessment Programme and Conservation of Arctic Fauna and Flora. These assessments provide a better understanding of major issues related to sustainable human development in the Arctic, and identify priorities and develop policies and plans to address them. All in all, various forms of capacity building are necessary to enhance the compliance of environmental law at regional and national level, also in Europe and Central Asia.

6.3.2.5 Environmental rights approaches

Globally and regionally the link between environmental protection and human rights has been increasingly emphasized over recent decades (Anton & Shelton, 2011; Boyle & Anderson, 1996; Picolotti & Taillant, 2003). When it comes to human rights approaches to protecting human health or the environment, a distinction is commonly made between substantive environmental rights (a right to a healthy environment) and environmental rights, which are procedural in nature (Anderson, 1996). The most prominent example of the latter is the Aarhus Convention from 1998: Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters. Within Europe and Central Asia, the European Court of Human Rights in Strasbourg has in particular been developing the link between human rights and environmental performance under the Convention for the Protection of Human Rights and Fundamental Freedoms from 1950. A number of court cases, above all linking poor environmental performance by state authorities to human well-being and health aspects, have taken place over recent years with the Lopez Ostra case in 1994 as a starting point (Shelton, 2014; Turgut, 2007). Hence, the relevant instruments are global and regional human rights conventions with their protocols, which emphasize basic rights such as the right to health, property, equality, and respect for private and family life as well as binding multilateral environmental agreements. The latter often include participatory and benefit-sharing mechanisms, indicating participation in environmental decision-making as more or less a moral imperative (e.g., the Aarhus Convention, Convention on Biological Diversity, the Forest principles). Such environmental rights have thus become important policy instruments to legitimize both the procedures and outcome of environmental policy processes (Johansson, 2013).

In assessing the effectiveness of the human rights approach to environmental protection, it has been suggested that the approach is individualistic and anthropocentric, steeped in Western philosophy and does not adequately address the intrinsic value of the environment and ecosystems (Gearty, 2010; Grear, 2011). The concept of participation and its practice has also been subject to significant critique (Nabatchi, 2012; Nabatchi *et al.*, 2015; Nabatchi & Leighninger, 2015); participation is often applied with the intent to increase efficiency or support governmental reform and implementation and not as a component of environmental rights (Hovik *et al.*, 2010; Reimerson, 2013). Ever since the link between human rights and environmental protection was recognized in the 1972 Stockholm Declaration, three main options to further the interaction between human rights and environmental policies have been discussed. The first option would, based on human rights laws, include for example a right to a clean environment. The second option would be to leverage environmental laws, for better protection of human rights. The third option would be to fuse environmental law and human rights (UNEP, 2012). The recently adopted Sustainable Development Goals seem to be moving in this third direction and the implications are currently being debated among social science scholars (Williams & Blaiklock, 2016).

In sum, these human rights approaches provide an alternative means to environmental and health protection for individuals where domestic environmental regulation fails to take biodiversity and nature's contributions to people, as well as good quality of life, into consideration. This is also relevant in Europe and Central Asia, where the European Court of Human Rights in Strasbourg has substantiated such approaches through case law. Moreover, this rights-based approach, with its focus on participation and power relations and rights claimed by citizens, has the potential to contribute to social action among indigenous peoples and local communities. The approach centres around principles such as equality, environmental justice and the identification of how, why and to what extent certain individuals or groups may be marginalized in formal and informal processes and actions (Dehm, 2016). The literature does, however, emphasize the complex trade-offs that exist between human well-being and biodiversity conservation goals (McShane *et al.*, 2011).

6.3.2.6 International standards on indigenous peoples and local communities

Over the last two to three decades the rights of indigenous peoples have been increasingly acknowledged and strengthened within the international legal system (Åhrén, 2016; Anaya, 2004; Xanthaki, 2009), a prominent example being the adoption of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) in 2007. Indigenous peoples' international status has also rapidly evolved from being viewed as objects of protection towards acceptance as self-governing nations who wish to preserve their culture and ways of life (Heinämäki, 2015). Hence, indigenous rights to self-determination, equality, non-discrimination, health and cultural matters are recognized internationally as well as in domestic legal systems – also within Europe and Central Asia.

In northern Europe, the Nordic Sámi are organized transnationally via the Sámi Council, while across Central Asia there are numerous indigenous communities and the Russian Association of Indigenous Peoples of the North is a key organization in the North, Siberia and Far East in Russia. Across Europe and Central Asia indigenous peoples and local communities represent a plethora of languages and livelihood practices. Within the Arctic there are trends of increased indigenous empowerment and improved local political and economic autonomy (Larsen & Fondahl, 2015). For the involvement of indigenous peoples' organizations in the Arctic of Europe and Central Asia, see Arctic Council under Section 6.3.2.2.

A specific contentious issue, in particular with respect to resource developments within indigenous traditional areas, are the land rights of indigenous peoples, including their possession over lands and traditionally used natural resources (Allard, 2015; Bankes & Koivurova, 2013; Gilbert, 2016). The right to be consulted or the "free prior and informed consent" of indigenous communities (UNDRIP, Articles 19, 28, 32) are instrumental when developments impact on biodiversity, nature's contributions to people, and good quality of life in traditional territories. The "free prior and informed consent" is a tool used to mitigate harmful effects on a specific community and its livelihood, including uneven power structures. Such tools rest on a notion that indigenous peoples are self-governing powers *vis-a-vis* the State, i.e. based on a "nation-to-nation" approach, which is not expected for minorities within international law (Anaya, 2004; Newman, 2014). As a result, partnerships with indigenous groups have created co-management regimes of certain protected areas, such as the United Nations Educational, Scientific and Cultural Organization's World Heritage site Laponia in northern Sweden (Reimerson, 2015).

The traditional ecological knowledge of indigenous peoples and local communities is increasingly being recognized in the area of conservation and sustainable use of natural resources (Hernandez *et al.*, 2014). Hence, international standards for environmental governance are focusing on decentralization and local influence, promoting public participation, and stressing the important role of indigenous peoples and local communities in natural resource and conservation governance and management (Fauchald *et al.*, 2014; Heinämäki, 2009; Lemos & Agrawal, 2006; Lindroth & Sinevaara-Niskanen, 2013; Reed, 2008). The Convention on Biological Diversity and its ecosystem approach, and the "new paradigm" established under the auspices of the International Union for Conservation of Nature, are of particular importance in this development. Article 8(j) of the Convention, and its related provisions, stress the importance of including indigenous peoples and local communities in nature conservation efforts.

International and non-governmental organizations, not least the Convention on Biological Diversity and the International Union for Conservation of Nature, have been fundamental to indigenous claims (Brosius, 2004; Fourmile, 1999; Posey, 1996; Richardson, 2001; Schroeder, 2010). The changing approaches towards indigenous peoples in international frameworks for natural resource and conservation governance are largely a result of those efforts. The outcomes of the International Union for Conservation of Nature's World Parks Congresses in 2003 and 2014 were a result of the broad mobilization of indigenous peoples demanding that protected areas recognize their rights, responsibilities, and contributions to conservation (Brosius, 2004; Stevens, 2014).

Indigenous peoples' organizations, however, continue to criticize international authorities for failing to fulfil their targets and obligations to indigenous peoples (Forest Peoples Programme, 2008, 2011, IIFB, 2006, 2008, 2010, 2012, 2014). Traditional power structures and conservation ideals are still present in protected area policy and practice (Benjaminsen & Svarstad, 2010; Sandlos, 2014; Wilshusen *et al.*, 2002), and national and local implementation of international standards often proves challenging (Benjaminsen & Svarstad, 2010; Koivurova & Heinämäki, 2006; Lane, 2003; Lane & Corbett, 2005; Minter *et al.*, 2014; Paulson *et al.*, 2012; Schroeder, 2010). Furthermore, indigenous peoples are largely left outside the development of treaty texts and the implementation of the treaties and, when included, they are often considered only holders of traditional knowledge. This risks reproducing discourses or ideas prioritizing conservation objectives over indigenous rights and reducing the ways indigenous peoples may influence the decision-making within the context of international treaties (Agrawal, 1995; Berkes, 2009; Berkes *et al.*, 2000; Reimerson, 2013; Turi & Keskitalo, 2014). This is also important for Europe and Central Asia with its different indigenous peoples and local communities and their varying historical legacies.

6.3.2.7 Information-based instruments building on private and business initiatives

There is increasing recognition of the need to enhance the use of economic instruments, such as market-based incentives, to complement traditional regulatory policy instruments at the international as well as national level. This is justified in assuming that such instruments are more efficient than traditional regulatory instruments, in particular when it comes to the implementation of multilateral environmental agreements. However, with the exception of payments for ecosystem services schemes, the adoption of economic instruments has mainly been advocated in developed countries, while their uptake in developing countries and countries in transition has been limited. This can partly be explained by the lack of capacity, in these countries, to design and implement economic instruments due, for example, to unclear property rights (Karsenty & Ongolo, 2012). Yet, the increasing uptake of economic instruments in the global environmental arena has opened up for various forms of sustainability standards, such as certification schemes, voluntary corporate initiatives, public-private partnerships, and transparency-based reporting schemes (Cashore, 2002; Derkx & Glasbergen, 2014; Glasbergen *et al.*, 2007; Gulbrandsen, 2014; Johansson, 2014).

In particular, voluntary and market-based certification schemes have emerged as innovative and dynamic institutions for non-State governance. Various certification schemes have been proposed and their number has grown rapidly over the last two decades. This has been largely in response to public failures to halt deforestation, depleting fish stocks (Gulbrandsen, 2010), and unsustainable production and consumption of a variety of commodities (Auld *et al.*, 2008), and certification has become an institutionalized governance approach to sustainable development (Visseren-Hamakers *et al.*, 2012). Today, consumers encounter organic or fair-trade labels on a variety of products, implying improved environmental conditions or more equitable market transactions (Auld, 2014).

Although such initiatives have been driven by private institutions, evidence suggests that the regulatory system and the political and administrative culture have influenced their adoption in different countries. This implies that the legal, socio-economic and political contexts may facilitate or hinder successful implementation in different sectors. For successful implementation, well-functioning legal systems and property rights must work, especially since private instruments are supposed to supplement, not replace, domestic legislation and enforcement (Gulbrandsen, 2010). Consequently, private instruments may not enhance the overall protection of natural resources in regions where government institutions are weak. At the same time, other aspects are also important here, such as the size and structure of the industry in the specific country, ownership of the resource (private vs public), and export dependence (Cashore *et al.*, 2004).

Analyses of previous research on various private social and information-based instruments confirm this picture, but show a relatively uneven distribution of uptake and effectiveness in different sectors (Auld, 2014; Gulbrandsen, 2010; Pirker *et al.*, 2016; Visseren-Hamakers *et al.*, 2015), and considerable variability among the social and distributive impacts of these instruments (Biermann & Gupta, 2011; Schouten & Glasbergen, 2012). For instance, certification schemes are important private alternatives, not least for the formulation of forest policies to halt deforestation, and such initiatives have received significant scholarly attention. One of the most well-known examples, the stakeholder-driven Forest Stewardship Council – attentive also to indigenous rights – has to date certified 48.2% of total FSC-certified area (94,389,400 ha) in Europe and Central Asia (FSC, 2017). Despite the considerable academic attention they have received, the sustainability impacts of forest certification standards, in terms of tangible change on-the-ground, is largely unknown (Johansson, 2013; Visseren-Hamakers *et al.*, 2015; Visseren-Hamakers & Pattberg, 2013).

6.3.3 Responses to transboundary environmental challenges

This section examines challenges related to the governance of ecosystems and the implementation of ecosystem-based management approaches across country boundaries and provides examples of regional cooperation. The focus is on broad ecosystem types and issues: groundwater and freshwater degradation and restoration, marine and coastal ecosystems, and invasive species. Each issue is examined under the headings, where relevant, of binding legal instruments, environmental rights approaches, soft law instruments and capacity building, and intergovernmental organizations. For responses to transboundary environmental challenges related to land degradation, we refer to the global IPBES Assessment on Land Degradation and Restoration, in particular Chapters 6 and 8 and the recently published reports of the Economics of Land Degradation Initiative (ELD Initiative, 2015a, 2015b). One regional report of the latter initiative has been dedicated to a synthesis of national studies in Central Asia (Quillérou *et al.*, 2016).

6.3.3.1 Groundwater and freshwater degradation and restoration

Groundwater and freshwater degradation processes are not constrained by national boundaries and are affected by cross-boundary policies and activities. This obligates cooperation and coordination in matters of natural resource management. Nevertheless, such collaborations are not very common (Saunders & Briggs, 2002). The capacity of freshwater systems for nutrient cycling and nutrient removal is particularly valuable in Europe because of the heavy pressure placed on water by human populations (Chapter 2, Section 2.2.1.7). At present, surface and groundwater availability is expected to decrease in many countries due to changing precipitation patterns and higher evapotranspiration (Chapter 5, Section 5.2.3.2). This trend will endanger habitats that depend on surface water dynamics, whereas those dependent on groundwater dynamics and water balance would be more buffered against hydrological stress (Chapter 5, Section 5.6.1).

6.3.3.1.1 Binding legal instruments

Challenges with regard to water resources in Europe and Central Asia call for integrative transboundary cooperation. In Central and Western Europe such efforts mainly rely on implementation of a number of policies and practices, including water pricing, efficient use of water, action against illegal water abstraction, measures to promote restoration and sustainable development (EEA, 2000, 2010). While in Central Asia, efforts rely merely on the principle of sustainability applied conjunctly by local governments and the coordinating support of international regulatory programmes (GIZ, 2013; GWP, 2014). However, constrained public human and financial resources dramatically limit the implementation of multilateral environmental agreements, which is thus heavily dependent on external cooperation and support (e.g. ERP Tajikistan, UNECE, 2012).

Nonetheless, in Central Asia the World Heritage Convention (and possibly Ramsar Convention) has been used to prevent transboundary impacts (e.g. impacts from hydropower planned in Mongolia on Lake Baikal in Russia (UNESCO, 2017). Both conventions include special provisions guiding parties on how to prevent damage to designated sites in other countries (UNESCO, 2016). Southern Caucasus countries have also signed conventions on watershed management, and while a report from the Global Water Partnership noted that a focus on integrated water resource management is not generally applied in the Caucasus, the water sectors in many of the countries are undergoing reform and new legislative water codes have been developed (GWP, 2014).

The importance of joint management of transboundary rivers and lakes to address water resource shortage and deterioration has long been recognized by governments. One of the oldest examples of an intergovernmental agreement to manage joint water bodies is the Albufeira Convention that dates from the 18th century. Nonetheless, it was not until 1992 that joint international governance mechanisms in United Nations Educational, Scientific and Cultural Organization regions were established, leading to the establishment of the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (also known as the Water Convention), which protects and ensures the quantity, quality and sustainable use of transboundary water resources through facilitated cooperation. Conservation and restoration of freshwater ecosystems is a specific obligation under this convention, which requires parties to take "all appropriate measures" to this end, including the establishment of water-quality objectives and criteria, and the development of concerted action programmes for the reduction of pollution. This convention has currently 42 signatories from Europe and Central Asia, but Kyrgyzstan, Tajikistan, Kazakhstan, Georgia and Turkey have not yet ratified it, due mostly to historical conflict issues (UNECE, 2011). Despite the fact that the status of these waters is now improving, transboundary water resources remain "*under great stress as a result of poor management practices, pollution, overexploitation, unsustainable production and consumption patterns, hydromorphological pressures, inadequate investment in infrastructure and low efficiency in water use"* (UNECE, 2011).

The European Union Water Framework Directive (Directive 2000/60/EC; European Community, 2000) was established to contribute to the implementation of community obligations under international conventions on water protection and management, notably the 1992 Water Convention. The river basin approach and the focus on ecology and sustainable use of water are the core innovative aspects of this directive. A similar focus is also to be seen in the Floods Directive (2007/60/EC; European Union, 2007b). The basin approach is applied for the protection of groundwater in about 600 transboundary aquifers, against pollution and deterioration, under Directive 2006/118/EC (European Union, 2006). This Directive establishes specific criteria for the assessment of good groundwater chemical status and criteria for the identification and reversal of significant and sustained upward trends and for the definition of starting points for trend reversals. This directive also complements the provisions preventing or limiting inputs of pollutants into groundwater already contained in the European Union Water Framework Directive, and aims to prevent the deterioration of the status of all bodies of groundwater.

The European Union Water Framework Directive, Article 3.4, stipulates a general obligation for the member States to cooperate. However, it does not prescribe any concrete instruments to shape this cooperation, nor does it provide exemptions in case of not achieving the results by a member State because of certain acts or omissions of another member State (Gilissen *et al.*, 2010). This often leads to problems between member States that have different systems and governmental responsibilities for water management.

6.3.3.1.2 Environmental rights approaches

The right to drinkable freshwater was first suggested as a binding law in the World Summit on Sustainable Development in Johannesburg in 2002 and was also a target in the Millennium Development Goals (Scanlon *et al.*, 2004) and now the Sustainable Development Goals. The environmental rights to terrestrial systems are mainly allocated to indigenous communities as defined by the United Nations Human Rights Office as "rights to their lands, territories and resources" (UNOHCHR, 2013). Under this perspective the natural habitat of indigenous people should also be preserved, except when the indigenous community is overexploiting their natural habitat (Kaapcke, 1994; Mustonen *et al.*, 2011; Roberts, 1992).

Rights of indigenous peoples and local communities to subsistence use of lands and natural resources, including subsistence fisheries, have been widely recognized in resource management systems of the northern parts of the Europe and Central Asia region. Presently, however, these rights are being reduced due to, for example, progressive resource privatization and increased population pressure (Simonov & Simonova, 2016).

6.3.3.1.3 Soft law instruments and capacity building

Although scientific research on transboundary preservation issues is fairly comprehensive, the actual implementation of management recommendations is commonly hindered by the absence of funding mechanisms. In addition, the definition of freshwater and its restoration are subjects of debate, even among researchers and organizations, with consequent implications for the development of common policy options (McDonald *et al.*, 2016).

The Central Asia subregion has a well-established, although limited, legal framework for inter-State cooperation in the management and use of transboundary water. From a legal point of view, it includes both binding instruments and numerous semi-formal arrangements and documents that are merely recommendations, i.e. soft-law instruments. Regional agreements of a general nature are in place, as well as several bilateral agreements on practical issues relating to specific watercourses or areas of interaction. However, the river-basin approach is not reflected in the existing agreements. The legal framework does not properly establish the hierarchy and mechanisms for the coordination and collaboration of the existing institutions, does not clearly delineate their competence and does not pay sufficient attention to reporting procedures, decision-making processes, implementation and enforcement (UNECE, 2011). A testing time for existing mechanisms came in 2016 when Kyrgyzstan suspended its participation in the International Commission for Sustainable Development, as Tajikistan started to build a major hydropower dam (Rogun HPP) without consent of downstream countries. This signifies that existing arrangements are subject to amendment and that some of the transboundary water management regimes may deteriorate due to divergent interests of parties.

Transnational cooperation on ecosystem-related topics is important for defining problems, obtaining information, and pursuing joint solutions. Examples include the prevention of water pollution in Russia-Mongolia and Russia-China relations (see supporting material Appendix 6.2[3] Table 6.2.1) in the context of the Amur River basin. However, despite Amur's importance for biodiversity, fisheries and food production, wetlands conservation or climate change adaptation, international treaties that have been signed to date have not been able to provide a solid basis for a holistic river basin management. It has been argued that the health of river ecosystems is yet to become a real practical priority in bilateral water management agreements and management efforts in Central Asia (Simonov & Egidarev, 2017).

6.3.3.1.4 Intergovernmental organizations, programmes and projects

An example of project facilitation across intergovernmental organizations is the World Bank and its Global Environment Facility, which promotes the Central Asia Transboundary Biodiversity Project, between Kyrgyz Republic, Kazakhstan and Uzbekistan. The United Nations Economic Commission for Europe is also engaged in transboundary regions preservation, within its regional dialogue and cooperation on land and water resources in Central Asia; aimed in particular at the Alazabi/Ganyykh basin and the Syr Darya (Aral Sea) Basin (UNECE, 2015c). A similar programme for the Isfra river basin is being coordinated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, which is synchronizing bilateral transboundary preservation operation between the Kyrgyz Republic and Tajikistan with the financial support of the European Union (GIZ, 2013).

6.3.3.1.5 Private and business initiatives

A recent report of the Economics of Land Degradation initiative highlighted that the returns from sustainable land management are realized through the use of robust economic valuation methodologies (ELD Initiative, 2015b). Those returns are provoking the private sector to promote economic growth, food security and sustainable livelihoods and to reduce conflict over natural resources. The scope of institutions set up at the river basin often includes groundwater management, in particular where aquifer boundaries do not follow the boundaries of the river basin. Where groundwater does not follow a particular river basin, a water framework plan is assigned with integrated valuation to the nearest or most appropriate river basin. Less frequently, a mechanism is set up specifically at the aquifer level concerning potential trade-offs and power relations (Mechlem, 2016).

Transboundary associations of non-governmental organizations' activists and experts identify and draw attention to transboundary ecosystem degradation problems and policy solutions are illustrated by the recent report on integrated flood management options prepared by several non-governmental organizations and expert bodies for the transboundary Amur River Basin published by the World Wide Fund for Nature (Simonov *et al.*, 2016a, 2016b).

There is a widely recognized gap in existing regulations on spatial planning of industrial activities, especially in a transboundary context. Often industrial facilities (such as hydropower plants, cement plants or coal mines) are placed at inappropriate locations where they cause huge damage to biodiversity and ecosystem services. Strategic assessments of sectoral development schemes and programmes are often employed to direct development away from sensitive areas. A good example of this is the strategic assessment of basin-wide hydropower impacts performed jointly by companies and non-governmental organizations for the Amur River Basin (Simonov *et al.*, 2015, see also Section 6.5.4).

6.3.3.2 Marine and coastal systems

Transboundary issues are particularly relevant for marine and coastal ecosystems where processes can impact huge areas that do not adhere to any clear political

3. Available at https://www.ipbes.net/sites/default/files/eca_ch_6_appendix_6.2_responses_to_transboundary_environmental_challenges_.pdf

or administrative boundaries. An essential feature of ecosystem-based management is that account is taken of aggregate pressures and impacts rather than just analyzing individual pressures and impacts in isolation. This also implies conducting the analysis across an entire ecosystem's range rather than just for parts of it (i.e. instead of within member State political boundaries). As pointed out by the European Environment Agency (EEA, 2015d), it is a significant challenge to properly account for cumulative pressures and impacts across such large areas, especially because not accounting for these cumulative pressures and impacts poses tremendous risks to adequately assessing ecosystem health and safeguarding key ecosystem services.

This fact is recognized by the existence of a number of Regional Sea Conventions and international organizations that monitor the status of the marine environment and the level of pressures from different sectors or sources, on regional marine and coastal ecosystems. The following section outlines the major instruments and approaches employed to facilitate cross-border protection of marine ecosystems and the transboundary challenges that need to be overcome in order to facilitate more effective governance and protection.

6.3.3.2.1 Binding legal instruments

The key binding legal instrument in the European Union aimed at formalizing an ecosystem-based approach to marine environmental management is the European Union Marine Strategy Framework Directive. It is important from a transboundary perspective as it specifically requires regional and transboundary cooperation (European Union, 2008, Article 5.2). Article 10 also specifically refers to the Regional Sea Conventions: "*Member States shall take into account the continuing application of relevant existing environmental targets laid down at national, community or international level in respect of the same waters, ensuring that these targets are mutually compatible and that relevant transboundary impacts and transboundary features are also taken into account, to the extent possible*". In addition to the European Union Marine Strategy Framework Directive, the European Union's Maritime Policy Action Plan recognizes that efforts to coordinate current sectoral policies require integrated and cross-cutting actions that operate across national boundaries. The action plan recognizes the fact that an integrated maritime policy requires a governance framework that applies the integrated approach at every level, as well as horizontally and with the use of cross-cutting policy tools.

There are a number of key conventions aimed at fostering transboundary marine protection in Europe and Central Asia (see supporting material Appendix 6.2[4] Table 6.2.2).

4. Available at https://www.ipbes.net/sites/default/files/eca_ch_6_appendix_6.2_responses_to_transboundary_environmental_challenges_.pdf

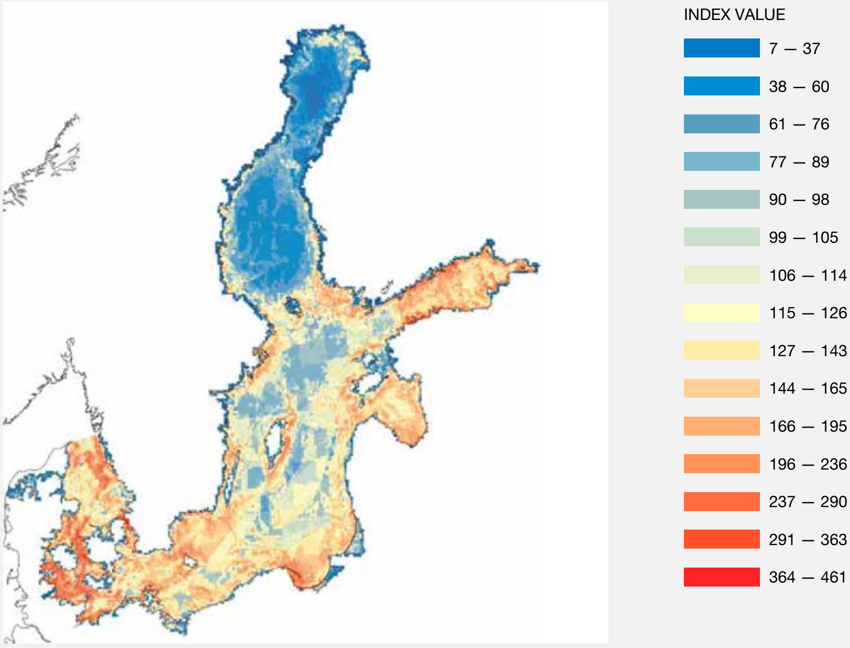
The Regional Sea Conventions have demonstrated that it is possible to develop an integrated ecosystem assessment on a regional scale. The Baltic Marine Environment Protection Commission (HELCOM, 2010), for example achieved this under the Helsinki Convention by harmonizing and combining maps of ecosystem features with maps of pressures resulting from human activities in a combined spatial analysis that crosses national jurisdictions. This allowed for a spatial description of the relative impacts of human activities across the Baltic Sea **(Figure 6.3)**.

The Regional Sea Conventions have been seen to be successful in the joint management and conservation of large marine areas, but an early report by the United Nations Environmental Programme on their success did warn that "*In many regions the level of expertise and facilities available for the actual implementation and conduct of the agreed action plans is limited*" (UNEP, 1982). More recently Mackelworth (2016) notes that while modern conservation principles are explicitly incorporated or implicitly applied under the relevant regional instruments, they still require further operationalization and consistent application by all organizations and countries involved. Rochette and Chabason (2011) also highlighted the differences in regional arrangements and fragmented international governance in limiting the success of the conventions. An assessment of management effectiveness by Van Lavieren and Klaus (2013) revealed variable levels of performance across the members and the authors recommended the adoption of the Regional Protocol on Biological Diversity and Specially Protected Areas.

6.3.3.2.2 Soft law instruments and capacity building

Softer forms of international cooperation for the joint management and conservation of the seas include the Trilateral Wadden Sea Cooperation. Since 1978, the Netherlands, Germany and Denmark have cooperated to protect the Wadden Sea as an ecosystem. The guiding principle of the Trilateral Wadden Sea Cooperation is to "*achieve, as far as possible, a natural and sustainable ecosystem in which natural processes proceed in an undisturbed way*". The Cooperation is based on the "Joint Declaration on the Protection of the Wadden Sea", which was first signed in 1982 and then updated in 2010. The Joint Declaration is a declaration of intent, including objectives and areas of cooperation, as well as institutional and financial arrangements. For over 30 years, the Cooperation has united partners from politics, nature conservation, science and administration, along with local stakeholders, who together represent an enormous store of knowledge and experience. It is a unique example of effective transboundary ecosystem-based collaboration to jointly conserve a World Heritage site (Common Wadden Sea Secretariat, 2017).

Figure 6 3 **Baltic Sea Impact Index (BSII) showing the potential impact of anthropogenic pressures. Source: HELCOM (2010).**



Through its European Neighbourhood Policy, the European Union works with its southern and eastern neighbours to achieve the closest possible political association and the greatest possible degree of economic integration. The European Neighbourhood Policy is a key part of the European Union's foreign policy. Partner countries have agreed on a European Neighbourhood Policy action plan or an Association Agenda with the European Union demonstrating their commitment to, amongst other issues, environmental protection and sustainable development. In particular, this intergovernmental policy seeks to strengthen marine environment protection across borders with the European Union by "*better preserving shared natural resources and improving conditions for fisheries*" and by ensuring "*the protection of shared seas and river basins*". The European Neighbourhood Policy is a jointly owned initiative and its implementation requires action on both sides, by the neighbouring state and by the European Union. There are currently 16 neighbouring states involved including, Jordan, Israel, Georgia, Armenia and Azerbaijan (Wesselink & Boschma, 2017).

6.3.3.2.3 Private and business initiatives

The use of ecolabels and certificates of sustainability may be an effective means of promoting more sustainable practices in shared marine waters for wild-captured fisheries, but also for the aquaculture industry. Companies may also employ instruments other than eco-labels such as green procurement (Runhaar, 2016). According to estimates, there are over 400 existing ecolabels marking consumer products worldwide (Golden, 2010). The marine-based ecolabels tend to certify sustainability of caught or farmed marine seafood. For example, Unilever and the World Wide Fund for Nature joined forces in 1997 to create the Marine Stewardship Council. The Council is a non-profit organization that has developed a global environmental standard for sustainable fishing. Some of the standards measured by the Marine Stewardship Council (MSC) include the maintenance of sustainable fish populations and the minimization of environmental impacts. At present, 286 certified fisheries can be found in 36 countries, accounting for 10% of all global catch (92 still in assessment) and there are 37,121 sites with chain-of-custody certification which assures consumers and seafood-buyers that MSC-labelled seafood comes from a certified sustainable fishery (Marine Stewardship Council, 2016). Although overfishing and depletion of global fish stocks continue, there are indications that, in Marine Stewardship Council-certified fisheries, some improvements are being made in fisheries management and practices (Agnew *et al.*, 2014; Gulbrandsen, 2010).

6.3.3.2.4 Assessment of transboundary challenges in marine and coastal areas

Hanley and co-authors (2015) point out that the integration of economic and biophysical ecosystem service valuation into marine policy formation remains challenging due to the fact that these ecosystems tend to be large, and often overlap multiple political jurisdictions. The authors also point to the fact that, even in the European Union, where an integrated institutional framework exists for the governance of regional seas in the form of the Marine Strategy Framework Directive, member States have not yet been able to collaborate in an effective manner at the regional seas level when carrying out the assessment work that is a requirement of the Directive. Elsewhere Oinonen and co-authors (2016) point out that several of the descriptors of "good environmental status" under the Marine Strategy Framework Directive are already regulated by existing legislation and recommend that economic analysis for the implementation of the Marine Strategy Framework Directive should place particular emphasis on those descriptors that are not covered by any other piece of legislation, such as underwater noise and marine litter.

The political commitment to cooperative management by the Governments of countries bordering regional seas is a fundamental requirement for success of any agreements aimed at the implementation of environmental protection measures. This regional cooperation translates into the meaningful exchange of information across countries. Many marine ecosystems and the environmental pressures and impacts acting upon them are transboundary in nature. Therefore, the information and databases needed to identify these pressures must cover all of the ecosystems in question rather than the parts of it that lie within a country's border.

It is also recognized that the effective management of marine ecosystems requires the use of cost-benefit analysis and cost-effectiveness analysis to ensure the sustainable use of marine resources (European Union, 2008, Article 8). These economic tools can also help to identify cost-effective approaches and abatement options to protect or restore the provision of marine ecosystem services. It has been pointed out elsewhere (Oinonen *et al.*, 2016), however, that if cost-effectiveness analysis were to be carried out at the regional seas level, more cost-effective abatement alternatives may present themselves that might not be obvious at the individual member State level. This could result in more cost-effective alternatives being chosen to achieve the environmental goals.

It is worth noting that a report by the United Nations Development Programme (UNDP, 2015) points out that starting regional cooperation initiatives in geographical areas with little experience of an inter-State cooperation requires a discussion of possible institutional models of the future interstate regional cooperation to be developed. It gives the example of the Aral Sea Basin where many regional cooperation organizations operate with rules and procedures that are a mix of the approaches from the former Soviet centralized system and are partly based on the principles of the cooperation between the independent States. Ultimately, the success of any transboundary conservation instrument will depend on the effective collaborate of the bordering parties.

6.3.3.3 Invasive alien species

Invasive alien species are a major concern within Europe and Central Asia. However, their control is complex and, in many cases, difficult to handle with legal instruments. This situation is reflected in a vague text on invasive alien species from the thirteenth meeting of the Conference of the Parties to the Convention on Biological Diversity in Cancún, Mexico (CBD, 2016a). Achieving Aichi Biodiversity Target 9 on preventing and controlling invasive alien species is likely to be a considerable challenge.

Trade and transport are important factors affecting the introduction and spread of invasive alien species (Hulme, 2009; Pyšek *et al.*, 2012), with the amount of exchanged commodities expanding more than 30-fold since 1950 (WTO, 2013). In addition to the direct effects of trade on the spread of invasive alien species, new transport corridors and enlarging of existing ones supports an upsurge of introductions. The Suez Canal recently underwent a major enlargement (Suez Canal Authority, 2016), and the expansion of the Panama Canal was intended to double its capacity and transit vessels three times as big as possible in 2015. A third canal may also be built, across Nicaragua. While global trade and shipping are vital to society, existing international environmental agreements also recognize the urgent need for sustainable practices that minimize the unwanted impacts and long-term consequences of bio-invasions – these are essentially transboundary issues.

6.3.3.3.1 Binding legal instruments

The need to tackle biological invasions, to develop a common policy and to establish an early warning system, has been recognized at European Union level, for example by the European Commission (i.e. Communication "Towards an EU Strategy on Invasive Species" - European Commission, 2008) and EU Biodiversity Strategy to 2020. Other instruments recognizing the spread of invasive alien species are listed in **Table 6.4**.

Many countries in Europe and Central Asia have only scattered legislative or advisory tools (e.g. codes of conducts; Caffrey *et al.*, 2014; Halford *et al.*, 2014; Heywood & Brunel, 2011). The United Kingdom is the exception with its invasive non-native species strategy and dedicated secretariat.

6.3.3.3.2 Soft law instruments and capacity building

Several bodies serve in an advisory capacity concerning monitoring, research and management of alien species across national boundaries at both global and regional levels. These include the European Environment Agency and the European Invasive Species Specialist Group of the International Union for Conservation of Nature. At the

Table 6 4 **Instruments for addressing invasive alien species. Source: Own representation.**

Policy area	Instrument title	Responsible institution	Description
European Union	The Habitats Directive	European Commission	Directive 92/43/EEC lists over 1,000 animal and plant species, as well as 200 habitat types under protection. Its sole mention of non-native species pertains to provision for supplementary measures to govern their possible introduction.
Mediterranean Sea	Barcelona Convention	United Nations	Adopted in 1976, amended in 1995 and came into force on 9 July 2004. An Action Plan concerning species introductions and invasive species in the Mediterranean Sea was adopted in 2003 (UNEP, n.d.), and again in 2016 (UNEP, 2016b).
Western, Central and Eastern Europe	Bern Convention	Council of Europe	The Standing Committee of the Bern Convention recommended in 2003 that Contracting Parties implement national strategies on invasive alien species and co-operate in the prevention, mitigation and eradication of invasive alien species, where feasible and practical.
European Union	European Union Regulation 1143/2014 on Invasive Alien Species	European Commission	Entered into force January 1st 2015. It is an important instrument setting out the provisions and responsibilities concerning invasive alien species of Union, regional and member State concern.
Mediterranean	The Barcelona Convention	European Commission	The convention provides seven protocols to address specific aspects of Mediterranean environmental conservation including marine biological diversity and pollution from exploration and exploitation offshore.
European seas	European Union Marine Strategy Framework Directive	European Commission	Acknowledges the critical role of vectors in biological invasions and considers it crucial to manage the pathways.
Caspian Sea	Ballast Water Management Convention	International Maritime Organization	Under the Convention's terms, ships will be required to manage their ballast water to remove, render harmless, or avoid the uptake or discharge of aquatic organisms and pathogens within ballast water and sediments. However, IMO's guidelines for the control and management of ships' biofouling, is voluntary.

international level, there is a long-lasting cooperation in the field of phytosanitary, veterinary and pest management regulatory principles through the European Plant Protection Organization, European Food Safety Authority and the United Kingdom Department for Environment, Food and Rural Affairs. Similarly, these agricultural branches have efficient domestic regulations based on a long history leading to effective monitoring and management of pests.

Present national and regional inventories of alien species are heterogeneous in terms of their spatial, temporal and taxonomic coverage as well as their accuracy. At continental level notable datasets include the European Network on Invasive Alien Species (NOBANIS, 2017) or Delivering Alien Invasive Species Inventories for Europe (DAISIE, 2017). The new European Union invasive alien species regulation calls for a centralized information system collating the existing information on alien species in the Union and allowing access to information on the presence of species, their spread, ecology, invasion history and all other information available. This was partly achieved by Delivering Alien Invasive Species Inventories for Europe, which initiated the collection of data from adjacent non-member States and less developed countries. Recently, a data aggregating portal linking some existing national and continental sources was constructed through The European Alien Species Information Network (EASIN, 2017).

The recent meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols (Barcelona Convention) adopted an action plan and monitoring and assessment programme that ostensibly deals with non-indigenous and invasive species (UNEP, 2016a, 2016b). Though replete with expressions of concern for the Mediterranean marine environment, neither document deals with the most significant pathway and the majority of the invasive alien species.

The spread of invasive alien species along trade routes such as the "new silk road" which, if successful, may soon triple or quadruple trade in Europe and Central Asia, is expected to lead to accelerating biological invasions (Ding *et al.*, 2008; Zhang & Jiang, 2016). Responding to these developments, the China Ministry of Environment already started research on possible ways to control the spread of invasive or exotic species in the region in 2015. Given that great numbers of marine and terrestrial invasive species may come to Europe and Central Asia from East Asia this is considered a timely effort that may need focused international cooperation in the realm of the Shanghai Cooperation Organization, China-European Union cooperation and other multilateral platforms.

6.3.3.3.3 Assessment of challenges related to invasive alien species

Current legislative and management efforts have failed to address the introduction and spread of invasive alien species in terrestrial, inland aquatic and marine environments across Europe and neighbouring regions for a number of reasons (Galil *et al.*, 2018; García-de-Lomas & Vilà, 2015; Genovesi *et al.*, 2015; Hulme, 2009):

1. The European Union invasive alien species regulation should focus on preventive actions concerning vectors and pathways of introductions, in addition to control and mitigation measures of significantly-impacting invasive alien species already present.
2. International cooperation is insufficient.
3. Transboundary impacts of man-made corridors of introduction are neglected.
4. Transfer of best-practice management in dealing with invasive alien species lacks support (e.g. use of chemical treatment).
5. Border control is limited.
6. Timely information exchange of invasive alien species distribution and their impacts is lacking.

Mediterranean countries have not taken sufficient measures to address biosecurity hazards relating to movement of stock, feed, and equipment that may result in the introduction of marine invasive alien species (CIESM, 2007; Golani *et al.*, 2015; Marchini *et al.*, 2016) or illegal introductions. The appearance of five non-indigenous prawn species in the Mediterranean, all of commercial interest and newly recorded in the past decade, suggest intentional introduction, particularly as these species have been found in the vicinity of fish and shellfish farms. The European Union established a legal framework to limit the environmental risks related to the introduction and translocation of non-native species in aquaculture (European Union, 2007a) but, as it pertains only to member States, and is unevenly regulated even in those countries, illegal introductions and intra-national translocation of shellfish stocks (and their associated biota) continue to contribute to the introduction and spread of marine invasive alien species in the Mediterranean Sea (Bakir & Aydin, 2016).

6.4 ENVIRONMENTAL AND CONSERVATION POLICIES IN EUROPE AND CENTRAL ASIA

6.4.1 Policies for biodiversity and nature conservation

6.4.1.1 Policy objectives

Nature conservation and biodiversity policy objectives usually relate to the following four major areas: i) the conservation of nature and biodiversity; ii) the sustainable use of biological resources; iii) the fair and equitable sharing of the benefits from the use of genetic resources; and iv) the restoration of degraded ecosystems. Although these objectives are at first sight policy objectives of the conservation sector only, mainstreaming the conservation and sustainable use of biodiversity into national sectoral and cross-sectoral strategies, policies, plans and programmes is a priority of both international and European Union biodiversity strategies (European Commission, 2011a; CBD, 2011). This section will address the first and, to some extent, the third objective, while sustainable use will be dealt with in Section 6.5, especially agriculture, forestry and fisheries. The fourth objective, ecosystem restoration, is becoming ever more important due to unabated land-use intensification and land degradation in many parts of Europe and Central Asia (see Chapter 4, Section 4.5). As this topic is comprehensively assessed in the IPBES Land Degradation and Restoration Assessment (see Chapters 6 and 8 for response options), it is only shortly addressed here (see also Quillérou *et al.*, 2016, for a synthesis on the economics of land degradation for Central Asian countries).

In Europe and Central Asia, nature and biodiversity conservation activities are embedded in a complex network of international and regional objectives and targets. At the international level, several biodiversity-related conventions and strategies promote the implementation of the Convention on Biological Diversity (CBD, 2010), such as the Ramsar Convention, the Convention on International Trade in Endangered Species of Wild Fauna and Flora or the Convention on the Conservation of Migratory Species of Wild Animals (see Section 6.3 and supporting material

Appendix 6.1[5], Table 6.1.1 on Multilateral Environmental Agreements). The United Nations Strategic Plan for Biodiversity (2011 – 2020) includes the 20 Aichi Biodiversity Targets to promote the implementation of the Convention on Biodiversity. These targets cover the protection of biodiversity from anthropogenic pressures, the distribution of benefits from biodiversity and ecosystem services and the enhancement of implementation through participation, knowledge management and capacity-building. In Europe and Central Asia an increasing number of countries have become Parties to the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization, which is addressed in Aichi Biodiversity Target 16. By 2014, when the Nagoya Protocol entered into force, eight parties to the Protocol (15%) in Europe and Central Asia had ratified the Protocol, while by 2017, the number had grown to 25 (46%), including the European Union (CBD, 2017b). Through national biodiversity strategies and action plans (NBSAPs), the Aichi Biodiversity Targets have been translated into national-level targets in all except 13 countries in Europe and Central Asia (https://www.cbd.int/nbsap/) (see also Chapter 3), with varying weights assigned to different aspects of the targets (Pisupati & Prip, 2015). Hence, there are good reasons to assume that action will be developed in most of the countries that have completed their post-2010 national biodiversity strategies and action plans and thereby fulfilled one important part of Aichi Biodiversity Target 17. In Western and Eastern Europe, almost all countries have submitted a plan, whereas in Central Asia and Central Europe, a number of countries has not yet submitted (CBD, 2016c). However, the fact that a national biodiversity strategy and action plan has been submitted does not necessarily mean that intended measures, such as the mainstreaming of biodiversity and nature's contributions to people, will be effectively implemented. On the contrary, our assessment of the various policy sectors shows that there are still a number of opportunities to increase the pace of implementation and thereby improve the conservation and sustainable use of biodiversity (see synthesis **Table 6.11**).

In 2015, the 193 member States of the United Nations adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (Sustainable Development Goals) that were agreed to replace the Millennium Development Goals (United Nations, 2015). Of these, Goal 14 (Conserve and sustainably use the oceans, seas and marine resources) and Goal 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss) are of particular relevance for nature conservation.

For Europe and Central Asia, the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) was conceived as an instrument to support the implementation of the Convention on Biological Diversity. It was endorsed in 1995 by the Ministers of Environment in the region covered by the United Nations Economic Commission for Europe and thus, reached well beyond the European Union at the time[6]. Its aim was to support implementation of the Convention on Biological Diversity and to serve as a coordinating and unifying framework for strengthening and building on existing initiatives (UNEP & UNECE, 2016). In Eastern Europe, the Caucasus and Central Asia, the strategy and related activities were successful in facilitating capacity building for the implementation of the Convention on Biological Diversity and in enhancing NGO involvement. The strategy was terminated in 2011. Prip (2013, p. 5) has drawn a key lesson from this process – "*that policy on its own does not deliver action unless supported by allocation of resources*". The lack of a financial mechanism with adequate, stable and predictable funding was deemed a major obstacle to the strategy's implementation. Another lesson was that full support from the European Union and its member States was lacking, especially after the enlargement of the European Union. In 2011, a new strategy, the Pan-European 2020 Strategy for Biodiversity (UNEP, 2011b), was developed as the successor to PEBLDS. This new strategy refocuses efforts to prevent further loss of biodiversity in the pan-European region, in line with the Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets.

The "EU Biodiversity Strategy to 2020" (European Commission, 2011a, an expansion of the EU Biodiversity Action Plan of 2006) has been instrumental in creating momentum for better integrating aspects of biodiversity and ecosystem services into the European legislation. It works as an umbrella for existing, more specific policies. The strategy consists of six complementary targets whose implementation should contribute to mitigating the main drivers of biodiversity loss in the European Union. The achievement of these targets relies principally on better uptake of existing European Union legislation, notably through a better anchoring of biodiversity objectives in key sectoral policies. Specifically, the six targets focus on: 1) the full implementation of the European Union nature legislation, in particular the Birds and Habitats Directive (improvements of the Natura 2000 network); 2) better protection and restoration of biodiversity and ecosystem services, notably via a greater reliance on green infrastructure development; 3) more sustainable farmland and forestry management, as the agriculture and forestry sectors combined cover almost 72% of the land in the European Union (ameliorations in the

5. Available at https://www.ipbes.net/sites/default/files/eca_ch_6_appendix_6.1_responses_to_global_environmental_challenges.pdf

6. Although the United Nations Environment Programme pan-European region comes close to the area covered by the IPBES Regional Assessment for Europe and Central Asia, it is not quite identical (see UNEP & UNECE, 2016 for an overview of countries belonging to the pan-European region).

Common Agricultural Policy); 4) sustainable management of fish stocks and fisheries (75% of European Union fisheries are overexploited) through a coherent ecosystem approach and reducing bycatch; 5) a tighter control of invasive alien species; and 6) all this in an effort to avert the global biodiversity crisis, notably through a reduction in negative drivers. Each target is accompanied by an ambitious action plan, while indicators for monitoring (since 2010) are provided to ensure the effectiveness of future implementation towards the 2020 biodiversity targets.

Although there has been progress in the implementation of the strategy, it seems unlikely that most of its objectives and targets will be met within the allotted timeframe (EEA, 2015c; European Commission, 2015b; Tittensor *et al.*, 2014; CBD, 2016d; Chapter 3). In the European Union, the mid-term review of the EU Biodiversity Strategy concluded that, despite progress in most fields and areas, biodiversity loss and ecosystem services degradation continues unabatedly, which casts serious doubts on the *"capacity of biodiversity to meet human needs in the future"* (European Commission, 2015b, p. 4 and 19). The remainder of this section is an assessment of the reasons for this failure, highlighting opportunities for improvements.

6.4.1.2 Governance modes and policy instruments

While top-down, hierarchical governance is still the dominant mode of governance in the conservation sector, international conventions such as the Convention on Biological Diversity, the Aarhus Convention and the 2030 Agenda for Sustainable Development, call for alternative modes of governance to include effective collaboration among different public and private actors and stakeholders to solve environmental problems (see **Figure 6.2**). Greater public engagement through consultation, negotiation, and cooperation in policy design, and in the governance and management of biodiversity, is assumed to be linked with increased effectiveness, sharing of knowledge and understanding and legitimacy of biodiversity conservation and restoration policies (Ansell & Gash, 2008; Bodin & Crona, 2009; Couix & Gonzalo-Turpin, 2015; Decker *et al.*, 2016; Larrosa *et al.*, 2016; Paloniemi *et al.*, 2015; Whitehead *et al.*, 2014). As a response to this call, European Union member States and, increasingly, also countries in Eastern Europe and Central Asia (Kluvánková-Oravská *et al.*, 2009; OECD, 2005), tend to highlight the importance of decentralization or public-private governance in conservation policies and strategies. Such governance modes may contribute toward better taking account of the needs of local governments, communities, citizens and local knowledge holders when designing and implementing conservation policies and actions (Yang *et al.*, 2015).

New modes of governance have been applied, for example, in the governance of national parks and other protected areas (Holmgren *et al.*, 2016; Kluvánková-Oravská *et al.*, 2009; Reimerson, 2015; Yakusheva, 2017) and in the governance and management of large carnivores and other species. In Western Europe, the legislative and budgetary responsibilities of protected area governance are often vested at subnational levels with important roles for subnational authorities. For example, decentralization processes in France led to closer involvement of local authorities in the management of protected areas, and gave subnational authorities the power to create nature reserves (IUCN France, 2013). This development was further strengthened, giving local authorities a greater role in the governance of national parks, accompanied by changes in intergovernmental fiscal transfers that provided local authorities with more financial resources (Borie *et al.*, 2014). In Central and Eastern European countries, there is a shift from spatially isolated protected areas with top-down regulations towards more connected bottom-up approaches (Kluvánková-Oravská *et al.*, 2009; Yakusheva, 2017). In Central Asia, the institutional mechanisms for biodiversity conservation were developed during the Soviet era and, over the last decades, the management of protected areas has been strengthened, partly due to financial support from international donors. Moreover, protected area coverage has expanded and protection regimes have been widened by introducing categories of protection stipulated by the International Union for Conservation of Nature (IUCN) (Yakusheva, 2017).

With large carnivores recolonizing many European countries (Chapron *et al.*, 2014), mitigation measures to manage human-wildlife conflicts are needed. Norway introduced regional large carnivore committees, with local politicians appointed by the Ministry of the Environment. Sweden has wildlife management delegations at a regional level with politicians and stakeholders, while Finland uses national, regional and local large carnivore management organizations including public and private actors (Redpath *et al.*, 2017; Sandström *et al.*, 2009). These committees are in charge of developing and adopting management plans, determining or providing advice on population targets (including hunting quotas), and mitigating conflicts between wildlife and livestock. They are often also included in monitoring and information sharing (Sjölander-Lindqvist *et al.*, 2015). Human-wildlife conflicts have recently also increased due to the success of the European Union's conservation policies with strictly protected species such as cormorants, otters and the Baltic seal becoming more abundant. This caused the original conflicts with fisheries and aquaculture to resurge so that reconciliation strategies were needed (Klenke *et al.*, 2013a). Such conflicts require relevant stakeholder groups to be brought together, thus moving from hierarchical protection strategies to public-private partnerships, co-management and possibly modes of self-governance. This includes policy instruments such as damage compensation programmes and rewarding land users for biodiversity-friendly practices or monitoring activities as certain human-wildlife conflicts also raise justice concerns in terms of the distribution of their damages (Jacobsen & Linnell, 2016; see also Chapter 2, Box 2.5). As the core of the conflict usually consists of different interests and values among different stakeholder groups, successful conflict reconciliation strategies take stakeholder perceptions seriously and build on participatory processes (Klenke *et al.*, 2013b; Manfredo *et al.*, 2009). Further empowerment of national and local stakeholders is also considered key to success in wildlife management in Central Asia. Successful conservation measures require multi-stakeholder partnership and integrated efforts, yet regional cooperation in Central Asia still faces a number of challenges (Michel *et al.*, 2015). These include the economic situation, with continuous financing depending on external donors, and differing cultural perceptions and values with regard to wildlife and hunting.

Although the arguments in favour of these new modes of governance and the studies supporting these claims are many, there is also evidence that participation does not always deliver substantial benefits. Hence, caution is warranted against considering these new modes of governance as solutions for all kinds of conservation challenges. For example, there are problems related to the representation of different interests, the lack of opportunities for deliberation, the lack of mechanisms for conflict resolution, and misunderstandings of the mechanism by which decisions are made (Ansell & Gash, 2008). Nevertheless, in spite of these problems, studies also show the potential of participatory processes to contribute to social and organizational learning, as well as to the achievement of conservation and management outcomes (Emerson & Nabatchi, 2015).

The toolbox of policy instruments for biodiversity conservation, ecosystem restoration and sustaining nature's contributions to people, is well equipped. Due to the many challenges and complexities, real-world policies for the conservation, restoration and sustainable use of biodiversity typically apply multiple instruments at the same time. These challenges involve dealing with heterogeneity and multiple objectives, irreversibility in the face of species extinction and tipping points in ecosystems, information gaps, diverse values, multiple market, policy and institutional failures, a wide range of drivers impacting nature, and multiple actors at different spatial scales (OECD, 1999; Ring & Schröter-Schlaack, 2011, 2015; TEEB, 2011b). A comprehensive literature review of the various instruments for biodiversity conservation and the sustained provision of ecosystem services showed that combinations of instruments can be justified for a range of motives. Based on this review, **Table 6.5** presents characteristics of the major instruments reviewed as well as the main findings for the performance of the different instruments (Ring & Schröter-Schlaack, 2011, 2015; Schröter-Schlaack & Ring, 2011). Each instrument category covered (legal and regulatory, economic and financial, social and information-based instruments) has a role to play in an overall policy mix due to varying goals, actors addressed, and policy context.

Legal and regulatory instruments are the backbone of policy mixes, necessary to promote the conservation, restoration and sustainable use of biodiversity. Establishment of protected areas and their networks is an essential policy response to habitat loss and fragmentation (see Chapter 4, Section 4.5) (CBD, 2014; UNEP & UNECE, 2016). This legal instrument is implemented in all subregions of Europe and Central Asia, although with room for improvement (see corresponding column in synthesis **Table 6.11**). The core of the European Union biodiversity policy is the Habitats Directive and the Birds Directive, which established the Natura 2000 network. Member States have to implement the Nature Directives through national conservation law. Although not obligatory, the European Commission strongly recommends management plans as an operational instrument outlining practical measures to achieve the conservation objectives for Natura 2000 sites (EEA, 2015c). Whether part of management plans or not, member States are required to draw up conservation measures applying to all habitats and species on the Natura 2000 sites. A recent analysis of national reports by the European Environment Agency (EEA, 2015c) showed that conservation measures related to spatial planning (e.g. establishing protected areas or sites, legal protection of habitats and species, and other spatial measures) dominate the commonly reported conservation measures. Further significant categories include measures related to wetland, freshwater and coastal habitats, agriculture and open habitats and forest habitats. As the terrestrial part of the Natura 2000 network is predominantly covered by woodland, cropland and grassland, mainstreaming biodiversity into agriculture and forestry is a key task (Sections 6.5.1 and 6.5.2).

Many of the recent improvements in biodiversity conservation have been a result of effective regulation. The European Union Nature Directives allow the European Union to meet its objectives under international law, and, by way of the Natura 2000 network, have led to an increase in the number and quality of protected areas (UK NEA, 2011, p. 53). The Natura 2000 network is now the most extensive network of protected areas in the world, including more than 27,000 sites and covering 18% of the terrestrial area of the European Union member States and 4% of European Union marine waters (EEA, 2015c). The marine component of the Natura 2000 network is still very incomplete, particularly for offshore sites, yet with substantial designations in recent

Table 6 5 **Reviewing the performance of selected single instruments for biodiversity conservation.**

Instrument type	Direct regulation, e.g. protected area designation	Offsets, habitat banking and permit trading	Tax reliefs
Goal	Safeguard important areas for species and habitat conservation	Account for and mitigate inevitable impacts on biodiversity and ecosystems	Account for positive environmental externalities provided by land users
Actors addressed	Private and public actors	Private and public actors	Private actors
Baseline and policy context	Protection provided by other primary instruments (e.g. emission / management standards) or existing protected area network, very often no protection at all	Impacts allowed by (management / emission / performance) standards	Tax payers' behaviour without the tax relief (business as usual might be biodiversity friendly anyhow)
Conservation effectiveness	High – increase in and conservation of biodiversity and ecosystem service provision; however, effectiveness may be at risk due to weak enforcement or may erode in the future due to changing environmental conditions (e.g. climate change)	Medium – although typically designed to allow for a "no net loss"-goal, problems arise in assuring equivalence of mitigation measures and their long-term monitoring	Low – depending on tax burden relieved (existence of tax, actual enforcement of payments, and sufficient tax rate); non-targeted approach
Associated costs and proxies for cost-effectiveness	Medium – though protected areas very often show a positive benefit-cost-relationship, local opportunity costs can be substantial	High – in particular the option to trade mitigation measures significantly reduces opportunity costs; however, some ecosystem or habitat types may be (too) costly to restore	Medium – low transaction costs as resting on existing administrative procedure; however, very often incentives provided insufficient for required change in land-use practice
Social impacts and equity	Medium – ecosystem services protected by protected areas may benefit (local) population; however, substantial opportunity costs and risk to revoke informal rights (e.g. access/abstraction) in area designation	Medium – increase in education/job and income opportunities for rural landowners marketing offsets; compensation of opportunity cost of land conservation (tradable development rights)	Medium – compensation for opportunity costs of environmentally friendly land-use practices; however, only applicable to tax debtors (e.g. landowners)

years (EEA, 2012a, 2015c). The Natura 2000 network forms the backbone of the European Union's green infrastructure (Mazza *et al.*, 2011). The Emerald Network launched by the Council of Europe in 1999 is based on the same principles as Natura 2000 and represents its extension to non-European Union countries (EEA, 2012a; UNEP & UNECE, 2016). The Pan-European Ecological Network, originally launched in the framework of the Pan-European Biological and Landscape Diversity Strategy, builds on the Natura 2000 network and the Emerald network. In addition to the latter two, the Pan-European Ecological Network aims at linking core areas physically by way of preserving and restoring corridors (Jongman *et al.*, 2011; UNEP & UNECE, 2016). Protected areas as a legal conservation policy instrument are widely applied in Eastern Europe and Central Asia, although problems exist with enforcing regulations and effective monitoring due to insufficient institutional capacities and human and financial resources (Mammadov *et al.*, 2016; OECD, 2005).

Economic and financial instruments in conservation policies penalize activities that negatively affect the environment, or they provide public and private actors with the resources needed to achieve conservation goals and to implement conservation measures. Biodiversity financing by way of public financial support programmes is an important topic in Europe and Central Asia. Apart from a few dedicated biodiversity conservation funding schemes such as the LIFE fund, the European Union's approach to financing biodiversity and nature conservation is largely based on "integrated financing", using a range of existing financial instruments from other sectors, such as agriculture, fisheries and regional development, as well as social and cohesion funds (Kettunen *et al.*, 2017). Since financial resources still fall far short of providing sufficient resources to achieve agreed biodiversity objectives (Gantioler *et al.*, 2010; Tucker *et al.*, 2013b), Kettunen *et al.* (2017) suggest a range of policy instruments as opportunities for innovative biodiversity financing in the European Union,

Ecological fiscal transfers	Payments for ecosystem services (PES)	Certification, e.g. forest certification
Compensating decentralized governments for opportunity and/or management costs as well as spillover benefits of protected areas	Incentivizing land users for biodiversity conservation and ecosystem service provision, e.g. by compensating for associated opportunity and management costs	Promote biodiversity- and environmentally-friendly forest production in accordance with legal codes and certification requirements
Public actors	Mostly private actors/land users	Private actors (consumers)
Protected areas coverage when instrument is introduced	Land-use practice without incentives by payment for ecosystem services schemes (business-as-usual could be either static, declining or improving)	National forestry regulation, certification process most often progressive and adaptive
Medium to high – increase in quantity and quality of protected areas likely (especially when beneficiary of transfers can influence quantity and quality of protected areas)	Low to high – depending on instrument design regarding baseline, and additionality, leakage, permanence and participation	Medium – impacts dependent on rigorousness of standard and framing conditions, such as intensity of investment, difficulties in transport and licensing, land tenure and conflicts with competing land uses
Medium – low transaction costs as it builds on existing mechanism (fiscal transfer schemes and protected areas designation)	Medium to high – no up-front public investment for buying land, auction-based programmes limit excessive rents; however potentially high transaction costs	Medium – administrative costs of certification scheme may be substantial (in particular in tropical forests)
Medium – depending on entry point of protected areas in fiscal transfer systems; fiscal transfers as such address inequalities between jurisdictions	Medium – support of rural livelihoods, resource management and social coordination capacities; but enrolment constrained by insecure property rights and transaction costs, mixed effect on poverty alleviation	Low to medium – difficult to reach smaller operators due to complex procedures; communities often benefit through workforce participation and engagement in co-benefits

Source: Adapted from Ring & Schröter-Schlaack (2015); Schröter-Schlaack & Ring (2011). Based on individual instrument reviews from Kaechele *et al.* (2011); Oosterhuis (2011); Porras *et al.* (2011); Ring *et al.* (2011, 2017); Santos *et al.* (2015b); Schröter-Schlaack & Blumentrath (2011).

among them ecological fiscal transfers (EFT), tax reliefs, marketed products as well as fees and charges (Kettunen & Illes, 2017). Ring & Barton (2015) and Ring & Schröter-Schlaack (2011) provide a review of economic instruments in policy mixes for biodiversity conservation and the sustained provision of ecosystem services, assessing their effectiveness, associated costs and social impacts, and pointing to shortcomings and misperceptions of the relevant instruments **(Table 6.5)**. Whereas payments for ecosystem services are commonly implemented in Western and Central Europe (although with scope for improvement, see synthesis **Table 6.11**), further economic instruments are only applied in a few countries, are under development or have only recently started. Portugal was the first European Union member State to introduce ecological fiscal transfers, using Natura 2000 sites and other national protected areas as indicators for redistributing general tax revenues from the national level to all municipalities hosting such areas (Santos *et al.*, 2012). In this way, economic instruments can support the implementation of legal and regulatory instruments by providing financial resources to subnational governments responsible for managing such sites.

There is room for considerable development of economic instruments in nature conservation and ecosystem restoration policies especially in Eastern Europe and Central Asia, where few countries apply such instruments (Kobakhidze, 2015; OECD, 2005; UNEP & UNECE, 2016). The current work programme of the Pan-European Biodiversity Platform includes as one of its three overarching priorities, "*improving the manner in which biodiversity and ecosystem services concerns and requirements* *are reflected in economic and development frameworks and policies*" (UNEP, 2014b, p. 7). Selected activities supported under this priority include: (i) mapping and assessing ecosystems and their services; (ii) in-country and subregional studies following the approach of the international initiative on the economics of ecosystems and biodiversity (TEEB); and (iii) capacity support for the use of market-based instruments (UNEP, 2014b). Especially following the publications of the TEEB initiative, marked-based instruments have been gaining ground in policy strategies for conservation. In Eastern Europe and Central Asia, for example, payments for environmental services have been introduced and tested as pilot projects in some countries. However, these initiatives are supported by donors and their national ownership is low. There is no observed trend of wider application of this instrument in the region.

Social and information-based instruments operate by providing additional information for policy target groups on the impacts of their activities regarding biodiversity and nature's contributions to people. Certification acts as a bridge between market regulation and conservation governance by emphasizing specific criteria in response to consumers' demands for sustainably produced products (see Sections 6.5, 6.6.2 and 6.6.5.3 for applications in agriculture, forestry and fisheries and the role of certification as part of a policy mix; synthesis **Table 6.11**). Regarding science, data, indicators and monitoring, the Environmental Performance Reviews of the United Nations Economic Commission for Europe provide regular knowledge updates on a number of biodiversity-relevant issues, covering countries in Central Europe, Eastern Europe (except Russian Federation) and Central Asia (see UNECE, 2017b for reviewed countries, 2017c; UNEP & UNECE, 2016).

Rights-based instruments and customary norms are especially important for indigenous and local people. Over recent decades, the rights of indigenous peoples have been increasingly acknowledged and strengthened within the international legal system (Section 6.3.2.6). To some extent, this is also reflected in national-level biodiversity conservation polices in Europe and Central Asia. One example of this policy change is the management arrangement for the Laponia World Heritage site in northern Sweden where the Sami have secured significant influence over the management of the site, and label it a victory for Sami political struggle (Reimerson, 2015). There are also many marine areas where the customary laws of indigenous peoples are recognized and respected by the broader society (EEA, 2012a). Indigenous and local knowledge is a rich source of local understandings and traditional management practices that can play an important role in the conservation and sustainable use of biodiversity (Babai *et al.*, 2015; Hartel *et al.*, 2015; Molnár, 2014; Oteros-Rozas *et al.*, 2013; Roué & Molnár, 2017; Varga *et al.*, 2016; Varga & Molnár, 2014). Examples of such traditional management practices and extensive measures are livestock grazing in lowland grasslands; mowing by hand in montane grasslands, and; coppicing, pollarding or small-scale felling in forests. Local foresters, herders and rangers may recognize and provide explanations to structural and species compositional changes in different ecosystems and their knowledge is often passed on over many generations (Berkes *et al.*, 2000).

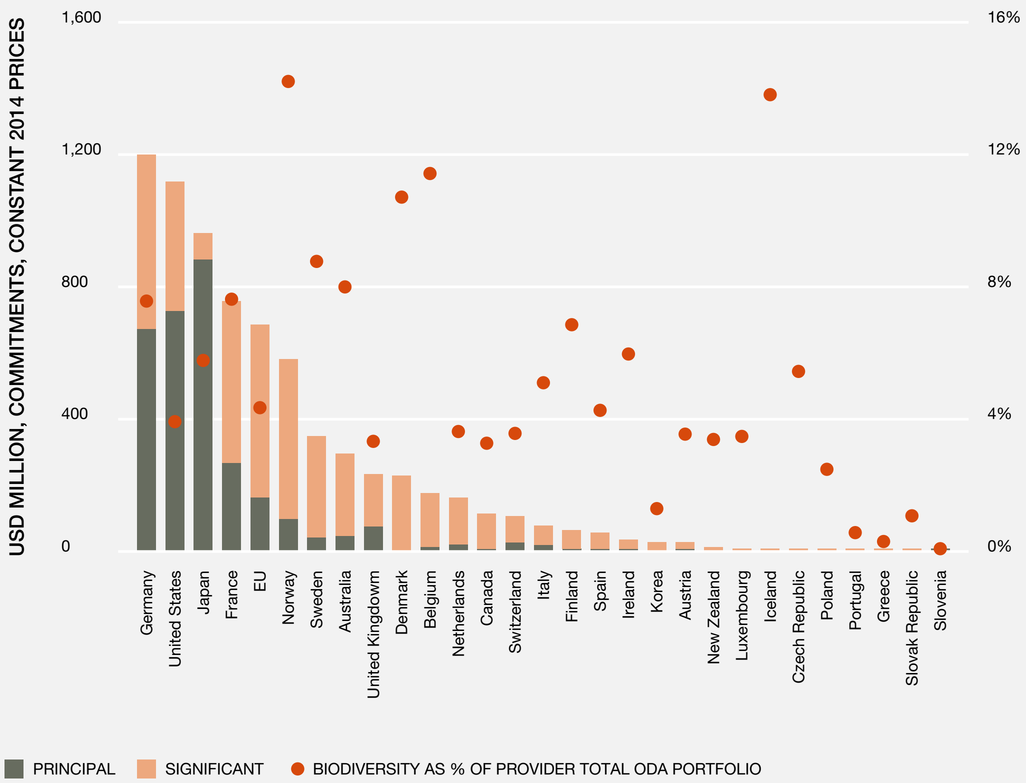
The mobilization of financial resources is a continuous task, to which Aichi Biodiversity Target 20 is dedicated. Sufficient financial resources are considered crucial if biodiversity is to be conserved and the sustainable use of biodiversity and ecosystems enhanced. This holds especially true for developing countries with limited domestic funds (Richerzhagen *et al.*, 2016). In Europe and Central Asia, Turkey and the Ukraine were among the top 10 recipients globally of bilateral biodiversity-related official development assistance, whereas 20 Western European and 3 Eastern European countries as well as the European Union were providers of such assistance **(Figure 6.4)**. The top 10 providers account for nearly 90% of biodiversity-related official development assistance, among them six European countries and the European Union (all figures 2011-1015 average) (OECD, 2016a). **Figure 6.5** shows the global distribution of biodiversity-focused aid from Development Assistance Committee members of the OECD for the years 2006 – 2012, with only few recipients in Europe and Central Asia.

6.4.1.3 Constraints and opportunities

Despite accelerating policy and management responses to the global loss of biodiversity, the impacts of these efforts are unlikely to be reflected in improved trends in the state of biodiversity by 2020 (Tittensor *et al.*, 2014). In view of these developments, Di Marco *et al.* (2016) call for a refocus of biodiversity conservation priorities, by defining sufficient and more ambitious biodiversity targets, increasing the amount of financial resources necessary to achieve these targets, and spending them more efficiently. Recent reviews and assessments at the regional level mirror these findings and necessities stated for the global level, including for Europe and Central Asia. The mid-term review of the EU Biodiversity Strategy to 2020 (European Commission, 2015b) emphasizes that key threats to biodiversity continue to exert pressure. Land-use change, in particular through urban sprawl, agricultural intensification, land abandonment and intensively managed forests, pollution, extraction of natural resources (e.g. mining, fisheries), invasive species and climate change, still cause loss of species and habitats and result in ecosystem degradation and weakening of ecosystem resilience (Chapter 4) (EEA, 2015d; European Commission, 2015b; UNEP & UNECE, 2016).

Figure 6 4 **Providers of bilateral biodiversity-related official development assistance (ODA), among them 23 countries from Western and Central Europe and the European Union (EU).**

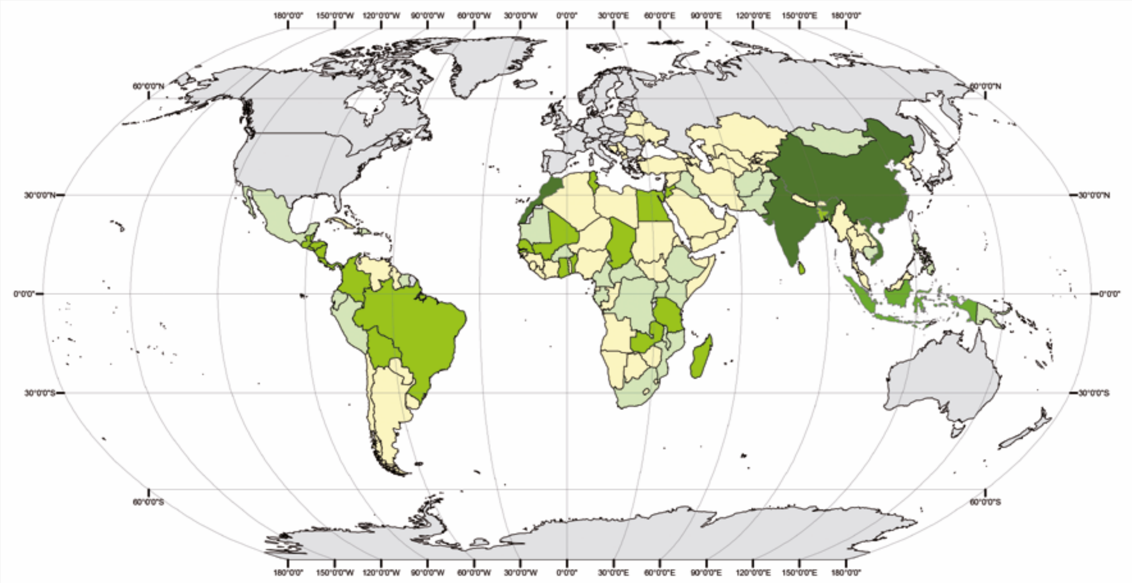
This figure considers only members of the Development Assistance Committee of the OECD. "Principal" means that biodiversity was targeted as a primary objective, implying that activities would not have been funded but for their biodiversity-related goals. "Significant" means that biodiversity was targeted as a secondary objective, indicating that biodiversity is being mainstreamed into development cooperation activities with other primary objectives. Norway, Iceland and Belgium dedicated the highest shares of their official development assistance portfolios to biodiversity-related activities (see red dots relating to right-hand y-axis). Source: OECD (2016a).



The failure of the European Union's 2010 target to halt biodiversity loss has been attributed to the following major problems (Fournier *et al.*, 2010; Tinch *et al.*, 2011): "*(a) incomplete implementation of existing legislation; (b) insufficient funding; (c) limited awareness about biodiversity; (d) inadequate governance and administrative capacity; and (e) gaps in skills and knowledge*." Despite the adoption of the EU Biodiversity Strategy 2011 – 2020, it has been argued that these problems still apply (Tucker *et al.*, 2013a). In a similar vein, Steiner (2009) (cited in Tinch *et al.*, 2011), stated from a global perspective that current governance systems cannot achieve environment and development goals "*due to lack of adequate financing, incoherence among bodies, weak linkages between science and policy, insufficient capacity at the national level to implement laws and policies, and a significant disconnect between the environmental and the economic and social spheres.*" Therefore, short-term priorities tend to dominate long-term visions, and societies fail to consider and develop transformative strategies for achieving sustainability. Recognition of the need for profound societal transformation towards sustainability has just started. It is gaining momentum in Western Europe (EEA, 2015d), but still needs to be initiated in other subregions of Europe and Central Asia (see synthesis **Table 6.11**). All policy options and opportunities related to awareness raising in the synthesis **Table 6.11**, would need stronger support in Eastern Europe and Central Asia to become effective.

Mainstreaming biodiversity and nature's contributions to people into all policy areas that depend on or affect biodiversity, has become a key strategy to counteract these deficiencies. In Europe and Central Asia, as well as globally, the concept of a "green economy" is gaining increasing support (Economic Commission for Europe, 2016; European Commission, 2013b; UNEP, 2011a, 2016a). Biodiversity conservation, sustainable resource use and ecosystem restoration feature prominently on the agenda of

Figure 6 5 **Biodiversity-focused aid from Development Assistance Committee members of the Organisation for Economic Co-operation and Development. Source: Adapted from UNEP-WCMC & BIP (2017); Data: OECD (2017).**



BIODIVERSITY-FOCUSED AID

In million USD, 2012 constant prices	0	0 – 5	5 – 15	15 – 50	50 – 150	> 500

these strategies. However, despite the long recognition of the need for mainstreaming, there remain important barriers such as "*shortcomings in training and a lack of skills, guidance and tools to enable non-specialists from other sectors to take account of both their dependence and their impacts on biodiversity and ecosystems*" (Tinch *et al.* 2010). Promoting information sharing, transparency, knowledge management and training is of special relevance in Eastern Europe and Central Asia (see synthesis **Table 6.11**).

The heterogeneity of biodiversity conservation, with its multiple taxa, organizational levels and multiple objectives, represents a key challenge for policy development. Biodiversity also affects many aspects of society, different sectors, and is highly relevant in spiritual, religious and cultural contexts. In response to these complex challenges, a huge number of international and regional conventions and policy instruments deal with biodiversity in Europe and Central Asia. For many countries in the region, it has become increasingly difficult to fully implement or even follow the targets set by the Strategic Plan for Biodiversity 2011-2020, due to its vast range of topics and issues (UNEP & UNECE, 2016). Institutional fragmentation between different policy sectors represents another barrier to achieving biodiversity objectives. It involves split competences, conflicts, and scale and boundary mismatches between regulatory authorities and biodiversity processes (Koetz *et al.*, 2012). Such fragmentation can lead to policies harmful to biodiversity. Examples are found in policy sectors such as energy, transport, fisheries or agriculture (see Sections 6.5.1, 6.5.3, 6.5.4 and 6.5.5). Phasing out of harmful subsidies remains an important task for all policy sectors and across all subregions of Europe and Central Asia (synthesis **Table 6.11**). Conversely, more progress has been made in relation to taxing and charging negative environmental impacts, with the exception of the fisheries sector (see Section 6.5.3 and synthesis **Table 6.11**) (Hansjürgens *et al.*, 2011b; Lehmann *et al.*, 2011; OECD, 2013b).

Mainstreaming and policy integration remain a priority. This includes setting and achieving objectives in policy areas not directly targeted by biodiversity policies, notably other environmental policies such as climate, air, chemicals, water and soil protection (see next Section 6.4.2) and further sector policies such as agriculture, forestry, fisheries, resource extraction and manufacturing, and the services sector (see Section 6.5) (EEA, 2015c; European Commission, 2015b; PBL, 2014; Tinch *et al.*, 2011; UNEP & UNECE, 2016). Beyond certain thresholds or "tipping points", impacts may be irreversible and cause species extinction or ecosystem collapse. Small impacts accumulating over a long period may create large losses with irreversible outcomes. Making trade-offs and tipping points visible at the relevant spatial scales remains an important policy option for all subregions of Europe and Central Asia (synthesis **Table 6.11**). If early warnings are taken seriously and preventative action is taken, negative outcomes can be avoided or at least reduced. Precautionary approaches can help manage the fast-changing, multiple, systemic challenges the world faces today (EEA, 2013b).

Recent progress in establishing policy frameworks needs to be translated into concrete actions at national, subnational and local levels, if the status of biodiversity is to improve on the ground. Full exploitation of current commitments is needed, as well as stepping up efforts to improve on the current situation in critical policy areas such as biodiversity (UNEP & UNECE, 2016). Improved science-policy interfaces such as IPBES, and relevant interfaces and networks at subregional, national and subnational levels, currently serve as valuable mechanisms to provide the best available evidence for evidence-based policymaking. A key opportunity is to demonstrate to business the benefits it derives from biodiversity, and the ways in which it can manage its impacts on biodiversity (see Aichi Biodiversity Target 4) (TEEB, 2012) (see also Sections 6.5.4, 6.5.5 and 6.6.3.2). Due to the multi-facetted relationships and interlinkages between so many policy sectors and societal actors, the concept of nature's contributions to people provides opportunities to better assess synergies and trade-offs between biodiversity conservation and the many contributions of nature to people and quality of life (Bouma & van Beukering, 2015; Elmqvist *et al.*, 2010; Potschin *et al.*, 2016; for ecological restoration: Tolvanen & Aronson, 2016) **(Box 6.1)**.

It is expected that the shift from traditional hierarchical modes of governance towards more inclusive modes such as public-private partnerships or co-governance would result in better decisions and policy outcomes. This holds for the literature assessed, as well as international

Box 6 1 Synergies and trade-offs: assessing the links between biodiversity and nature's contributions to people.

Although the number of publications on ecosystem services has increased markedly in recent years (see Chapter 1 and Chapter 2), we still have limited understanding of the synergies and trade-offs between biodiversity and nature's contributions to people, or ecosystem services (Elmqvist *et al.*, 2010; Turkelboom *et al.*, 2016). Trade-offs exist between material contributions to people (or provisioning services) and biodiversity, but also between biodiversity and other categories of ecosystem services, as the Millennium Ecosystem Assessment (MEA, 2005c) has prominently stated. Intensification in the provision of material contributions may arise from objectives in other policy sectors, e.g. climate and related agricultural, forestry or energy policies (see Sections 6.4.2, 6.5.1, 6.5.2 and 6.5.4).

For example, policies for climate change mitigation involve moving from fossil fuels to renewable energy sources, often accompanied by financial incentives to land users in agriculture or forestry that lead to intensified production. Albert and co-authors, for example, assessed biodiversity and ecosystem service trade-offs in agrarian landscapes that arise from increased biogas production in Germany (Albert *et al.*, 2016b). Policies promoting forest expansion for increased carbon sequestration at the expense of semi-natural grasslands may further risk the overall reduction of biodiversity in the European Union (Burrascano *et al.*, 2016). In Eastern Europe and Central Asia, many low-income rural households still rely on traditional biomass (straw, wood or coal) for cooking and heating. Here, the development of proper management systems promises to prevent the loss of biodiversity and degradation of local biomass resources (IEA, 2015; Kobakhidze, 2015).

Mainstreaming biodiversity into climate change mitigation and adaptation policies also has the potential for various synergies. This is the case for peatland conservation and re-wetting of farmed peatlands, sustainable forest management or the conservation and restoration of near-natural floodplains (TEEB-DE, 2015). Further synergies relate to the significant overlap between Natura 2000 sites and regions with high carbon content across European Union countries. Biodiversity protection and climate change mitigation through conservation of soil carbon could be simultaneously achieved in Natura 2000 sites and beyond (Jantke *et al.*, 2016). Considering bundles of ecosystem services and the multifunctionality of landscapes helps to tease out such synergies (Howe *et al.*, 2014; Mouchet *et al.*, 2017; Ruijs *et al.*, 2013; Sil *et al.*, 2016).

At a more general level, mapping and assessments of nature's contributions to people provide valuable information for a range of public and private decision-makers (Chapter 2). The provision of biophysical maps of ecosystem services at the European Union level is regarded as a crucial step in setting new targets for biodiversity (Rodwell *et al.*, 2013). Maes *et al.* (2014, 2015, 2016) and Schröter *et al.* (2016) have taken important steps towards mapping and assessing ecosystem services in the European Union. Comparable initiatives exist for Eastern Europe (Bukvareva *et al.*, 2015; Grunewald *et al.*, 2014). In Central Asia, most recent ecosystem (service) assessments have been performed in relation to sustainable land management by the Economics of Land Degradation (ELD) initiative (Quillérou *et al.*, 2016).

conventions and national policies. The inclusion of stakeholders and/or previously marginalized actors in consensus-based, deliberative processes in policymaking and decision-making is seen as a promising mechanism for managing environmental problems including conservation. This would enhance the effectiveness, efficiency and equity of the decision-making process, by reducing transaction costs, improving the legitimacy of decisions, and increasing the sustainability of resources and livelihoods (Bodin, 2017). While there is a growing literature on these more inclusive modes of governance in relation to wider environmental issues, agriculture, forestry and fisheries (see Sections 6.4.2 and 6.5), there is no comprehensive overview on the role of participation in setting priorities for biodiversity policies. Furthermore, the focus in the literature is often on the processes of inclusion and not on the outcomes in terms of overall effectiveness of biodiversity policy. Although some countries in Europe and Central Asia, for example, produced second-generation national biodiversity strategies and action plans in the early 2000s through participatory processes (Moreno & Mueller, 2015; CBD, 2016d), there remains a considerable gap in addressing issues of public involvement, in particular concerning gender equality and women's empowerment, as well as the participation of indigenous peoples. Indigenous and local knowledge of biodiversity and nature's contributions to people in conservation policy and management is not sufficiently taken into consideration despite the recognition of the importance of, for instance, traditional farming (European Commission, 2014a; Roué & Molnár, 2017). Furthermore, linkages between science and policy, and between science and society, can be strengthened in this context (Arlettaz *et al.*, 2010; Buizer *et al.*, 2011; Mihók *et al.*, 2015; Pullin *et al.*, 2009). By taking individual and social preferences of people seriously, economics, the wider social sciences, and the humanities, may help to facilitate conservation policies, actions and outcomes that are more legitimate, salient, robust and effective compared to the current situation (Bennett *et al.*, 2017; Moon & Blackman, 2014). This has proven to be fruitful in relation to human-wildlife conflicts, where human dimensions of wildlife have developed as a transdisciplinary research field (Manfredo *et al.*, 2009; Paxton *et al.*, 2016). The same holds for nature's contributions to people, which have been developed as a boundary concept between the natural and the social sciences (Bouma & Beukering, 2015; Potschin *et al.*, 2016).

Although budgets for financing biodiversity conservation activities have been increased in recent years, adequate financing of biodiversity conservation is still lacking at the national level and throughout Europe and Central Asia (Florentina *et al.*, 2015; Kettunen *et al.*, 2017; Mammadov *et al.*, 2016; Tucker *et al.*, 2013b). The interim assessment of revised national biodiversity strategies and action plans found that many strategies and action plans were overly ambitious, while at the same time lacking a strategy for financing their implementation (Pisupati & Prip, 2015). The situation is especially serious in Central and Eastern Europe as well as in Central Asia, where insufficient capacity has been identified at the national level to implement laws and policies as well as to better deploy participatory approaches (Mammadov *et al.*, 2016; Mihók *et al.*, 2017; Niedziałkowski *et al.*, 2015; Simeonova *et al.*, 2016). The financial resources for scientific research, monitoring and training of specialists in the field of biodiversity conservation are deemed seriously insufficient in Eastern Europe and Central Asia (Kobakhidze, 2015).

However, lack of resources for biodiversity financing also applies to European Union member States. The mid-term review of the EU Biodiversity Strategy stated that achieving biodiversity targets requires adequate funding, yet there is still no detailed insight into the actual funding and financing of nature conservation by each member State. The review, supported by more recent assessments, calls for expanding the multi-fund approach to biodiversity financing, better linking the various existing financing tools, and exploring new economic and financial policy instruments that can provide funds for achieving objectives related to biodiversity and nature's contributions to people (European Commission, 2015b, 2016b; Kettunen *et al.*, 2017). For example, countries such as India and Brazil use conservation-related indicators for redistributing general tax income much more prominently than any country in Europe or Central Asia (Busch & Mukherjee, 2017; Ring, 2008b; Schröter-Schlaack *et al.*, 2014). Redistributing public revenues through intergovernmental fiscal relations from higher to lower levels of government may account for the opportunity costs of conservation, reward conservation activities of municipalities, and thus can provide incentives for conservation, when considering ecological and conservation-related indicators in redistribution formulas (Droste *et al.*, 2017). Such approaches also have the potential to be transferred to the distribution of European Union funds between the European Union and member States (Droste *et al.*, 2018; Kettunen *et al.*, 2017), or, more generally, for redistributing international funds, for example in relation to REDD+ initiative (Ring *et al.*, 2010).

6.4.1.4 Summary

There is a widespread call to strengthen the synergies between biodiversity-related conventions, to improve policy integration and mainstream biodiversity and nature's contributions to people into relevant policy sectors, as the complexity and fragmentation of biodiversity governance is seen as a constraint to effective policy design and implementation. IPBES may play an important role in the integration of relevant political processes and instruments (UNEP & UNECE, 2016, p. 89). Current assessments of status and trends of biodiversity and nature's contributions to people as well as policy responses indicate the need to strengthen the implementation of existing policies (EEA, 2015d; Tittensor *et al.*, 2014; UNEP & UNECE, 2016) (see Chapters 2–5). This requires full exploitation of current commitments to reach agreed environmental goals and targets and proactive learning from the wide spectrum of good-practice in the region. In critical areas, such as biodiversity, additional commitments and efforts are needed to improve on the current situation, including sufficient mobilization of financial resources (UNEP & UNECE, 2016).

Legal and regulatory instruments are the backbone of policy mixes for biodiversity conservation. Direct regulation, including, for example, protected areas, land-use management standards, or zoning regulations by spatial planning, is the most widely used approach in environmental protection, and this also holds true for biodiversity conservation (Schröter-Schlaack & Blumentrath, 2011). A well-defined and comprehensive regulatory framework provides the essential baseline for introducing other instruments (Hansjürgens, Schröter-Schlaack, *et al.*, 2011b). It can help to assure a safe minimum standard of conservation, making it an important ingredient in any conservation strategy. However, its social and equity impacts are somewhat mixed (Schröter-Schlaack & Ring, 2011), especially in relation to indigenous and local people (Allard, 2006; Elenius *et al.*, 2017). On the one hand, regulation makes use or access rights legally enforceable due to clearly defined property rights. This is an important enabling condition for the use of market-based instruments in conservation policies to work effectively. On the other hand, there is the risk of precluding informal property rights, such as those of indigenous peoples. For Kyrgyzstan, Kalkanbekov and Samakov (2017) suggest sacred sites to be considered as indigenous protected areas or, in other words, community-conserved areas, to increase their recognition as valuable nature-related cultural sites.

Applying and improving a wider range of economic instruments in the conservation and sustainable use of biodiversity and natural resources, as well as ecosystem restoration policies, remains a task in all subregions. It is important to note, however, that economic instruments include more options than only "market-based" instruments. The latter term is widely used by many stakeholders, often confusing everything related to economics, with markets (Vatn, 2015; Vatn *et al.*, 2011). Economic instruments in general require: (i) creation of the enabling conditions through legal and regulatory instruments; (ii) smart design and effective implementation; and (iii) consideration of their social impacts on the ground (Adams *et al.*, 2016; Kettunen & Illes, 2017; Ring & Schröter-Schlaack, 2011; Santos *et al.*, 2015b; Tinch *et al.*, 2011).

Social and information-based instruments are essential in the wider policy mix for biodiversity conservation. Although regular reporting and monitoring on the state of nature is now common practice in Europe and Central Asia, further streamlining and harmonization is needed to reduce differences in methodologies applied, which make data aggregation and comparison difficult. The quality of data reported suggests that countries need to further develop or complement their inventories and monitoring schemes (EEA, 2015c; OECD, 2005). In this regard, training, education and capacity-building are important steps forward (see synthesis **Table 6.11**).

Regarding rights-based instruments and customary norms, Varga *et al.* (2017) emphasize that conservation management practices (e.g. mulching hay meadows, shredding shrubbery) are often very different from traditional practices (Holl & Smith, 2002), as conservation managers' education is almost exclusively based on western science (Primack, 2010). At the same time, the ability of traditional ecological knowledge holders to protect their rights and to advance their own interests is relatively low (Heikkinen *et al.*, 2012). Policy instruments to reinforce the role indigenous peoples and local communities may include: strengthening the capacities of national human rights institutions; ensuring that national laws are harmonized with international human rights treaty standards; legislation with the purpose of defining property rights or access right to land; collaborative arrangements where the participation of indigenous groups and local communities are secured; and the implementation of mechanisms for free, prior and informed consent. Despite the fact that emerging and new approaches have contributed to changes with respect to indigenous rights and nature conservation, there are a number of challenges and difficulties in combining indigenous values with the views of western understandings of conservation (Elenius *et al.*, 2017).

6.4.2 Environmental governance for biodiversity and nature's contributions to people: synergies and trade-offs

6.4.2.1 Key environmental policies

In addition to the nature conservation policies described in Section 6.4.1, a broad range of environmental policies shape changes in biodiversity and nature's contributions to people, notably those addressing water quality and quantity (both marine and freshwater), flood management, air and wider environmental pollution, waste management, mitigation of, and adaptation to climate change, soil management and land degradation. These policies complement, overlap and intersect with policies in other sectors, for example, on agriculture, forestry, fisheries, resource extraction and energy (Section 6.5). In many cases, such environmental policies are intended to constrain land-use practices and abstraction of natural resources to safeguard environmental quality. While the general objective of these environmental policies is thus by definition to improve environmental quality, including the provision of nature's contributions to people, three main questions emerge. First, there might be implicit trade-offs between managing for different ecosystem services and/or biodiversity-related goals, for example, related to biofuel targets (Tosun & Schulze, 2015) or water management and biodiversity conservation (Beunen *et al.*, 2009): How do environmental policies deal with these conflicts, which ecosystem services are favoured, and which are negatively affected? Second, policies do not always achieve their intended aims, often due to a lack of enforcement or insufficient alignment across sectors: What are the *de facto* implications of the existing environmental policies for biodiversity and ecosystem services? Third, what are the options that emerge from this analysis to improve environmental governance in the future? This section concentrates on these questions, building on the presentation of international, regional and transboundary governance arrangements that address environmental challenges (Section 6.3) and providing the backdrop for the analysis of sectoral policies (Section 6.5).

In the European Union, there is a widespread perception that, in terms of the adoption and effectiveness of environmental policies, a lot of progress has been made over recent decades (EEA, 2015d; IEEP, 2013; Selin & VanDeveer, 2015), but that the challenges ahead are enormous (e.g., related to climate change), and that efforts therefore need to be sustained (EEA, 2015d). There is a recognition that societal-level transformations are needed rather than just gradual or very specific changes, i.e. that current lifestyles and associated expectations and value systems have to significantly change. However, the political and societal drive for economic growth and prosperity still does not tend to align with environmental aims and objectives, despite increasing efforts to identify win-win situations (e.g., IEEP, 2013). The recognition of this challenge has led to the incorporation of notions of societal change towards sustainability into environmental policy goals, blended with a language that is seen as compatible with economic thinking, using terms such as "natural capital" and "nature-based solutions". In this respect, policies are more than just sets of rules; they shape and are shaped by discourse and ways of thinking. Partly because of this realization, recent environmental policies in the European Union tend to adopt a much more systemic perspective than they previously did, grouping policies into larger packages rather than addressing single issues (EEA, 2015d; Hüesker & Moss, 2015). For example, the idea of a "circular economy" has been introduced to shape and provide the conceptual umbrella for strategies to deal with resource use and waste (EEA, 2015d; Lazarevic & Valve, 2017), while the "low-carbon society" provides direction to policies targeting the mitigation of climate change (EEA, 2015d) (see also **Box 6.2** for an example influenced by the "ecosystem approach"). However, Bouwma *et al.* (2018) suggest that within the body of European Union environmental law (the "acquis", which consists of more than 500 directives, regulations and decisions; EEA, 2015d; see Section 6.3 for an overview of the most important directives) the concept of ecosystem services has not yet been fully mainstreamed beyond those policies that focus on nature or natural resources.

In Eastern Europe and Central Asia, and in Central European countries outside the European Union, the overall picture appears to be more ambivalent. There is recognition that the region is very diverse and that a lot of progress has been made in recent years (OECD, 2012a; UNECE, 2015a, 2015b, 2016a, 2016b) compared with previous, much more negative assessments (OECD, 2005). However, the effectiveness of environmental policies still seems heavily dependent on legacies in the governance systems of these countries (Carmin & VanDeveer, 2005; Winqvist & Wolf, 2013) and their interactions with approaches adopted more recently (Agarin & Grīviņš, 2016). Framework legislation on environmental issues in these countries underwent a reform process in the 1990s and 2000s (OECD, 2005), and many countries have subsequently developed more detailed regulations and action plans (Winqvist & Wolf, 2013). In Central Asia, but also in Eastern and Central Europe, donor support and international assistance (see e.g., http://www.naturalresources-centralasia.org/) have played a strong role in the development of action plans and policies (OECD, 2005, 2012a; UNECE, 2015a). However, such reforms are not necessarily effective yet and have sometimes been compromised by subsequent interventions. In Georgia, for example, a reorganization of the environmental authorities in 2011 involved substantial cuts in budget and staff. Although partly reversed in 2013, these cuts still had longer-term impacts on institutional capacities (UNECE, 2016b). By comparison, in Serbia, new environmental laws and a large number of subsidiary regulations were adopted in recent years (UNECE, 2015b). However, not all of the new legal instruments have been followed up with strategies, action plans, reporting, or other operationalization and enforcement mechanisms. Overall it appears that, even where strong pro-environmental legislation exists, consistent implementation is often still lacking and would also benefit from being streamlined across sectors (OECD, 2012a). Currently, there are many encouraging developments towards more holistic management approaches, for example, in relation to Integrated Water Resources Management (OECD, 2005) and integrated management of peatlands (Council of Ministers of the Republic of Belarus, 2015). Overarching discourses such as "green growth" (e.g., OECD, 2012a) have also been used in an attempt to work towards more integrated approaches to policymaking. However, integration of environmental policies and management approaches into broader policy contexts across sectors seems to be still in its infancy, as does inter-sectoral coordination, for example, between ministries within a country (OECD, 2005), although progress has been made recently in some Eastern European and Central Asian countries (OECD, 2012a).

6.4.2.2 Governance modes and policy instruments

Environmental governance modes and policy instruments (see Section 6.2 for definitions) are extremely diverse and multi-faceted. Given the complexity and diversity of environmental governance across Europe and Central Asia as outlined above (Section 6.4.2.1), it is only possible to present a very selective review of the key governance mechanisms, their opportunities and constraints. The search terms used in the literature review couched the topic as "governance". Therefore, unsurprisingly, the majority of the reviewed literature addressed hierarchical or decentralized governance modes and legal, regulatory, economic and financial policy instruments. This notwithstanding, even within this sub-segment of the literature, a wide range of governance mechanisms is described.

For Eastern Europe and Central Asia, the majority of the literature focuses on hierarchical approaches to governance, including, for example, environmental quality standards, environmental impact assessments and permits as legal and regulatory instruments; national environmental action plans for overarching guidance; and pollution charges, pricing and fees for the abstraction of natural resources as economic instruments (OECD, 2005, 2012a). However, research that draws on a sociological perspective also highlights the role that culturally shared understandings of responsibility, agency and governance can play in shaping environmentally relevant behaviour. For example, a qualitative study from the Kalmyk Republic, Russia, found that individuals who had participated in Buddhist teachings had a much stronger sense of personal agency (i.e., a feeling of being able to act and change something). Consequently, they engaged much more in small-scale pro-environmental action, than those who adhered to a hierarchical collectivist understanding of governmental responsibility for environmental quality (Waylen *et al.*, 2012).

For the European Union, Bomberg (2007) describes how market-based instruments, informational schemes and voluntary agreements gained in importance in environmental policy during the 2004 round of accessions. These are often not obligatory, but are part of a portfolio of policy instruments that member States are able, and sometimes actively encouraged, to use when translating framework regulations (Section 6.3) into national or sub-national governance approaches (Bomberg, 2007). Such "new" policy instruments might be particularly attractive for the European Union with its complex decision-making

Box 6 2 Scotland's Land Use Strategy 2016-2021.

Although the United Kingdom has been characterized as having a strongly hierarchical approach to governance (Pierre, 2000), recent developments in the devolved administration in Scotland suggest a move to a more networked approach, characterized by steering instruments providing strategic direction. A good example of this is the Scottish Land Use Strategy (Scottish Government, 2016). The strategy was initiated as an action arising from the Climate Change (Scotland) Act 2009, and has recently been refreshed for a second five-year period. The Land Use Strategy encompasses all land in Scotland, both rural and urban, and is therefore a cross-sectoral and integrative steering mechanism to encourage a more holistic approach to land-use planning and practice. One of its guiding principles is the adoption of an Ecosystem Approach (Waylen *et al.*, 2014), promoting recognition of natural functions, working with nature's contributions and engaging people. The approach focuses on providing a strategic framework for voluntary action at local, regional and national scales. Recent pilots of a Land Use Strategy regional framework, in the Scottish Borders and Aberdeenshire, have illustrated the benefits of spatially explicit evidence of trends in ecosystem service delivery; the ability to explore possible future trajectories; and public engagement to determine what people want from their land and the best ways to achieve it (Davidson *et al.*, 2015). The pilots confirmed that while some win-win solutions are available, often land-use change involves difficult choices surrounding trade-offs. Overall, the approach made impacts of land-use decisions on biodiversity and other regulating ecosystem services more visible. The deliberations that were part of the approach helped stakeholders from diverse sectors to appreciate the distribution of impacts and to better understand the basis for differences in preferences about land use and land-use change. However, achieving material improvements to the integrated management of land still requires a combination of incentives and sanctions to prop up this strategic steer. Whilst the pilots illustrated the promise of the approach, there was no actual implementation of the approach beyond the pilots. Therefore, the pilots illustrated both substantive and instrumental advantages of participatory processes (see Section 6.6), but support of other policy instruments is required to achieve benefits for ecosystems and biodiversity (Verburg *et al.*, 2016). The Land Use Strategy has a policy to develop a network of regional land-use partnerships in order to stimulate this deliberative and systems-orientated approach to land use across the whole of Scotland.

structures that require new, creative ways of governing (Kassim & Le Galès, 2010; Jordan *et al.*, 2013). More recent arrangements have been even more multi-faceted and integrative, but the guidance collaboratively elaborated through such interactive approaches still needs to be complemented by additional enforcement and incentive mechanisms in order to be effective **(Box 6.2)**. From the viewpoint of environmental psychology, the role of social norms and other social factors in shaping environmentally relevant behaviour, such as climate-relevant behaviour, has been evidenced for many societies in Western, Central and Eastern Europe (e.g., Nyborg *et al.*, 2016).

Environmental governance is often nested, especially in the European Union. In other words, instruments interact with each other across multiple levels, often with those at higher levels acting as an umbrella for those lower down. For example, the European Union Water Framework Directive (WFD), as one way of achieving good status for surface and groundwater, requires member States to identify river basin districts and related authorities, which would then develop management plans and programmes of measures. Local and regional governance is thus embedded in national and European Union-level governance (Jager *et al.*, 2016). Similar structures have also been developed in non-European Union countries such as Ukraine that share river basins with European Union countries such as Poland and are willing to align their management approaches with those of the European Union (Hagemann *et al.*, 2014) (see Section 6.3 for more on transboundary cooperation). The European Union Marine Strategy Framework Directive (MSFD), which aims to achieving good environmental status in European Union marine waters, has a similar architecture. It defines marine regions according to geographical and ecological criteria and requires member States sharing a marine region to cooperate in developing national marine strategies (Boyes *et al.*, 2016).

Overall, in the European Union countries and, increasingly, in countries in Eastern Europe and Central Asia (OECD, 2005), the role of multi-actor environmental governance is recognized (Arts *et al.*, 2006; Newig & Fritsch, 2009). This involves both state and non-state actors at different levels from the local to the international (Betsill & Bulkeley, 2004). For example, the Water Framework Directive explicitly demands public participation in river basin management (Jager *et al.*, 2016). The implementation of the Directive can be regarded as co-management (Moss, 2012), i.e., management (or in many instances, governance - Fischer *et al.*, 2014) that is shared between governmental and non-governmental actors. However, the terms "co-management" and "local knowledge" appear much less in the literature on the governance of non-biotic environmental issues than in relation to protected areas, wildlife, forestry or nature conservation; but also in the governance of, for example, water catchments, local ecological (and hydrological) knowledge has an important role to play (Iniesta-Arandia *et al.*, 2015; Mustonen, 2013).

Private and civil society actors such as environmental NGOs and industry representatives can also potentially shape the implementation of legislation through lobbying (Selin & VanDeveer, 2015), as shown for the adoption of European Union biofuel targets in both European Union member States, and non-member States in Eastern Europe (Tosun & Schulze, 2015). Similarly, international environmental NGOs can significantly influence the adoption process of new environmental policy instruments such as financial instruments and voluntary action in new accession states (Bomberg, 2007). The effects of their engagement can, however, be complex and are not necessarily always positive for ecosystem services (Section 6.3.2; Agarin & Grīviņš, 2016). Together with the increasingly nested nature of governance structures that is inherently multi-levelled, such multi-actor approaches to polycentric governance may span all levels from the international to the local, as described for climate governance (Jordan *et al.*, 2015) and for policy networks around the European Union mercury policy (Adelle *et al.*, 2015).

Economic and non-economic policy instruments interact with each other, often across sectors, but often with environmentally adverse effects. For example, the OECD's report on "green growth" (OECD, 2012a) points out that in several Eastern European and Central Asian countries, the low financial price attached to pollution and the use of energy or water, subsidies that encourage environmentally harmful practices, and regulations that set environmental standards on the basis of dated technology work together to counteract general government priorities such as energy efficiency and renewable energies. The same can be said about the multiple formal and informal institutions that work against a societal transition to a low carbon economy in the European Union, a declared policy objective (European Commission, 2016a). Improvements in environmental policy integration, notably the explicit integration of environmental policy issues into all phases of policy development and implementation, could help to address this (Beunen *et al.*, 2009).

6.4.2.3 Constraints and opportunities

One of the key factors that constrain the effectiveness of existing environmental governance arrangements is their limited enforcement, which is affected by a range of circumstances. For example, the existence of a large informal (shadow) economy in many Eastern European and Central Asian countries means that governance instruments such as taxation or pollution charges can influence only a limited proportion of all economic activities. At the same time, a complex regulatory framework might deter some economic actors from moving from the informal to the formal sector (OECD, 2012a). Improvements to those environmental governance arrangements that might be seen as overly complicated could facilitate this move (OECD, 2012a). In their systematic review of studies evaluating low-carbon policies, Auld *et al.* (2014) find a major trade-off between the efficiency of policies and their accountability and impact. Notably, they found that voluntary agreements tended to be less costly and more efficient than government-led instruments, but at the same time, accountability and effectiveness were limited, as they were lacking compliance mechanisms and clearly assigned responsibilities. Similar patterns might be found in the Water Framework Directive (Voulvoulis *et al.*, 2017).

Effectiveness of existing governance mechanisms is also limited by the sheer size of the environmental impact of human activities. Although this is not often stated explicitly, it seems that even progressive governance approaches such as the European Union Water Framework Directive are often not able to achieve environmental policy objectives, especially in areas of intensive agriculture and high population densities such as in parts of Western and Central Europe. Addressing these shortcomings requires, at the very least, an even more integrated and cross-sectoral approach to land and resource management (EEA, 2015d).

Challenges associated with quantifying the targets within environmental policies make effective implementation difficult. For example, European Union member States have found it difficult to define, in a manner that is measurable, what is meant by "good environmental status" in the context of the Marine Strategy Framework Directive. In the absence of a clearly defined good environmental status, it is not always possible to measure the impacts on, or risks to, the marine environment. Furthermore, the definition of good environmental status and its indicators are generally left to the interpretation of the individual member States, which may lead to variation in implementation (Boyes *et al.*, 2016). Economic considerations are also central for developing the marine strategies required by the Marine Strategy Framework Directive as well as the Water Framework Directive. For example, cost-effectiveness analysis and cost-benefit analysis have to be carried out before the implementation of any new measure to reach good environmental status under the Marine Strategy Framework Directive. These economic assessments can play a major role in justifying exceptions from the requirement to reach good environmental status, but their meaningfulness is limited when there is ambiguity surrounding the definition of good environmental status as the target state (Bertram *et al.*, 2014).

Effectiveness might also be constrained by limited encouragement for innovation within the existing policies. For example, existing pollution charges in Eastern Europe and Central Asia are often low and based on present technological standards, thereby missing out on the opportunity to incentivize technological improvements, for example, in terms of energy efficiency. Substantial subsidies for fossil fuel use in both businesses and households counteract intentions to move to a low carbon economy (OECD, 2012a). Generally, policies that leave scope for flexibility to choose from different options and pathways to achieving the same goal, for example, to reduce greenhouse gas emissions, tend to be more efficient and procedurally superior to narrower and more rigid instruments. However, if policies offer too much flexibility (and thus loopholes), they might defeat their own purpose, or have negative side-effects on social objectives such as equity (Auld *et al.*, 2014). However, the incentive character of governance approaches (i.e., the degree to which these act in an encouraging way) also has to be considered for participatory approaches. In the Water Framework Directive, participatory processes lack political power. In the long term, this may make it difficult to encourage public participation in further processes, damage public trust in authorities and undermine the legitimacy of plans and measures (Jager *et al.*, 2016).

Environmental or ecological fiscal reform aims at redirecting a government's taxation and expenditure programmes to create an integrated set of incentives to support the shift to sustainable development (National Round Table on the Environment and the Economy, 2002). It refers to a range of taxation and pricing measures that can raise fiscal revenues while furthering environmental goals. This means that taxation schemes are designed in a way that they place the tax burden on environmentally undesirable activities, rather than on those that might be environmentally desirable. Such schemes have to be carefully developed to be fiscally and environmentally effective, administratively feasible, and to avoid disadvantaging those actors that are already disadvantaged. For example, taxation can have both direct positive and negative impacts on money available in a household, as well as indirect impacts on employment or access to resources. Earmarking tax revenue to support pro-environmental activities can help to implement new governance tools that require financial resources (such as payments for environmental services), but can also obscure the overall governmental budgeting process and decrease transparency and accountability (OECD, 2013b). To focus their impact, taxes on environmentally harmful behaviour can be combined with subsidies for less harmful options. Again, however, these need to be carefully designed to avoid constraining alternative pathways of innovation (Pfaller, 2010). Although attempts have been made to develop environmental taxes in several countries, there remains substantial potential for more profound reforms and increased effectiveness (see also Chapter 4, Sections 4.3.2, 4.4.4, 4.4.5) (Ludewig *et al.*, 2010; Pfaller, 2010). More recently, the concept of ecological fiscal reform has been expanded to address land-use issues, biodiversity conservation and ecosystem services provision and thus, towards rewarding environmentally-friendly behaviour by way of fiscal instruments such as ecological fiscal transfers (Ring, 2011; UNDP, 2017).

Increasing effectiveness through economic instruments is a challenge that needs to be complemented by non-economic approaches. Prices attached to resource use or abstraction (e.g., water, energy) need to consider effects on poorer parts of the population. Increasing the price of energy and water has implications for the affordability of these resources among poorer households. The key challenge is to improve both efficiency and economy of use in a way that is pro-poor. This can happen through economic instruments, such as differential tariffs for industrial and domestic customers as in Moldova (OECD, 2012a) or progressive taxes and compensation measures for poorer households (OECD, 2013b), but other, non-economic instruments need to contribute here, too.

Integration of resource management might cause tensions in terms of the appropriateness of governance level and "institutional fit" (Newig & Fritsch, 2009). For example, Integrated Water Resource Management, and thus the river basin management approach adopted in the Water Framework Directive, can be seen as a positive development as it moves beyond single-issue policies. However, the conclusion that governance of a river basin should be based on the corresponding hydrological unit can lead to institutional misfits in other regards as river basin management is not solely a hydrological issue (Jager *et al.*, 2016; Moss, 2012).

Integration and implementation of novel governance approaches often remain incomplete, and therefore ineffective. For example, in the case of the Water Framework Directive, many member States have opted to retain existing structures and procedures as far as possible, without transferring responsibilities and power to the new river basin authorities (Jager *et al.*, 2016). Member States often continue with traditional water management practices focused on specific pollutants, rather than addressing catchment governance in a systemic way. Programmes of measures are often not implemented, which compromises delivery of Water Framework Directive objectives (Voulvoulis *et al.*, 2017). The flexibility conceded to member States in the Water Framework Directive might thus hamper its effectiveness.

Changes in governance arrangements instigated by intentions of European Union alignment or accession – even if long-term and aspirational, or if accession is not aimed for – are often regarded as opportunities for improving environmental governance (Juelich, 2005; Rosell Perez, 2013). Organizations like the Energy Community can be seen as facilitating steps towards such alignment (Tosun & Schulze, 2015). While substantial progress has been made overall (EEA, 2015d), in many cases further steps need to be taken to make policy change really effective (Juelich, 2005; Rosell Perez, 2013). For example, the Ukraine has modified legislative and regulatory instruments for water quality and monitoring both in response to guidance from the United Nations Economic Commission for Europe and European Union policies (Hagemann *et al.*, 2014). In Serbia, the process of adopting the European Union environmental acquis has also progressed, but this rather complex task has been hampered by a lack of staff to develop the necessary legislation (UNECE, 2015b) (see also UNECE, 2015a on Montenegro).

However, institutional change, even if intentional and planned (Fischer *et al.*, 2007) might be much less linear and direct than expected (Cleaver, 2002). For example, Waylen and co-authors (2015) identify the impacts of institutional, cognitive and political "sticking points", i.e., legacy effects, on the development of natural resource management initiatives working towards the adoption of an ecosystems approach. Kasymov and co-authors (2016) describe how in Kyrgyzstan, the revision of legislation that governs pasture use by livestock herders was based on a learning process that included trial and error (see also Section 6.5.1.2). They stress that such joint learning processes that allow for adaptation in a dynamic world should be seen as positive and an opportunity to develop governance arrangements that work on the ground. However, they also recognize that any such arrangements were (by-)products of larger policy discourses, such as the Washington Consensus that gave primacy to privatization and decentralization in the early stages of the revision process, and later ideas of community-based resource management and inter-sectoral cooperation.

6.4.2.4 Summary

While assessing the relevant bodies of literature on environmental governance, the diversity of existing governance arrangements and opportunities for the future in Europe and Central Asia, a number of knowledge gaps became apparent.

First, there seem to be limited studies that take a multidisciplinary systemic perspective on environmental governance in the region, and that combine an analysis of policy instruments with an analysis of the behaviour of (economic) actors (e.g., households, companies) and the overarching economic and social system in which these behaviours are embedded. Such perspectives would provide insights into the root causes of the limited effectiveness of environmental governance.

Second, while there is some literature that comments on the effectiveness of environmental governance arrangements, few publications assess their implications for equity and environmental justice. There are also very limited comparative insights into the effectiveness and ways of working of alternative policy instruments, and their interactions with each other in context (Jordan *et al.*, 2013).

Third, analyses that trace the impacts of governance arrangements on biodiversity and ecosystem services (or nature's contributions to people) in some depth, and that report on synergies and trade-offs or conflicts between their impacts, are very scarce (see **Box 6.2** for an exception). For example, more research is needed on the interplay between the different European Union directives dealing with the natural environment (Boeuf & Fritsch, 2016). Synergies are sometimes assumed but are not necessarily an explicit topic of investigation.

Fourth, and perhaps to some extent an artefact of the search process applied, literature on environmental governance seems to be largely focused on policy instruments and formal institutions. For the environmental sector, much less research and analysis is available on informal and hybrid governance mechanisms such as co-management and public-private partnerships. In particular, there are very few analyses of governance as a process (rather than an assemblage of institutions) in Eastern Europe and Central Asia, and analyses of local governance mechanisms and the role of local knowledge in environmental issues beyond water management.

Keeping these knowledge gaps in mind, our overview suggests that overall, the governance literature focuses predominantly on hierarchical governance modes as opportunities for improvements, rather than on public-private partnerships or private and civil society governance. This is especially true for publications like those of the OECD and other reports that might be informing policymakers' views more directly than academic journal papers. This is positive, as it does not shift responsibilities away from governmental actors by putting the onus of delivery on citizens who might not be equipped for the task. Such tendencies, labelled "the neoliberal agenda" have been widely criticized elsewhere, for example, in the context of rural development and community empowerment (MacKinnon & Derickson, 2012). A strong reliance on civil society to effect larger change, for example, a transition to a low-carbon society, will also miss out on the power of hierarchical governance approaches. However, businesses and corporations also bear significant responsibility for such a transition. Finally, a stronger consideration of a wider set of governance modes and instruments that includes grassroots action and social and information-based instruments might help to make environmental governance both more resilient and more effective (Seyfang & Smith, 2007; Stirling, 2014).

6.5 SECTOR POLICIES AND INSTRUMENTS: KEY CONSTRAINTS AND OPPORTUNITIES

6.5.1 Agriculture

6.5.1.1 Policy objectives in Western and Central Europe

In Western and Central Europe, the Common Agriculture Policy (CAP) exerts a great influence on agricultural land and rural areas of the European Union member States. Since its inception in the early 1960s, the overall objective of the Common Agricultural Policy was to enhance agricultural production. This has been achieved mainly through a market and price policy, subsidizing production and regulating import and export (EEA, 2016; European Commission, 2004; Hodge *et al.*, 2015; Zanten *et al.*, 2014). Production, reaching a peak in the mid-1980s, led also to the destruction, stocking, or dumping of agricultural surplus in developing countries, and to the increase of Common Agricultural Policy expenditures to around 70-75% of the total European Union budget (European Commission, 2004, 2013a). Unfortunately, the increase in production and productivity, achieved through agricultural intensification (e.g. by chemical inputs and mechanization), undermined other nature's contributions to people such as the provision of water quality, soil erosion and water run-off control, conservation of species and habitats, and maintenance of traditional agricultural landscapes and cultural identities (see also Chapter 2) (EEA, 2015a, 2015b; Henle *et al.*, 2008; Stoate *et al.*, 2009; Zanten *et al.*, 2014).

Recognizing the economically, socially and environmentally unsustainable model of the Common Agricultural Policy, reforms were undertaken in 1992, 1999, 2003, 2008 (CAP health check) and 2013. The overall objectives of these reforms were: changing the policy from a production support system to one more suitable to adapt to market conditions in a system of liberalization of world trade; reducing agricultural surplus; keeping budget costs stable and manageable; and making the policy more flexible and better shaped to the social, economic and environmental needs and conditions of different rural areas. The 1992 Common Agricultural Policy reform introduced some accompanying measures such as Reg. 2080/92 on forestry, Reg. 2078/92 on agri-environmental measures, the set aside of arable land, and the marketing of quality products. Then Reg. 1257/99, and later Reg. 1698/05, unified in one Regulation for Rural Development a number of structural and accompanying measures and disciplines. The 2003 reform introduced de-coupling of payments from agricultural production and structured the Common Agricultural Policy into two pillars: the first addressing the common market organization (i.e. agricultural commodities), the second focusing on rural development and delivering of public goods. Cross-compliance[7] by farmers, was made compulsory to render them eligible for direct payments of pillar 1 by the 2003 Reform, envisaging also the transferring of funds from pillar 1 to 2 (i.e. modulation). In pillar 2 new measures were introduced for management practices of agricultural land compatible with the conservation of the environment and biodiversity (e.g. Natura 2000 payments).

The main objectives of the last 2013 Common Agricultural Policy reform were: 1) to ensure long-term food security for people in Europe and to contribute to the growing global demand for foodstuffs; 2) to sustainably produce diversified, high-quality food while conserving natural resources and biodiversity; and 3) to ensure the viability of rural areas (European Commission, 2013c). This reform has seen the reduction of pillar 1 funding by about 13% and of pillar 2 funding by about 18% compared with the previous programme period 2007-2013 (Pe'er *et al.*, 2014). Another objective of this reform was to further enhance the joint provision of private and public goods by increasing the integration of pillar 1 and 2 in a more targeted, efficient and complementary way (European Commission, 2013c). For example, this included the introduction of the mandatory greening component (making up 30% of direct payments under Common Agricultural Policy pillar 1) conditional on the adherence of farmers to three "greening requirements"[8].

6.5.1.2 Governance modes and policy instruments in Western and Central Europe

The policy instruments implemented by the Common Agricultural Policy cover almost all governance modes applied to the agricultural sector: hierarchical (e.g. directives and regulations), decentralized (e.g. rural development plans), public-private governance (e.g. agri-environmental measures contracts between national or local public administrations and farmers) and private (e.g. agricultural markets) governance modes.

Among the most relevant regulatory instruments used by the Common Agricultural Policy, are the cross-compliance and greening requirements and European Union Directives concerning environmental issues. The European Union Water Framework Directive (2000/60/EC) (WFD) and the Nitrates Directive (91/676/EEC), are implemented by the Common Agricultural Policy through cross-compliance requirements such as "*protection and management of water*" and to "*protect water against pollution and run-off and manage the use of water*" (Matthews, 2013). Under the Habitats (Directive 92/43/ECC) and Birds Directives (Directive 79/409/EEC amended in Directive 2009/147/EC), there are 57 types of habitats and 259 species recognized as depending on or somehow linked to the continuation of agricultural practices (European Commission, 2014a). The Framework Directive on the Sustainable Use of Pesticides (Directive 2009/128/EC) delegates to member States the delivery of national action plans to reduce the impacts of pesticides and promote alternative techniques such as integrated pest management.

The most important economic and financial policy instruments are direct payments (i.e. basic payments and the greening payments) (pillar 1) and rural development measures (pillar 2). In the financial year 2013 direct payments from pillar 1 amounted to 71% of the whole Common Agricultural Policy expenditure showing an increase from 61% in the financial year 2000 and 65% in the financial year 2005, mainly due to new member States joining the European Union (European Commission, 2014b). The level of direct payments differs between countries and farmers because they are calculated as compensation for support-price reduction taking historical production and past income support as reference. This has resulted in large productive farms receiving more payments than small ones, creating problems with distribution and social cohesion (European Commission, 2014b). For the period 2014-2020, 118 rural development plans with economic, environmental and social objectives for pillar 2 have been proposed by national or local administrations on the basis of European Union Reg. 1305/2013 and co-funded by the European Agricultural Fund for Rural Development (EAFRD). Agri-environmental-climate payments are allowed for farmers voluntary enrolling for a minimum period of 5-7 years and for practices going beyond cross-compliance and greening requirements. Agri-environment payments are estimated on the basis of additional costs and income foregone, resulting from the commitments to be undertaken by farmers. An additional payment can be granted to cover transaction costs up to 20% of the payment, or 30% in the case of commitments undertaken by a group of farmers. The spending for agri-environmental measures for the period 2014-2020 is foreseen to reach 25 billion Euro (European Commission, 2015a).

Rural tourism is a private sector activity driven by market demand with important linkages to cultural and territorial local identity, often resulting in diversification of small and

7. Cross-Compliance comprises Statutory Management Requirements (SMR), referring to standards in environment, food security and animal welfare, and Good Agricultural and Environmental Conditions (GAEC) referring to soil protection, maintenance of soil organic matter and structure, avoiding the deterioration of habitats and water management (Commission Regulation (EC) No 1122/2009).

8. The three greening requirements are: 1) to cultivate at least two or three different crops in case of arable land exceeding 10 ha or 30 ha, respectively ; 2) to maintain permanent pasture; and 3) to establish ecological focus areas on at least 5% of arable land exceeding 15 ha (Hodge *et al.*, 2015).

medium farms' activities. Rural tourism represents 10-20% of rural income and employment (European Parliament, 2013). Some rural development measures such as, for the period 2007-2013, "encouragement of tourism activities", and "conservation and upgrading of rural heritage" and the LEADER initiative promoting integrated and synergic development based on the endogenous resources of rural areas (European Commission, 2013d), support the maintenance of aesthetic qualities of the traditional landscape, which is a public good (Brelik *et al.*, 2014; Papageorgiou & Guitton, 2009).

Concerning social and information-based instruments, three European Union schemes, as part of the European Union food quality policy (Reg. (EU) No 1151/2012), directly link agricultural products and foodstuffs to stages of production, processing and preparation in a specific geographical area (namely protected designations of origin (PDO) and protected geographical indications (PGI)); and to traditional composition or means of production (traditional specialities guaranteed (TSG)). By promoting and protecting agricultural products and foodstuffs, these schemes also contribute to the maintenance of cultural heritage related to local gastronomic specialities and associated traditional agricultural landscapes and agro-biodiversity (i.e. local animal breeds and plant varieties) (Bérard & Marchenay, 2006).

In the European Union the conservation of traditional agricultural landscapes is crucial to retain local cultural identities and to achieve the EU 2020 Biodiversity Strategy targets (Beaufoy & Cooper, 2009; EEA, 2012b). The concept of "High Nature Value Farmland"[9] was developed in the early 1990s (Beaufoy & Cooper, 2009) and was adopted as an environmental indicator for the Common Monitoring and Evaluation Framework (CMEF) of the Common Agricultural Policy in the 2007-2013 programming period (see **Figure 6.6**). It is included among the priorities and targets for rural development to be addressed by the measures of pillar 2 and proposed by the European Commission also for the period beyond 2013 (EEA, 2012b).

9. "Three types of high nature value farmland are identified: Type 1: Farmland with a high proportion of semi-natural vegetation; Type 2: Farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, small rivers etc.; Type 3: Farmland supporting rare species or a high proportion of European or world populations" (European Commission, 2014a).

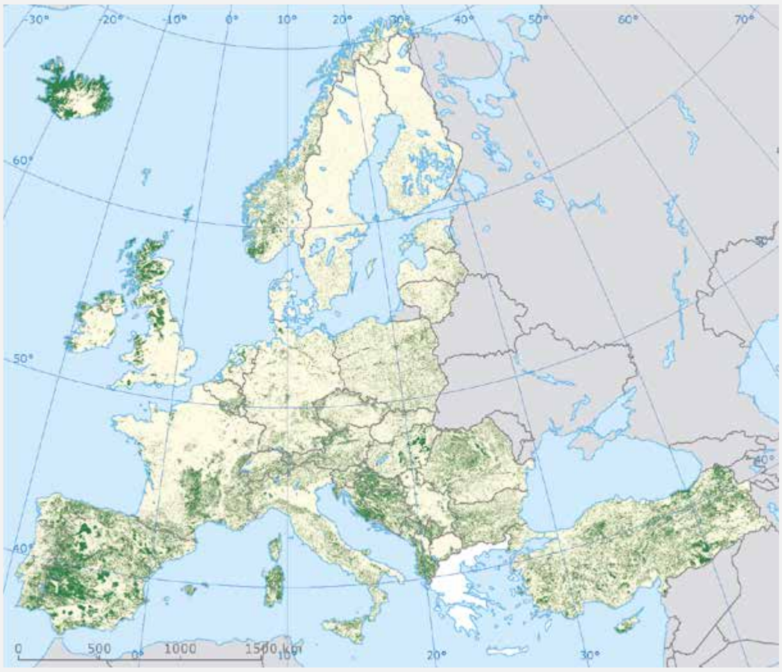
Box 6 3 Agri-environmental policy in Turkey.

Agriculture in Turkey, covering around 50% of the territory, has a far greater importance for the economy than it has in the EU-28. In 2012 agriculture in Turkey accounted for around 9% of GDP and 23.5% of total employment compared with 1.6% and 5%, respectively, in the EU-28 (European Commission, 2014d). Turkish farm structure is largely characterized by small farms, most of which are managed by families employing family labour, and practicing semi-subsistence agriculture (European Commission, 2014d).

In the last decades of the 20th century, the agricultural sector in Turkey was heavily influenced by government interventions such as the management of commodity prices through purchases and sales (e.g. cereals, sugar and tobacco), import tariffs and export subsidies, subsidized farm inputs (e.g. chemical fertilizers, diesel), and credit and investments in irrigation and other infrastructure (Larson *et al.*, 2014). Since 2001, following loan agreements with the International Monetary Fund, the Agricultural Reform Implementation Project (ARIP) was undertaken to change the commodity price support into "farm direct income support" de-coupled from production (Akder, 2007; Tan *et al.*, 2015). The resulting intensification of agriculture has caused on the one side, in the decade between 2003 and 2013, an annual wheat production of around 20 million tons (Tan *et al.*, 2015) and on the other, the loss of genetic diversity as testified by the low share (under 1%) of local wheat landraces in the total area of wheat production (FAO, 2015). Other environmental problems are related to soil erosion, over-consumption and waste of water, and excessive use of chemicals (Republic of Turkey, 2012). Unfortunately, although environmental issues in agriculture have been addressed by the Turkish Government since the 1990s, and are supposed to be increasingly considered by following the adoption of the Acquis Communautaire in the pre-accession process (Government of Turkey, 2012), the implementation of agri-environmental schemes is still in its infancy. Protection of the environment is mainly pursued through regulations while agri-environmental measures are still promoted only at a preparatory and pilot level, and organic agriculture has so far developed through export markets without any significant government support (Republic of Turkey, 2012).

There are clearly opportunities for improvement of agri-environmental policy, particularly considering that Turkey has an enormous potential to promote sustainability in agriculture because of a great richness of biodiversity and yet unexploited agro-ecosystems resulting from traditional extensive farming practices. Because of its geographical position, many fruit species, such as cherries, apricots, almonds and figs, originated in Turkey as well as wild relatives of other cultivated species such as wheat, chickpea, lentil, apple, pear, chestnut, hazelnut and pistachio (Republic of Turkey, 2012). Because wheat cultivation has been carried out for more than 8,000 years in Turkey, beside wild relatives and semi-domesticated varieties there is a large number of wheat landraces (FAO, 2015).

Figure 6 6 **Distribution of high nature value farmland in Western and Central Europe 2012 (Greece not included). Source: EEA (2015b).**



Indigenous local knowledge and practices are among the most important factors in managing high nature value farmland (Babai *et al.*, 2015; Iniesta-Arandia *et al.*, 2014). Biodiversity-rich landscapes are the result of traditional agricultural practices and local socio-economic features such as labour-intensive management and low mechanical and chemical inputs, small rotational parcel systems, mixed crops-forests-grazing systems, subsistence agriculture, traditional local knowledge, norms and institutions (Fischer *et al.*, 2012b; Molnár *et al.*, 2016). Unfortunately, while some Common Agricultural Policy instruments support general extensive management practices, the majority are not well suited to, or implemented by, particularly, Central European countries, to support indigenous and local knowledge and practices of small and semi-subsistence farms in high nature value farmland (Sutcliffe *et al.*, 2015).

6.5.1.3 Constraints and opportunities in Western Europe and Central Europe

In this sub-section, the assessment of constraints and opportunities is carried out by following categories of policy instruments. **Table 6.6** at the end of this section summarizes the results by looking at selected contributions of nature to people.

A number of factors would increase the effectiveness, efficiency and equity of policy instruments. These include: a better definition of clear and coherent objectives for the Common Agricultural Policy, simultaneously addressing multiple ecosystem services; a more defined focus on biodiversity conservation and delivery of nature's contributions to people at landscape level; a more explicit disclosure of trade-offs and synergies between different objectives; and more balanced and transparent funding between production of agricultural commodities and the delivery of public goods (Pe'er *et al.*, 2014) (see also synthesis **Table 6.11**).

With regard to legal and regulatory instruments (see synthesis **Table 6.11**), both cross-compliance and greening requirements have been criticized for the general environmental requirements being too loose to actually result in relevant ecological benefits (Hauck *et al.*, 2014; Hodge *et al.*, 2015; Pe'er *et al.*, 2014). Cross-compliance and the effectiveness of greening requirements, and that of regulatory instruments in general, depend on baseline, land-use alternatives, farming systems and site specific ecological characteristics (Hauck *et al.*, 2014), and on how European Union legislation is transposed and enforced by national Governments (Keenleyside *et al.*, 2014a). Art. 43 of Reg. 1307/2013 on rules for direct payments envisages the possibility of member States selecting greening equivalent practices tailored to their national situation, which *"yield an equivalent or higher level of benefit for the climate and the environment"* compared with the greening requirements. However, according to Hart (2015) this seems more an opportunity to facilitate the implementation of greening by farmers than actually increasing environmental outcomes. The actual provision of public goods by cross-compliance and greening requirements should be verified on a territorial basis and, in case of problems of effectiveness, reference levels should be adjusted locally (see also Tangermann, 2011) (synthesis **Table 6.11**). The integration of the territorial dimension in regulatory instruments is not new in European Union policy. It was already implemented in the European Union Water Framework Directive (2000/60/EC) (i.e. "good ecological status" baselines for water quality and river basins management plans) (EEA, 2015d) and in the Nitrates Directive (91/676/EEC) concerning the protection of waters against pollution caused by nitrates from agricultural sources (i.e. definition of "nitrate vulnerable zones" and implementation of farming practices following codes of good agricultural practice) (Stoate *et al.*, 2009).

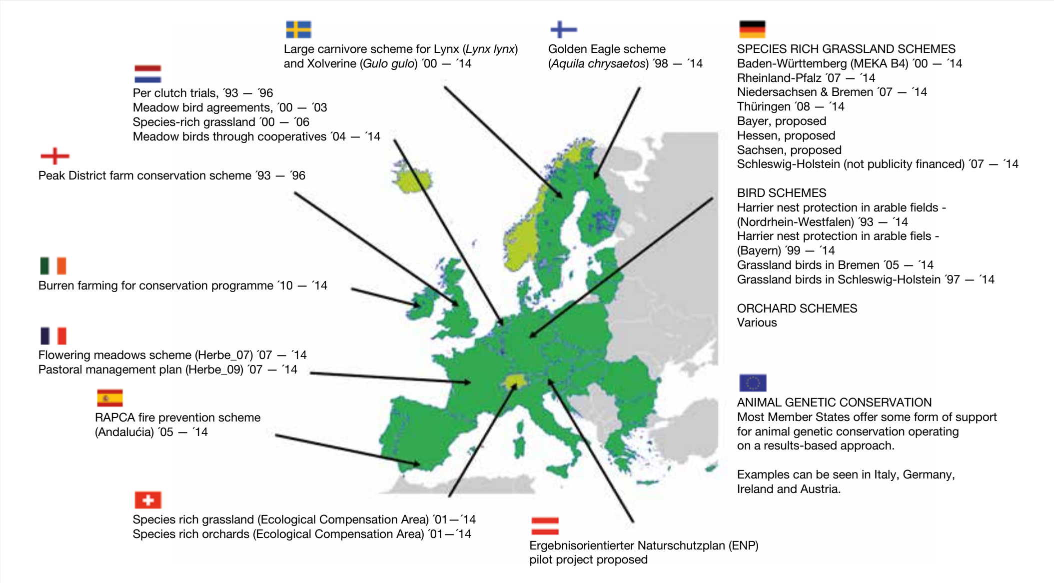
With regard to the conservation of biodiversity-rich agricultural habitats, out of 57 habitats associated with agricultural activities only 30 and 19 habitats have at least 60% and 30%, respectively, of their area included in the Natura 2000 Network. This precludes a large proportion of agricultural habitats that are rich in biodiversity from legal protection (European Commission, 2014a; Keenleyside *et al.*, 2014a). An opportunity to improve this situation is integrating biodiversity-rich agricultural habitats in the implementation of green infrastructure networks (EEA, 2014; European Commission, 2012, 2013b) (see also synthesis **Table 6.11**).

With regard to economic and financial instruments, food production has historically been heavily subsidized by the Common Agricultural Policy, at first by support prices and then, after the 1992 reform, increasingly by direct payments (Tangermann, 2011). Political justification for Common Agricultural Policy pillar 1 income support to European Union farmers are that farming is subject to volatile market prices, unpredictable weather conditions and variable input costs (European Commission, 2015a), essential to achieve food security and fundamental for the provisioning of some public goods of environmental and social character (Matthews, 2013; Tangermann, 2011). This approach has been criticized for lacking a robust rationale and clear objectives (Hodge *et al.*, 2015; Pe'er *et al.*, 2014). The rationale underlying the design of cross-compliance and greening requirements, to promote provision of public goods also by pillar 1, is that of having the greatest number of European Union farmers adhering to environmental requirements, so contributing to achieving positive ecological impacts and biodiversity conservation in agro-ecosystems. However, the definition of cross-compliance and greening requirements without appropriately considering local ecological and agronomic specificities, and therefore also different local opportunity costs, may result in ineffective, inefficient and inequitable policy (Matthews, 2013; Tangermann, 2011). Direct payments could be defined more transparently in terms of the income supporting objective and the ecological objective (Matthews, 2013) (see synthesis **Table 6.11**).

Amongst rural development measures of Common Agricultural Policy pillar 2, those supporting integrated pest management contribute to reducing pressures on fresh water bodies and to increasing pollination through reduced use of pesticides (Bengtsson *et al.*, 2005; Tuck *et al.*, 2014). However, the introduction of cross-compliance and greening requirements in pillar 1 makes the spending for integrated pest management (e.g. reduction and appropriate timing in pesticide use) less justifiable (synthesis **Table 6.11**). Integrated pest management could be included amongst the environmental requirements of pillar 1. This would free-up funds for other, more effective, agri-environmental payments such as organic agriculture and the establishment of buffer strips along water courses (Pe'er *et al.*, 2014; Stutter *et al.*, 2012). It could also help fund new measures such as the Green Infrastructure Strategy, as an innovative instrument for the conservation of habitats favourable to biodiversity and pollinators species (Liquete *et al.*, 2015; Pe'er *et al.*, 2014) (see also synthesis **Table 6.11**).

Agri-environmental policy design under the European Union Common Agricultural Policy has been largely based on action-oriented measures (i.e. farmers are required to adopt specific management practices) horizontally implemented (i.e. valid all over the European Union agricultural land) rather than based on results-oriented measures (i.e. compensation paid on the achievement of positive ecological impacts) addressing specific agro-ecosystems (see synthesis **Table 6.11**). The political, economic, ecological and social reasons for this are well understood (e.g. opportunity to enroll for the majority of farmers, farmers acceptance, high transaction and monitoring costs of result-oriented measures, success or failures in achieving an ecological target depending on causes other than the on-farm management practices such as climate, diffuse pollution, or the performance of neighbouring farms). However, there is also evidence to suggest that the effectiveness of action-oriented measures is lower than of results-oriented measures (Berendse *et al.*, 2004; Burton & Schwarz, 2013; Hodge *et al.*, 2015; Stoate *et al.*, 2009). In Western Europe, there is mounting evidence of already implemented and well-functioning result-oriented schemes (see **Figure 6.7**) (Keenleyside *et al.*, 2014b; Russi *et al.*, 2016). By adopting result-based agri-environmental policy, measures could be targeted more towards specific agro-ecosystems and socio-ecological systems. Contracts with farmers to deliver some of nature's contributions to people (e.g. maintenance of particular habitat, endemic species, scenery, cultural heritage, territorial identity) could be made at landscape level through collaborative agri-environmental schemes (McKenzie *et al.*, 2013; Prager,

Figure 6 7 **Results-oriented payment schemes in Western Europe. Source: Keenleyside *et al.* (2014b).**



2015). This would achieve critical territorial extension and reduce transaction and monitoring costs (Berendse *et al.*, 2004; Fleury *et al.*, 2015; Zanten *et al.*, 2014) (see synthesis **Table 6.11**). Moreover, results-oriented measures would also have cultural and psychological advantages. Paying farmers for contributing to biodiversity conservation and delivering ecological services at landscape level could enhance their environmental culture by adapting practices to local agro-ecosystems and offering them the opportunity to demonstrate their skills, and indigenous and local knowledge and practices in managing their farms (Burton & Paragahawewa, 2011). (See also **Box 6.4** and synthesis **Table 6.11**).

A finer targeting of agri-environmental measures to the local socio-ecological context is required also for high nature value farmland, where farms are disadvantaged by their low profitability compared with more intensive agricultural areas and therefore depend more on Common Agricultural Policy support measures. Unfortunately, many farms in high nature value farmland, particularly in Central Europe, are not eligible or unable to receive direct payments from pillar 1 and agri-environmental payments from pillar 2 (Keenleyside *et al.*, 2014a; Sutcliffe *et al.*, 2015). This is because of high administrative costs, small size, lack of financial capital, non-inclusion in the agricultural land categories defined by the European Union, or insufficient payment entitlements based on low historical support records. This situation further exacerbates the loss of indigenous and local knowledge and the abandonment of traditional agricultural land (Fischer *et al.*, 2012b; Molnár *et al.*, 2016) (see also synthesis **Table 6.11**). Besides benefiting from a better fine-tuning of agri-environmental measures to indigenous and local knowledge, farmers managing high nature value farmland could take advantage also of the opportunities offered by rural tourism being attracted to traditional agricultural landscapes. Market opportunities for small to medium-sized farms located in high nature value farmland could be further enhanced by promoting short food supply chains such as farm direct selling of local products to visitors, farmers' markets and e-commerce (Simoncini, 2015), and networking of farmers.

Among social and information-based instruments, information and training for farmers is crucial for the management of biodiversity and delivering of nature's contributions to people in farmland. The lack of advice and training for conservation of biodiversity related to Natura 2000 has been highlighted as a major shortcoming (European Commission, 2016c) (see also **Box 6.5** below and synthesis **Table 6.11**). A study reviewing the social aspects of Natura 2000 (European Commission, 2016d) found that "*the limited participation of stakeholders, the negative perceptions of the network and a lack of consideration of the local context hinder the network's effectiveness*", and that these need to be tackled by increasing public awareness. Advisory services on the delivery of public goods (e.g. biodiversity, cultural, territorial and relational values generated by local food production, processing, selling and consumption) could be enhanced (European Network for Rural Development, 2013) and the resulting advantages for farmers and civil society clearly explained (Fleury *et al.*, 2015) (see synthesis **Table 6.11**).

Box 6 4 Are only economic incentives at the base of adopting ecological behaviour by farmers? The case of Switzerland.

Since 1993 in Switzerland a voluntary agri-environmental scheme promoting integrated production was introduced. In 1998 the standards of integrated production became the basis of compulsory cross-compliance requirements, named "proof of ecological performance", to be adhered to by farmers to be eligible for direct payments (Herzog *et al.*, 2008). Cross-compliance further requires animal welfare, nutrient balance, crop rotations with a minimum number of crops per farm, and the establishment of "biodiversity promotion areas" (formerly called ecological compensation areas until 2014) on at least 7% of the area of a farm (Aviron *et al.*, 2009). Biodiversity promotion areas include extensively managed meadows and pastures, traditional high-stem fruit trees, hedges, stone walls and wildflower strips (Albrecht *et al.*, 2007; Birrer *et al.*, 2007; FOAG, 2015; Home *et al.*, 2014). The 2014-2017 agricultural policy revised the direct payment system to promote species and habitat diversity in agriculture through contributions to cultural and quality landscape, to ecological compensation, to biodiversity quality and to linking of habitats and designation of biodiversity acreages as parts of the Swiss ecological infrastructure, to production systems which are in harmony with nature and animal and environmental friendly, and to resource efficient practices (FOAG, 2015).

In Switzerland, according to Aviron and co-authors (2009), cross-compliance payments amount to 20% of farms' returns. The economic incentive effect of the agri-environmental scheme is therefore fundamental to maintain extensive agricultural practices beneficial to biodiversity. However, to enhance the effectiveness of agri-environmental schemes by increasing quality and connectivity of biodiversity promotion areas, it is necessary also to consider other motivations of farmers to adopt more ecological behaviour. According to Home and co-authors (2014), for farmers in Swiss lowlands such factors, beside financial incentives, also include their personal experiences and identities, trust in the expected outcome of the scheme, and the fact that they feel somehow trapped between societal expectation to conserve nature and the pride to show productive success towards other farmers. Schenk and co-authors (2007) highlighted that, beside subsidies, factors such as clear information, face to face communication, active co-operation of farmers in agri-environmental scheme design and consideration of different perceptions of environmental problems held by authorities and farmers, are all key in the formation of long-term acceptance of nature conservation measures. Also, there is the need for a concerted effort by farmers, policymakers, NGOs and landscape planners to improve agri-environmental schemes by addressing the specificity of more vulnerable target species at landscape level (Aviron *et al.*, 2009; Meyer *et al.*, 2017; von Glasenapp & Thornton, 2011). Von Glasenapp and Thornton (2011) report of an ongoing Vernetzungsprojekt (project to connect habitats and biodiversity) in Vals to incentivize farmers to adopt biodiversity-friendly practices beyond mandatory requirements. In this project payments are negotiated on an individual basis by the farmer and a biologist together assessing the farm biodiversity value and classifying the land into different categories eligible for payments. The adoption of agricultural practices suitable for the land is the result of these "walking negotiations", enhancing the share of scientific as well as indigenous and local knowledge (von Glasenapp & Thornton, 2011).

Box 6 5 Shortcomings in the implementation of Natura 2000 payments by European Union member States.

Agricultural land included in the Natura 2000 network covers 10.6% of utilized agricultural area of the EU-27 (European Commission, 2013d). Most Common Agricultural Policy pillar 2 direct policy instruments for biodiversity and habitats conservation are Natura 2000 payments supporting areas associated with agriculture and forestry. However, in the 2007-2013 period in the EU-27, Natura 2000 payments and payments linked to Directive 2000/60/EC (Water Framework Directive) comprised only 0.1% and 0.5%, respectively, of the European Agriculture Fund for Rural Development expenditures for Axis 2 of rural development on the environment (European Commission, 2013d). Consequently, this resulted in under-funding of Natura 2000 areas (Hansjürgens *et al.*, 2011a; Hochkirch *et al.*, 2013). During the 2007-2013 programming period, only half of European Union member States included Natura 2000 payments in their rural development plans. According to the European Commission (European Commission, 2016c) reasons for this vary from legal constraints (England) to the small number of approved management plans (Romania and Slovenia) (European Commission, 2016c). In other cases Natura 2000 payments were implemented only in agricultural areas (Portugal, Spain-Aragon) or forestry areas (Germany, Mecklenburg-Vorpommern) and only in some cases in both (Bulgaria, Slovakia and Estonia) (European Commission, 2016c). To increase the impact of Natura 2000, the lack of adoption of Natura 2000 payments in national and regional rural development plans by member States and the low enrolment by farmers need to be addressed by a multifaceted strategy. This includes increasing awareness of the positive Natura 2000 effects among national governments and the general public, advice and training to farmers, better tailoring of the measures to the local context, improving monitoring and reporting, and studying the promotion of a result-based "biodiversity conservation premium" (see synthesis **Table 6.11**).

Table 6 6 **Main policy objectives, instruments, status and trend of delivery and key findings for selected contributions from nature to people in agricultural land in Western and Central Europe.**

(See also Highlights in supporting material Appendix 6.3*)

*Available at https://www.ipbes.net/system/tdf/eca_ch_6_appendix_6.3_agriculture_finalv3.pdf?file=1&type=node&id=16600

Nature's contributions to people	Main Policy Objectives	Main Policy Instruments	State and trends of delivery of nature's contributions to people
Food	Long-term food security in European Union; growing global food demand; sustainable production	**Regulatory** e.g. cross-compliance, and greening requirements **Economic:** e.g. World markets; subsidies such as farm direct payments **Social and information-based:** quality product certification	Food self-sufficiency but imports for some products →
Energy (Biomass-based)	European Union Directive 2009/28/EC on renewable energy (RED) sets a 20% share of energy from renewable sources to be achieved by 2020	**Regulatory:** RED (art. 17, 18, 19) mandatory sustainability criteria for biofuels and bio-liquids; RED excludes land categories, with high biodiversity value, from being used for bio-fuel production Common Agricultural Policy CC requirements **Economic:** RD measures supporting production of biomass for bio-energy; Energy and CO_2 prices	Supply not at risk ↗
Regulating fresh water quality	Surface water bodies to reach Good Ecological Status by 2015	**Regulatory** (e.g. WFD, Nitrates Directive, Common Agricultural Policy pillar 1, CC, greening) **Economic:** Pricing policy (Full Cost Recovery of water services)	Self-purification as a service delivery is decreasing ↘ Water quality increasing due to limitation of pollutants from policies but still at risks of insufficiency for surface water ↗
Climate regulation	Objectives of RD linked to climate 1) Restoring, preserving, enhancing agriculture & forestry ecosystems 2) Promoting resource efficiency and the shift towards a low carbon & climate resilient economy	**Regulatory** e.g. CC, and greening requirements **Economic:** RD measures supporting establishing of semi-natural areas, CO_2 sequestration, promoting reduced emissions and energy use efficiency Energy and CO_2 prices	Sufficient in extensive agricultural land (also because of forest surface increases) → Not sufficient in intensive agricultural land →
Pollination	To produce diversified, high-quality food while conserving natural resources and biodiversity	**Regulatory** (e.g. Framework Directive on the sustainable use of pesticides, Common Agricultural Policy pillar 1, CC, greening) **Economic** (PES such as Agri-environmental measures for integrated pest management & organic agriculture)	Insufficient delivering ↓
Habitat & biodiversity	EU Biodiversity Strategy 2020 To halt the loss of biodiversity by 2020 Achi Biodiversity Targets	**Regulatory** (e.g. Habitats and Birds Directives; WFD; Common Agricultural Policy pillar 1 CC and Greening) **Economic** (AEM such as Natura 2000 payments) **Social and information-based:** HNVF concept	Insufficient delivering ↓
Physical & psychological experience	Not identified	**Economic** (e.g. Rural tourism demand; AEM on encouragement of tourism activities); social and information-based (e.g. some LEADER initiatives) **Social and information-based:** HNVF concept, farmers' indigenous and local knowledge	Increasing in traditional agricultural landscape ↗ Insufficient in areas of agriculture intensification
Heritage	Protection, management & planning of landscape in Europe (Council of Europe, 2000) Directive 2006/144/EC lists conservation and development of HNVF as a priority for RD 2007/2013	**Regulatory** (e.g., national laws) **Economic** (e.g. AEM on Conservation of rural heritage); social and information-based (e.g. geographical indications, some LEADER initiatives) **Social and information-based:** labelling, HNVF concept, farmers' indigenous and local knowledge	Increasing awareness but still insufficient in intensive agricultural areas ↗ Insufficient maintenance of indigenous and local knowledge →

LEGEND

Trend of nature's contributions to people delivering	Abbreviations	
↑ = strongly increasing ↗ = increasing → = stable ↘ = decreasing ↓ = strongly decreasing	AEM = Agri-Environmental Measures CC = Cross Compliance GR = Greening Requirements HNVF = High Nature Value Farmland IPM = Integrated Pest Management	PES = Payments for Environmental Services RD = Rural Development WFD = Water Framework Directive

Key Findings: Constraints	Key Findings: Opportunities
Difficult traceability of some food chains (e.g. meat) Stenmark *et al.* (2016) estimated that in 2012 in EU-28, food wastes amounted to 88 million tonnes of which 53% was attributable to households, 19% to processing, 12% to food service, 11% to production and 5% to wholesale and retail Competition with other contributions from nature to people	Cross-compliance and greening levels better defined if accounting for local ecological and agronomic requirements Possibility to increase modulation from pillar 1 to pillar 2 Incentivize short food supply chains Reducing industrial meat production due to its environmental impacts and large dependency on imports Promoting extensive livestock farming and pastoralism Halting land grabbing, land degradation and sealing
Possible intensification of energy crops production with direct and indirect impacts on biodiversity and trade-off with other contributions from nature to people (e.g. food production) Emissions from transportation of biomass from sites of production to be consumed far away Competition with other contributions from nature to people	Important source of energy for remote rural areas Local production and consumption of bio-based energy is usually more sustainable than having biomass travelling long distances
Need to further improve CC, efficiency of nitrogen use, waste water management and full compliance with the Nitrates Directive (EEA, 2015c) Need to restore riparian vegetation	Clear policy targets and territorial approaches such as, respectively, Good Ecological Status and river basin plans, allows better monitoring and feedback for amelioration of policies Establishing green infrastructure strategy
Use of fossil fuels, chemical inputs, and deep ploughing, intensive rearing of cattle are amongst the main factors contributing greenhouse gases emissions from agriculture	Possibility for European Union member States to use some RD measures of Common Agricultural Policy pillar 2 to address climate emissions and CO_2 sequestration Greening conservation of grassland and ecological focus area could have some positive effects on carbon sequestration if thresholds are set at an appropriate level Emissions from agriculture are decreasing
Too loose and general reference levels by Common Agricultural Policy CC and GR of Common Agricultural Policy pillar 1	Green Infrastructure Strategy could be an innovative instrument for the conservation of habitats favourable to pollinators species but it is still under development Referenced level in CC requirements should match actual IPM and agri-environmental payments should be allowed only for organic agriculture (see also responses in Table 6.4.1 and Table 6.4.2.1, chapter 6 IPBES Pollination Assessment (S. G. Potts, Imperatriz-Fonseca, & Ngo, 2016))
Too loose and general reference levels for supplying also public goods by CC and GR of Common Agricultural Policy Insufficient funding of instruments targeted to habitat & biodiversity Insufficient political commitment at national and local levels Severe under-funding of Natura 2000 areas and HNVF by insufficient implementation of locally relevant AEM Insufficient advisory services for farm biodiversity management	CC and GR tailored on agro-ecosystem typologies Increasing advisory services for farm biodiversity management Establishing green infrastructure strategy Enforcing the delivering of management plans for biodiversity conservation in order to receive compensations Design of local result-oriented AEM Adequate compensation to the income forgone (and to ecological added value)
Missing thorough official statistics data on rural tourism at European Union level Risk of tourism congestion in some areas and absence in others Competition with other contributions from nature to people	Increasing offer and demand for recreational activities and rural tourism The private character of rural tourism business is linked to the delivering of other public goods such as maintenance of traditional landscapes and cultural heritage
Homogenization of culture and tastes Costs of maintenance of traditional rural infrastructure Difficulties on making HNVF concept operational because of lack of data and different methodologies used to identify HNVF (Beaufoy & Cooper, 2009; EEA, 2012b; Keenleyside *et al.*, 2014a) Low profitability of HNVF Difficulties in accessing Common Agricultural Policy payments by small farms in HNVF	Understanding motivations of farmers managing HNVF Societal recognition of the importance of farmers managing HNVF Increasing solidarity between farmers and the public Developing short food supply chains (e.g. Quality product market niches, On-Farm direct selling, Farmer markets, delivering box schemes, e-commerce) Establishing a European Union labelling for agricultural products from HNVF and Natura 2000 areas

Stoate *et al.* (2009) indicate that in France around 70% of the Protected Denomination of Origin products are found in high nature value farmland. The design of an innovative eco-labelling European Union scheme for those agricultural products coming from high nature value farmland and Natura 2000 areas, could be an opportunity to allow European consumers to contribute to biodiversity conservation while buying traditional and high-quality food (see synthesis **Table 6.11**). However, a strategy to enhance the sustainability of high nature value farmland should also consider non-economic benefits such as motivations of farmers to manage high nature value farmland, their indigenous and local knowledge and practices, their socio-ecological context and life style, and their need for social and political recognition (EIP-AGRI Focus Group, 2016; Fischer *et al.*, 2012b; Gómez-Baggethun & Reyes-García, 2013; Iniesta-Arandia *et al.*, 2015).

6.5.1.4 Agriculture context in Eastern Europe and Central Asia

The agricultural sector is crucial for the economic development of Eastern Europe. As the region benefits from a mild climate and highly productive agricultural soil, it can contribute to meeting the increasing global demand for food in the future. Water resources and developed irrigation systems are other important assets of the subregion's agricultural sector (OECD, 2011). Radical land reform implemented after the dissolution of the Soviet Union in 1991 has strongly affected agriculture in the region in the 1990s. Agricultural land was divided into small plots and distributed among former farms' members and employees. However, large areas of land such as pastures and reserve lands remained in public ownership. In Georgia, Azerbaijan and Armenia, the agricultural sector is represented largely by small rural households whose main agricultural activities include animal husbandry, grazing in high mountain pastures, and cultivation of plateaus. Small farms produce mostly for subsistence consumption with a small surplus being sold at local markets (about 95% of agricultural products in Georgia and Azerbaijan, and 97% in Armenia). Conversely, in Russia, Belarus and Ukraine the sector is dominated by large agro-enterprises producing grains and oilseeds for export (FAO, 2012).

Privatization reforms in Eastern Europe were initiated with the objective of facilitating fast development of land markets, economies of scale and farm management. However, this did not happen in the majority of countries. Instead, the reforms shifted the sector to less intensive agricultural production and decreased productivity, which has generally benefited the environment (FAO, 2012). Prishchepov *et al*. (2012) report that institutional change in many post-Soviet countries led to agricultural land abandonment and that many abandoned agricultural fields are slowly reverting to grassland and forest. This may have major implications for biodiversity. For example, land abandonment may increase landscape heterogeneity and biodiversity of bird population.

There are, however, indications that the economies of transition countries are starting to grow, and pressure on natural resources will increase again, again with major implications for biodiversity and ecosystem services (Sutton *et al.*, 2008). The challenge faced today is how to encourage the development of more sustainable production systems and the provision of ecosystem services. Failure to do so has serious economic, environmental and social costs. For example, in Moldova, soil erosion is estimated to cost at least $40 million per year; in Ukraine about 50% of agricultural land is eroded; and contamination of water by agricultural nutrients and pesticides is of great concern across the subregion.

Similar to Eastern Europe, Central Asian countries **(Box 6.6)** experienced the Soviet regime and are facing rapid transformation processes since independence in 1991, thereby gaining valuable experience in designing institutions in natural resource management that had to be adapted to the specific natural conditions and agricultural practices of the subregion. The agricultural sector is of fundamental importance in the subregion's economies. The use of 399.4 million hectares of agricultural land is constrained, however, by biophysical factors of arid and continental climate. Most of the territory of Central Asia is covered by deserts, steppes and mountains. Winters are extremely cold and summers hot and dry, and precipitation relatively low (up to 150 mm in deserts of Turkmenistan and Uzbekistan, up to 400 mm in Kazakhstan's steps and up to 800 mm in the mountain areas of Kyrgyzstan and Tajikistan). Due to climatic and topographic conditions, grassland is a dominant type of land here with only 8% of arable and 4% forest land **(Figure 6.8)**.

Small and medium-sized family farms established in Central Asian countries during the last decade play a crucial role in agriculture today. Their share of gross agricultural output is between 71% (Kazakhstan) and 98% (Uzbekistan) (Schroeder, 2016). However, the opposite trend has also been observed recently, i.e. the accumulation of land by large agro-holding companies in Kazakhstan, and an increase in farm size in Uzbekistan as a result of the governmental policy of "land optimization". Although land is leased to farmers for up to 50 years in Uzbekistan, they may lose their land if they do not execute state orders for producing cotton and wheat (Schroeder, 2016).

High unemployment in Kyrgyzstan, Tajikistan and Uzbekistan contributes to poverty, which has become a serious problem in these countries **(Table 6.7)**. Although

Box 6 6 Agriculture in Central Asian countries (Quillérou *et al.*, 2016).

In **Kyrgyzstan**, seasonal migratory grazing was historically the main type of livestock management. However, more accessible spring/autumn pastures are now used during all seasons. As a result, they are overgrazed, requiring improvement of their management.

In **Tajikistan**, most economic and livelihood activities of the country's population take place in the foothills and low mountains where the country has largest type of pastures (by size).

In **Turkmenistan**, lowland pastures provide around 60% of the economic value of ecosystem services to traditional rural communities.

Uzbekistan consumes the largest share of available water in the region to irrigate the largest area of land, which contributes 20-30% to the country's GDP.

Kazakhstan has the second largest area of irrigated land. Moreover, about 80% of pastures depend on manmade facilities using subsurface water.

Figure 6 8 Land cover map of Central Asia. Source: Zhou *et al.* (2015).

as Soviet republics they were already the poorest of the USSR (in particular Kyrgyzstan and Tajikistan), the situation has substantially worsened over the last decade. This is especially the case for rural populations living in areas where fertile land and water are scarce, and where deterioration of these resources is a serious problem. Extensive degradation is observed in the region with estimates that 4-10% of cropped land, 27-68% of pastures and 1-8% of forest land, are degraded (Quillérou *et al.*, 2016). As a result, migration from rural areas is increasing. The majority of migrants move to cities and neighbouring countries such as Kazakhstan and Russia. According to Schroeder (2016), about 4.5 million migrants from Kyrgyzstan, Tajikistan and Uzbekistan live and work in Russia.

Table 6 7 **Population wealth and livelihood indicators in Central Asian countries. Source: IMF (2015); World Bank (2015); UN DESA (2015), cited in Schroeder (2016).**

	Population (mln.)	Average population growth (annual %)	Per capita GDP (USD)	Average GDP growth (annual %)	Unemployment rate (%)	Agriculture value-added (% of GDP)
	2014	2010-2014	2014	2010-2014	2014	2014
World	7,259.7	1.19	10,739	2.5	5.9	3.1
Kazakhstan	17.3	1.4	12,276	6.0	4.1	4.6
Kyrgyzstan	5.8	1.6	1,269	3.7	8.1	17.3
Tajikistan	8.3	2.3	1,114	7.1	10.1	27.4
Turkmenistan	5.3	1.3	9,032	11.0	10.5	14.5
Uzbekistan	30.7	2.0	2,038	8.2	10.6	18.8

6.5.1.5 Transformation of environmental governance in Eastern Europe and Central Asia

In Eastern Europe and Central Asia, the importance of environmental protection is usually recognized in the statements of agricultural policies, but countries often struggle to implement these. An illustrative example of this is the soil protection institutions in Ukraine. Stupak (2016, p. 86) argues "*that having destroyed the elaborate Soviet soil protection system, Ukraine did not manage to develop a new set of legal rules, nor their enforcement mechanisms, to enable soil protection in the new political and economic setting*". During the last decade of post-socialist transition, agricultural policies in the subregion have been dominated by privatization reforms implemented with strong technical and financial backstopping from international donors. The World Bank and the International Monetary Fund conceptually and financially supported the design and implementation of the transition reforms for all post-Soviet countries. The objective of these purely economic policy-based prescriptions, known as the "Washington Consensus", consisted of four policy interventions: price liberalization, stabilization, privatization and minimization of the state role. The reforms had a powerful impact on the management of natural resources and shifted the governance modes away from hierarchical centralized governance. The situation varies from country to country, but it seems that the new modes of governance (decentralized, public-private partnerships and private governance) are still under development and the mismatch between the hierarchical governance structures and the new decentralized institutions persists in many post-socialist countries (Kluvánková-Oravská *et al.*, 2009).

The literature reports a land-grabbing problem in post-Soviet Eurasia (Visser & Spoor, 2011). This is particularly relevant for Russia, Ukraine and Kazakhstan where large domestic and foreign state and private companies acquire vast areas of farmland. Deininger & Byerlee (2011 p. 88) warn: "*If property rights are secure, markets function well, and areas with high social or environmental value are protected effectively (possibly using market mechanisms, such as payments for environmental services) the public sector's role is mainly regulatory. The public sector takes care of environmental externalities and allows markets, including those for land, to function smoothly and to encourage expansion into low grade pastures and degraded forest rather than into areas already occupied or with high biodiversity value. But if land rights are insecure or ill-defined, large-scale land acquisition may threaten forest or lead to conflict with existing land users*". The large-scale land acquisitions in these countries might well have far-reaching consequences for the livelihoods of the rural population, nature's contributions to people and biodiversity.

Since the dissolution of the Soviet Union in 1991, independent Eastern European and Central Asian countries have implemented reforms and policies transforming environmental governance. Many natural resource management systems such as irrigation, forest, and pasture organizations were highly centralized and had to undergo fundamental transformation.

In Central Asia, decentralization policies were introduced with the objective of promoting the more sustainable use of natural resources. Countries received strong financial and logistic support from international donor agencies. For instance, Kyrgyzstan implements devolution of power and decentralization of authority in pasture management to the newly created political level of "local self-governance" and "pasture user unions and pasture committees" **(Box 6.7)**. Other Central Asian countries are currently considering following this example by introducing new regulations with individual or common forms of tenure (Robinson *et al.*, 2012).

With regard to irrigation water, Central Asian countries have transferred authority for management to non-commercial voluntary organizations of water users that finance themselves through members' payments for water service delivery. They are responsible for operating, maintaining and rehabilitating the irrigation system, delivering water to end users, purchasing water from the state, and collecting water fees from users (Herrfahrdt *et al.*, 2006; Ul Hassan *et al.*, 2004; Sehring, 2007 cited in Bichsel *et al.*, 2010).

This represents a fundamental change in the relationship between state, market and civil society with regard to pasture and irrigation water management, by moving away from the hierarchical top-down governance and command and control policy instruments, inherited from the Soviet past **(Box 6.7)**.

6.5.1.6 Assessment of environmental governance in Eastern Europe and Central Asia

Despite the challenges in transforming environmental governance in Eastern Europe and Central Asia, there are several positive trends reported in the literature (Sutton *et al.*, 2008). For instance, the latest agricultural strategies incorporate or integrate environmental targets including their evaluation, while inter-ministerial cooperation is improving in most countries (see synthesis **Table 6.11**). Moreover, agricultural and research systems are increasingly addressing environmental and sustainability issues.

However, other important policy instruments such as awareness and capacity building of farmers are generally inadequate (see synthesis **Table 6.11**). The non-existence of advisory and extension services may contribute to the problem. The previous system of top-down directives to collective and state farms is no longer relevant and has to be replaced, but only a few countries have experimented with innovative and low-cost alternatives. Other problematic issues to be addressed include: the need to strengthen monitoring systems, lack of programmes addressing widespread erosion problems; weak certification policies and nutrient management; and lack of strategies to promote organic farming and certification (see synthesis **Table 6.11**) (Sutton *et al.*, 2008).

The Central Asian experience of the decentralization of environmental governance offers valuable insights. Based on the design and implementation of irrigation water management reforms, it can be observed that, despite the introduction of different agricultural policies and formal institutions, the problems remained similar. This includes weak, newly established institutions; poor public acceptance and lack of legitimization of new regulations and governance structures among resource users; and the growing gap between the implemented policies and the users' resource use and management practices (Hamidov, 2015; Sehring, 2007). This is very much true for the pasture sector **(Box 6.7)**. A brief review of the literature presented here offers some important insights regarding constraints faced by policymakers and resource users in both key sectors.

The life and scope of action of resource users and policymakers in Central Asia are profoundly affected by multiple historic turning points, each characterized by a radical change of systems and ideologies. Transformation

Box 6 7 Shifting governance arrangements and policy reforms in Central Asia: The case of pasture management in Kyrgyzstan.

Pasture land is a key natural resource in Kyrgyzstan **(Figure 6.9)**. There is strong consensus among scholars today that sustainable pasture use and management in Central Asia depends largely on pastoral migration **(Figure 6.10)**. However, the early post-Soviet pasture management reforms in Kyrgyzstan did not recognize the importance of institutions coordinating pastoral migration and did not take into account the economic and political dynamics related to mobile herding (Dörre, 2012; Jacquesson, 2010; Steimann, 2011; Undeland, 2005). As a result, a massive reduction in pastoral mobility was observed after implementation of those early reforms (1991-2009). Reduced mobility led to the overgrazing of pastures, decreasing livestock productivity and increasing conflicts between pasture users over access to the resource (Farrington, 2005; Ludi, 2003; Undeland, 2005; Wright *et al.*, 2003). In Kyrgyzstan, overgrazing causing soil and land degradation is also perceived as the key pressure and driver of changes in biodiversity and ecosystem services. For instance, the National Report on Conservation of Biodiversity states that pressure on more than 3,500 species, which grow on pastures, increases due to overgrazing (Government of Kyrgyzstan, 2013).

Box 6 7

Figure 6 9 **Pastures in Kyrgyzstan. Source: Adapted from Penkina (2004).**

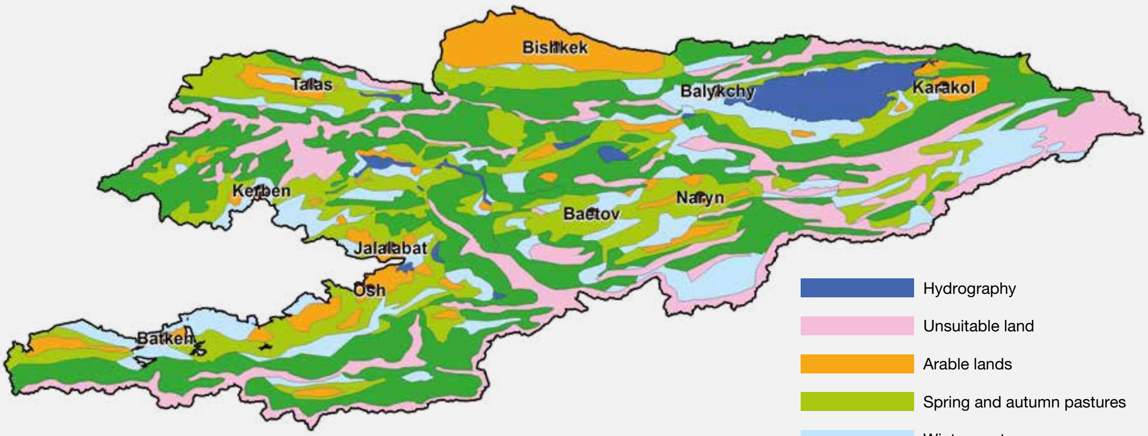


Figure 6 10 **Herders on summer pastures in Kyrgyzstan. Photo: Ulan Kasymov.**

Responding to pasture-related problems the Kyrgyz parliament adopted a new law "on pasture" in January 2009 (Government of Kyrgyzstan, 2009). With the objective of promoting more sustainable use of pastures, the new law introduced radical changes to the pasture management system: (1) it abolished the three-level Soviet-era system of state pasture management based on spatial pasture characteristics – transferring the responsibility for pasture management substantially to the local level and placing it on municipalities and the newly formed pasture user unions and pasture committees; (2) it abolished

Box 6 7

the area-based long-term pasture lease system and introduced an annual livestock-based pasture fee ("pasture ticket"); and, lastly, (3) it introduced a planning and monitoring system for pasture use and management. By 2011, pasture user unions and pasture committees had been created in 454 municipalities in Kyrgyzstan (World Bank, 2011).

The shift in governance is a fundamental change of roles and positions between state, market and civil society with regard to use and management of pastures and is an attempt to move away from the hierarchical top-down governance, inherited from the Soviet period, to a hybrid one – a mix between the "decentralized", "self-governance" and "private governance" modes. As a result, considerable changes of actors and institutional features have occurred in Kyrgyzstan **(Table 6.8)**.

Table 6 8 **Governance modes in pasture management in Kyrgyzstan. Source: Own representation.**

	Hierarchical governance before 1991	Decentralized (since 1995)	Public-private governance (since 2009)	Self-governance (since 1991)
Actors	Department of Pasture at the Ministry of Agriculture at national level Departments of pasture at the regional and district levels	Department of pasture at the Ministry of Agriculture at national level Departments of pasture at the regional and district levels Municipalities	Municipalities, pasture user unions and pasture committees	Pasture users (e.g., herders and livestock owners)
Power	Coercion	Coercion	Competitiveness	Autonomy of pasture users Informal leaders Social capital and trust
Representation	Pluralist ((supra) national elections)	Pluralist (local elections)	Partnerships Arrangements between pasture committees and pasture users	Partnerships Participatory private-private governing arrangements (e.g., informal herding arrangements)
Mechanism of social interaction	Top-down; command and control	Municipalities decide autonomously on pastures within their boundaries	Pasture Committees develop and enforce the implementation of the pasture management plans in a participatory process	Bottom up; social learning, deliberation and negotiation regarding access to and use of the resource

Since 1991, new key actors have emerged, changing the configuration of stakeholders: (a) after the dissolution of state farms and privatization of livestock, private livestock owners and herders became *de facto* managers of pastures; (b) municipalities within the borders of former collective/state farms were created during the decentralization reform; and (c) pasture committees and pasture user unions were established within the latest pasture legislation. Power relations among those stakeholders have also changed significantly. Initially, the main responsibility for managing pastures within the municipality borders was delegated from the national and regional levels to the municipal level. Later, this responsibility was shifted again to the newly established pasture committees and pasture user unions. Furthermore, "representation" has changed from "pluralistic" at the national and regional level to a mix between the "pluralistic" and "corporatist" at the local level, when pasture-use agreements are to be negotiated between pasture committees and pasture users. Finally, the "mechanism of social interaction" has been transformed from "top down" and "command and control" to a less formal and more interactive one.

An important feature of the latest pasture reform is that a mix of policy instruments was developed just after the legislation was

Box 6 7

approved by the parliament in 2009, and tested while the reform was implemented **(Table 6.9)**. One of the first tasks for each newly established pasture committee is the collection of pasture fees and the allocation of pasture tickets to pasture users. The collected pasture fees finance the committee's overhead costs and are invested in pasture infrastructures and improvement. The pasture fee is defined annually by the pasture committee for each type of livestock as well as for each type of pasture. It cannot be lower than the basic tax for using a pasture, and it needs to be approved by the respective municipality. The collection of pasture fees is, however, a difficult task, since livestock monitoring is a problem in many communities. The pasture ticket is allocated according to annual pasture use and a management plan, which is developed and implemented under the coordination of the responsible pasture committee. The capacity and condition of pastures (productivity and level of degradation) and the size of livestock populations need to be monitored and assessed annually by pasture committees as a basis for negotiations concerning the allocation of pastures for the following year's pasture use plan.

Table 6 9 **Policy instruments in pasture management in Kyrgyzstan since 2009. Source: Own representation.**

Legal and regulatory instruments	Economic and financial instruments	Social and information-based instruments	Rights-based instruments and customary norms
Pasture Law (2009) Pasture use and management planning Pasture use monitoring	Pasture fee and land tax Grants to pasture committees and pasture unions	Information regarding pastures (e.g., distribution, state) Awareness building and trainings organized by NGOs and extension services	Pasture collective rights Customary norms and institutions

The literature is divided in assessing the effectiveness of the more recent pasture reform in Kyrgyzstan (implemented since 2009): to what extent did the policy intervention contribute to achieving a more sustainable use of pastures as the main policy objective? Critical assessments of the reform's impact are offered by Crewett (2015) and Dörre (2015). While Crewett investigates how policy implementers at the local level ("street-level bureaucrats") simplify information rules in the donor-initiated natural resource governance reforms at the expense of a more participatory resource user involvement, Dörre (2015, p. 1) compares "promises" of Kyrgyzstan's pasture-related legislation and "realities" of its implementation. In his opinion, *"the recent innovation in pasture law has not comprehensively resulted in the desired outcomes on the ground"*. Furthermore, Ridder *et al.* (2017) evaluate the costs and instrumental benefits of different land-use strategies with regard to pasture degradation. The study comparatively assesses alternative pasture management strategies, reflecting on their impact on pasture and livestock productivity. The authors conclude that allowing pastures to rest will lead to higher net benefits and would be a more beneficial choice for herders economically. However, awareness about the relationship between overgrazing and pasture or livestock productivity has not been translated into action by pasture users due to the lack of consensus between experts and herders regarding which interventions are needed and how they should be organized (Ridder *et al.*, 2017). Kasymov (2016, p. 7) argues, on the other hand, that enforcement of new formal institutions in pasture use and management affects the relative bargaining power and distributional advantage of actors. Thus, it has a redistributive character in supporting less powerful actors and contributing to the selection of more socially-optimal strategies adopted by pasture users. All authors agree, however, that the latest reform in pasture management in Kyrgyzstan is still a "work in progress" and a longer-term perspective as well as more research will be required to evaluate the environmental and social impacts.

in natural resource use and management in Central Asia has been shaped not only by its Soviet past, but also its colonial past (Schmidt, 2013). Decentralization policies are largely built on the longstanding misconception of traditional institutions (Jacquesson, 2010). For instance, agro-pastoral communities in Central Asia are often perceived as homogenous, which they no longer are. Increasingly, rural communities are characterized by striking power asymmetries (Kerven *et al.*, 2011; Steimann, 2011). Furthermore, the role of bargaining power is underestimated in policymakers' societal perceptions, beliefs and formal institutions, but it plays a huge role in access to the resource itself and the creation of informal rules among resource users. The ability of policy interventions to reduce power asymmetries is decisive in changing informal rules and resource use and management practices (Kasymov, 2016).

Governance of natural resources and biodiversity requires compatibility between ecological and social systems (Paavola & Adger, 2005) and implies that institutions coordinate complex interactions between people and nature, maintaining the ability of the ecological system to support the social and economic systems (Hodgson, 2004). To address the problems listed above, Eastern European and Central Asian countries may need to transform environmental governance, redefining the role of state and civil society, their power, and mechanisms of interactions in natural resource management.

Several aspects need to be considered when designing policy interventions in Eastern Europe and Central Asia. First, for the countries rich in land resources, such as Russia, Ukraine and Kazakhstan, an important governance challenge is to address land grabbing and the potential exploitation of existing institutional weaknesses by powerful investors (see also synthesis **Table 6.11**). Second, the governing dynamics of land abandonment observed during the initial transition period, and recent intensification of land use, will be crucial for protecting environmental services and biodiversity in the regions. Finally, Central Asian experiences in decentralization and devolution illustrate that the process of institutional change is not straightforward but rather, complex and dynamic. As institutions are designed to coordinate complex interactions between ecological and social systems, which is characterized by processes of evaluation and co-evolution, institutional development is also very much a result of co-adaptation and learning. Therefore, institutional design to protect biodiversity and environmental services must strengthen and build upon local knowledge, practices and agricultural institutions (synthesis **Table 6.11**).

6.5.1.7 Summary

In recent decades, the governance of the agricultural sector has undergone important changes in Europe and Central Asia.

In Western and Central Europe, the establishment of the European Union Common Agricultural Policy saw at first strong support for production by government intervention, which led to unsustainable negative impacts on the economic, socio-cultural and environmental systems. Then, from the 1980s, Common Agricultural Policy reforms promoted the decoupling of farm income support from production, the reduction of agricultural surplus, the control of budget costs and the integration of socio-cultural and environmental objectives into the policy. Various policy instruments from different instrument categories were used to achieve these objectives, such as relevant environmental regulations and laws, rural development plans, agri-environmental measures, food quality labelling, participatory processes involving stakeholders, and the adaptation to market conditions by farms. While the Common Agricultural Policy budget spent on production of agricultural commodities was reduced and agricultural pressures on the environment lessened, significant progress is still lacking in enhancing the delivery by the agricultural sector of some of nature's contributions to people that are public goods such as air, water, and climate regulation, soil erosion and water run-off control, conservation of habitats and biodiversity, and maintenance of traditional culture and agricultural landscapes. The delivery of nature's contributions to people may be supported by the agricultural sector if the Common Agricultural Policy objectives are defined more clearly (e.g. what are farm income and environmental objectives supported in the policy's pillar 1) (see also synthesis **Table 6.11**) and policy instruments are made more efficient and effective. This could be achieved, for example, by fine tuning the Common Agricultural Policy cross-compliance and greening requirements to critical ecological thresholds for nature's contributions to people delivery by agro-ecosystems at local level in pillar 1 and by developing more effective and more result-oriented agri-environmental measures tailored to local conditions in pillar 2 (see synthesis **Table 6.11**).

In Eastern Europe and Central Asia, the dissolution of the Soviet Union in the 1990s led to a decentralization of governance of the agricultural sector and to privatization and redistribution of land to farmers. This has, in many countries, resulted in a reduction of big state farms in favour of small to medium-sized private farms producing for subsistence consumption and local markets. It also resulted in the establishment of large agro-enterprises producing grains and oilseeds for exports in Russia, Belarus and Ukraine in Eastern Europe and Kazakhstan in Central Asia, and big farms as a result of "land optimization" governmental policy in Uzbekistan. The results of these land reforms, from an environmental point of view, have been less intensive agricultural production, a decrease in productivity in small- to medium-size farms, and land abandonment that have generally benefited the environment. However, the transition toward a market economy is already showing signs of increasing intensification of agricultural practices leading to big environmental impacts (e.g. soil erosion in Moldova), high unemployment rates in rural areas (e.g. in Kyrgyzstan, Tajikistan and Uzbekistan), and land-grabbing problems in post-Soviet Eurasia (e.g. Russia, Ukraine and Kazakhstan). Since the dissolution of the Soviet Union in 1991, in independent Central Asian countries many natural resource management systems such as irrigation, forest, and pasture organizations have transferred authority to local stakeholders (e.g. pasture user unions and pasture committees in Kyrgyzstan, non-commercial voluntary organizations of water users for irrigation of water). This represents a fundamental change in the relationship between state, market and civil society with regard to pasture and irrigation water management, by moving away from the hierarchical top-down governance and command-and-control policy instruments, inherited from the Soviet past.

Despite these positive trends, such as the integration and evaluation of environmental targets, inter-ministerial cooperation, and improved research systems (see also synthesis **Table 6.11**) there are many pitfalls. These include the lack of awareness and capacity building of farmers, non-existence of advisory and extension services, weakness of newly established institutions, poor public acceptance and lack of legitimization of new regulations and governance structures among resource users, and the growing gap between the implemented policies and actual management practices (see also synthesis **Table 6.11**). To address these problems, there is a need to transform environmental governance by redefining the role of state and civil society, their power, and mechanisms of interactions in natural resource management (see also synthesis **Table 6.11)**. To enhance nature's contributions to people and biodiversity conservation in the regions, new governance systems will also have to address the problem of land grabbing and the potential exploitation of existing institutional weaknesses by powerful investors (e.g. in Russia, Ukraine and Kazakhstan). Governance systems will also have to address the abandonment of land and the recent intensification of land use by securing property rights and responsibilities, as well as designing and enforcing legal standards to sustain biodiversity and nature's contributions to people (see synthesis **Table 6.11**).

6.5.2 Forestry

6.5.2.1 Policy objectives

Forests and other wooded land cover about 1,172 million ha in Europe and Central Asia. Since 2000 there has been a net increase of forest in nearly all countries due to afforestation policies and natural expansion on, for example, abandoned agricultural land (see Chapter 4) (UNECE/FAO, 2015). The forest area is heterogeneously distributed across the region (UNECE/FAO, 2015). The Russian Federation has by far the most, with 890 million hectares, which represent 54% of its total land area. This is far above the average proportion for other Eastern European countries (approximately 40%), as well as Western Europe (about 35%), and Central Asia (< 10%). The economic significance of forestry varies between countries of the region. Based on the current system of national accounts (see Section 6.6.3), the contribution of the forestry sector to the overall GDP is below 1% on average, except for several eastern and northern European countries, such as Latvia (6.5%), Estonia (4.3%), Finland (4.3%), Sweden (2.9%), Slovakia (2.4%), Lithuania (2.4%), Romania (1.9%), Slovenia (1.8%). In addition to the variation in biophysical and socio-economic factors, there is a large variation in forest property rights within Europe and Central Asia. Private ownership of forest land ranges from about 40 to 80% in the northern and north-western European countries and from 10 to 60% in Eastern Europe. Small-scale land holding (up to 5 ha) makes up about 85% of all forest owners in surveyed countries in Western and Central Europe (Schmithüsen & Hirsch, 2010). In Central Asia, almost all forests are publicly owned, mainly by the central government (FAO, 2010). User or access rights, e.g. for the purpose of recreation or berry and mushroom picking, as well as usufruct rights for indigenous peoples and local communities, also exist in some countries in Europe and Central Asia. These factors have shaped the forest policies and forest acts of individual countries in this region towards either a more production or a more post-production orientation (Arts, 2014; Forest Europe, 2015). The goal of these policies is often a multifunctional forest, including the mainstreaming of biodiversity and nature's contributions to people (see Chapter 4, Section 4.5.3). They include both managed and "near-natural" landscape elements and frequently aim – besides timber production – at providing ecological functions and recreation opportunities (Hunziker *et al.*, 2012). In Forest Europe member countries, more than 30 million hectares of forests have been protected for the main purpose of conserving biodiversity, habitats or landscapes (see Chapter 4, Section 4.5.3). Over 110 million ha of forests are designated to protect water, soil and ecosystems as well as infrastructures. In mountainous regions, larger forest areas are designated for natural hazard control (see Chapter 2, Section 2.2.1.8). A majority of countries names soil protection as one of the main policy objectives, while about 30 percent indicate water protection as a priority (Forest Europe, 2015). However, this does not correspond to the policy goals set in various international and national policies. Biodiversity is still deteriorating in many countries. There are, however, many opportunities to improve the situation to achieve overarching policy objectives for the conservation of forest land, and to mainstream biodiversity and nature's contributions to people into forest policy (see synthesis **Table 6.11**).

One such opportunity would be to develop international forest policies to ensure both the conservation of biodiversity and the mainstreaming of biodiversity and nature´s contributions to people at multiple levels. Almost all European and Central Asian countries are currently participating in one or more of the international or European processes towards the establishment of criteria and indicators for sustainable forest management (e.g., "Forest Europe", the "Montreal process" and the "Near East Process"). However, the internationalization of forest policy poses substantial challenges for actors in the policy process (Werland, 2009). Several forest-related instruments are applied in parallel, and processes take place simultaneously at different governance levels, which can be distinguished into relatively "hard" legal instruments (e.g., United Nations Framework Convention on Climate Change, Convention on Biological Diversity, General Agreement on Tariffs and Trade), "soft" international laws (e.g., United Nations Conference on Environment and Development Forest Principles, Agenda 21, United Nations Forum on Forests), and "private" international laws (e.g., Forest Stewardship Council, Programme for the Endorsement of Forest Certification) (Giessen, 2013). In other areas soft laws (defined as non-binding), through "*carefully negotiated and drafted statements*" (Birnie *et al.*, 2009, p. 34), have been transformed into binding treaties, such as international environmental, bioethics or human rights law. In the forest sector the emerging mixed policy regime has been characterized as fragmented, ineffective and failed (Giessen, 2013), mainly due to the failure to agree on legally-binding commitments, the existence of multiple policy arenas and actors, and the change of guiding principles over time (Singer & Giessen, 2017). Major drivers of fragmentation of the international forest regime can be found in the international as well as in the domestic realm (Giessen, 2013). The main reasons for this fragmentation have been identified as institutional competition, inconsistent targets and differing sectoral interests, as well as the simultaneous application of different policy instruments (e.g. hierarchical regulation and financial incentives or "soft" measures, such as discursive or informative approaches) (Sotirov *et al.*, 2015). Hence, Winkel and Sotirov (2016, p. 496) define the current situation in terms of a "*policy (dis)integration paradox*", since little policy integration at multiple levels has been achieved, although several initiatives are in place recognizing the need to develop an international forest policy.

Although there are many opportunities to develop policies to take forests and forestry into consideration, a similar situation can be found at the European Union-level since there is no explicit forest policy mandate at this level. This can primarily be explained due to the principle of subsidiarity, variations in the management of forests and the responsibility of conducting negotiations (Edwards & Kleinschmit, 2013). In the European Union, forest issues are seen as appendices to the agricultural, energy, or environmental sector (Söderberg & Eckerberg, 2013). The European Union's biodiversity policy, in particular Natura 2000, is for example supposed to have a major impact on the protection of forest land at the national level (Forest Europe, 2015). However, relatively little information is available concerning the formal and financial implementation of the policy in the national forest sector (Winkel *et al.*, 2015). This is partly because decisions concerning the national allocation of European Union forest funding are increasingly taken by the domestic governments according to their priorities (Kati *et al.*, 2014; Sotirov *et al.*, 2015).

6.5.2.2 Governance modes and policy instruments

Governance modes in the forest sector vary depending on the share of private and public forest land in different countries. In countries with a large share of public forest land, the forest sector is often governed through traditional hierarchical governance modes, while in countries with a large share of private forest owners, various forms of decentralized partnerships or even private governance are more common (Beland Lindahl *et al.*, 2017).

New governance systems are evolving in the forestry sector aiming to secure sustainability of timber production and forest ecosystems through the mainstreaming of biodiversity and nature's contributions to people. Whether these emerging systems lead to a simultaneous retreat of the state and a reduction in governmental control is subject to debate (Arts, 2014). A possible relocation of political power could take three different directions: upward to the international level as mentioned above, downward to the sub-national level, and outward to private and semi-public levels (Pierre & Peters, 2000). However, there are still substantial challenges, especially in Eastern Europe and Central Asia, in developing integrated environmental governance systems, including the adaptation of regulations and the enhancement of education measures in the forest sector (Carter *et al.*, 2010; Djanibekov *et al.*, 2015; Křenová & Kindlmann, 2015) (see also synthesis **Table 6.11**). New international tools and financial incentives could trigger such changes. However, a strong "ideological and institutional anchoring" of the stakeholders in the national forestry sectors might impede major improvements in the development of new and more integrative governance modes and mechanisms (Brukas, 2015; Singer & Giessen, 2017).

Forest laws are the most important regulatory policy instrument in all European and East Asian countries. However, in countries with a large share of private forest owners, where national governments are dependent on forest owners' willingness to protect forests, governments and authorities are making increasing use of voluntary contracts or public-private partnerships with private forest owners to protect biodiversity (Amacher *et al.*, 2014; Primmer *et al.*, 2013). In this mixed "public-private area", financial payment is the main instrument applied to incentivize targeted private forest management activities. However, the suitability and effectiveness of such initiatives depend on the appropriateness of the programme design as well as on the institutional context, and might vary from country to country, as demonstrated by voluntary environmental agreements in forestry (Forest Stewardship Council, Programme for the Endorsement of Forest Certification) or fishery (Marine Stewardship Council) (Prakash & Potoski, 2012; see also 6.3). Further, due to competition rules, European Union regulation constrains the use of these instruments in ways that would reward biodiversity impacts (Raitanen *et al.*, 2013). In Eastern European countries the compulsory forest planning process is often conducted by governmental agencies without active participation of forest owners, thereby impeding the enhancement of learning and adaptation capacities (Bouriaud *et al.*, 2013) (see also synthesis **Table 6.11**). Further, insufficient knowledge and a low priority of biodiversity conservation, a lack of planning tools and transparency, as well as limited resources, can reduce the effectiveness of policy implementation (Blicharska *et al.*, 2011; Demeter, 2017; Kirchhoff & Fabian, 2010; Krilašević, 2010).

Concerning the private level, forest certification is often considered as one of the most important private or self-governance initiatives (see **Figure 6.2** and Chapter 4, Section 4.5.3), due to the inclusion of stakeholder groups (environmental non-governmental organizations, and social groups such as indigenous peoples and labour organizations) and forest owners in the schemes. Certification of forestry is lacking in Central Asia and Russia, and forest management planning is not a legal requirement in several countries (UNECE/FAO, 2015). Power asymmetries and a lack of transparency and accountability in private governance tend to undermine the effectiveness to achieve stated environmental objectives as well as equity-related goals among the actors involved (Auld & Gulbrandsen, 2010; Auld *et al.*, 2008; Johansson, 2013). Furthermore, advice on concrete goal-oriented management practices is often missing (Foster *et al.*, 2010). In consequence, sustainable forest management may have to be pursued through trial-and-error, which may be ineffective and inefficient. Despite their shortcomings, certification schemes have shown to be particularly important for indigenous peoples such as the Sami people, who have usufruct rights to herd reindeer in approximately 30-50% of the forest land in Norway, Finland and Sweden. Certification has, in the absence of national legislation to protect indigenous traditional use of forestry, not only opened up for collaborative arrangements between the Sami and the forest industry, but also paved the way for the Human Rights Committee to engage in this conflict (Human Rights Committee, 2005). Although conflicts still occur, certification schemes provide an important framework for the development of new policy instruments such as participatory GIS and indigenous mapping (Roturier, 2009; Roturier & Bergsten, 2006; Sandström & Widmark, 2007; Sandström *et al.*, 2012). In addition, specifically in the private-owner context, information instruments are still crucial for integrating biodiversity conservation into forestry. Criteria and indicators, such as the six pan-European criteria for sustainable forest management, provide crucial information for policy development, assessment and communication at different governance levels (Forest Europe, 2016). Forest inventories support national planning, and planning at the local level is often merged with forest owner advice systems (Primmer, 2011).

6.5.2.3 Constraints and opportunities

Several possibly interdependent challenges have been identified for mainstreaming nature conservation in forest policy (see synthesis **Table 6.11**): (i) balancing of conservation and production aspects; (ii) integration of science and stakeholders; (iii) climate change; (iv) effective funding; and (v) conflicts with policies related to other sectors (Keskitalo & Pettersson, 2016; Makkonen *et al.*, 2015; Winkel *et al.*, 2015). Concerning sectoral policies, a mismatch has been detected between the low degree of forest sector integration with other policy sectors on the one hand, and on the other its high potential to contribute (Sotirov *et al.*, 2015), for example to the Bioeconomy Strategy or Rural Development Policy as well as the Water Framework Directive (European Commission, 2016c; UNEP & UNECE, 2016) (see Sections 6.3.2 and 6.4.2). To utilize this potential and to overcome the current fragmented policy framework, horizontal coordination between the different sectors (i.e. forestry, conservation, energy) is required as well as vertical coherence of policy targets and institutions at the different governance levels (international, European Union, national, regional). These targets might be hindered by decentralizing forest policy decision-making. Thus, it is advisable to supplement the current policy framework with a bottom-up process, including broad participation and conflict management processes at the different governance levels (Sotirov *et al.*, 2015; Ulybina, 2014). As an example, Veenman *et al.* (2009, p. 202) analyzed the process of "de-institutionalization" in the Netherlands, which led to a nearly complete integration of forest policy into nature policy. They identified the four dimensions of *"discourse, power, rules and actors"*, which have been working in the same direction, as an explanation for this development. However, such a convergence is an exception rather than the rule.

Another option would be to elaborate more systematically on environmental policy integration through novel governance modes. However, countries thus need to overcome challenges related to (i) the currently established legal and policy system, and (ii) the capacity of new, private actors to be involved in policy formulation and implementation. Concerning the first aspect, Schulz *et al.* (2014) compare nine European Union countries and subnational jurisdictions and analyze the relationship between property rights and economic importance on the one hand, and the degree of formally implemented "integrative nature conservation" in forest policy on the other. They found that the more important the forest sector and the more decision-making is influenced by small "peak interest organizations", the less conservation rules are formally implemented. Related to the second aspect, Howlett & Rayner (2006) recognize the importance of private actors and interest groups in the reconfiguration of governance structures. Decentralization and participatory approaches have become important issues in the forestry sector, and are seen as measures to increase the effectiveness of forest policy. As a means to bring decision-making closer to the implementation level, four variables are most important for achieving sustainable forest management via nation-wide Forest Programmes: participation, collaboration, inter-sectoral cooperation, and long-term iterative adaptive approaches (Humphreys, 2004, p. 18). At the local level, participatory approaches such as forest collaborative arrangements or partnerships seem promising, but have so far often been underutilized (e.g., between forestry and reindeer husbandry) (Roturier *et al.*, 2017). Impeding factors can be fragmented private ownership, strong interest groups and clientelism, established legal traditions and policy cultures. Decentralization does not necessarily mean a withdrawal of the government, because *"control by the state and self-governance by people go hand in hand"* (Arts, 2014, p. 17). In general, such programmes make less use of participants' inputs than they could, and the participatory processes are generally not designed to resolve conflicts or trade-offs (Primmer & Kyllönen, 2006; Saarikoski *et al.*, 2012).

6.5.2.4 Summary

The key aspects of an effective and sustainable integrated forest policy and management approach, including the protection of biodiversity and mainstreaming of biodiversity and nature´s contributions to people, can be summarized as: (i) bringing together different public and private actors; (ii) encouraging joint learning and developing a common understanding; (iii) identifying and addressing trade-offs; (iv) developing a coherent policy at different levels; and (v) managing conflicts by applying various policy instruments appropriately designed for the respective institutional context (Sotirov *et al.*, 2015).

However, structural governance change happens at different speeds, to different degrees and is influenced by various factors. The scope of change can vary from changing the policy setting, while instruments and goals remain the same, to changing setting and instruments without changing the goals, and changing all three elements (setting, instruments, and goals) of forest policy (Borrass *et al.*, 2015). The degree of change depends on the national legal and policy system currently in place, as well as the readiness of interest groups to participate in the process of multilevel governance. Given the diverse character of change, it can be quite demanding for private actors to develop respective capacities and coping strategies (Juerges & Newig, 2015; Tysiachniouk & McDermott, 2016). This is particularly the case for indigenous peoples who lack the necessary organizational capacity to adapt to this change (Widmark, 2009). Furthermore, success or failure of governance shifts can be determined by external factors such as *"adjacent policy arrangements, socio-political trends and shock events"*, and internal factor such as *"policy entrepreneurs"* (Arnouts *et al.*, 2012, p. 47) (see also Chapter 4). Examples from Europe and Central Asia show that this holds for eastern as well as western countries (Blicharska *et al.*, 2011; Borrass *et al.*, 2015; Bouriaud *et al.*, 2013; Brukas, 2015; Krilašević, 2010; Vuletić *et al.*, 2010).

6.5.3 Fisheries and aquaculture

6.5.3.1 Policy objectives

Fisheries and aquaculture policies such as the European Union Common Fisheries Policy and the European Union Strategy for Sustainable Development of European Aquaculture have the policy objectives of ensuring that fishing and aquaculture are environmentally, economically and socially sustainable and that they provide a source of healthy food for consumers. Such policies are also aimed at fostering a dynamic fishing and aquaculture industry and ensuring a fair standard of living for coastal communities (European Commission, 2017). The fisheries sector – fisheries and aquaculture – is important from a marine ecosystem and biodiversity sustainability perspective due to its interconnectivity with, and reliance on, aquatic ecosystems (UNEP, 2014a). Indeed, globally, aquaculture has been the fastest growing food production sector of the past 40 years and now supplies more than half of the world's fish produce. Fishing and aquaculture policy that promote overfishing or targeting of species when they are at a vulnerable stage of their lifecycle, can affect biodiversity by reducing species richness (Lee & Safina, 1995).

Fisheries pressure on biodiversity can also affect the heritable adaptations of a species and alter its characteristics and the characteristics of an ecosystem over time. Fishing and aquaculture related policies can also introduce new species to a given ecosystem. For example, the Pacific oyster was introduced to help boost Britain's declining commercial shellfish fishery. It was assumed that this species would not reproduce in Britain's cooler waters, but it is now spreading in the wild. Fisheries policy can also cause loss of genetic variability simply by reducing a species to such a low level that there are not enough individuals in the gene pool to carry the full range of variability that once comprised the population. For example, an Irish commercial fishery for orange roughy began in the North East Atlantic in 2001 with the assistance of government grants. The fishery began as an open access, non-quota fishery. Similar to orange roughy fisheries elsewhere the fishery resulted in unsustainable fishing levels and the subsequent depletion of the fish population. Given that orange roughy is often found near deep water seamounts and cold-water corals, there was also collateral damage to cold water corals. Foley and co-authors (2011) suggest that, in the absence of the subsidies, deep water trawling for orange roughy would not have been viable and the depletion of the species by the Irish fleet would have been avoided.

6.5.3.2 Governance modes and policy instruments

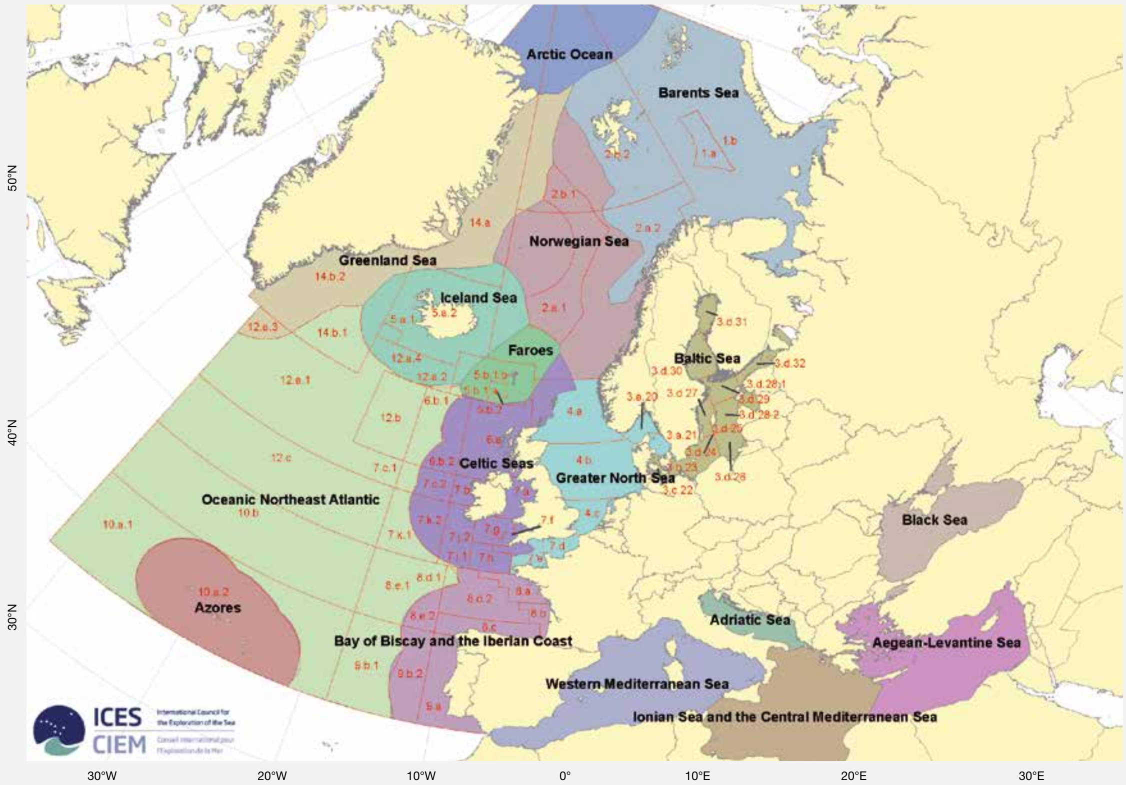
Numerous policies and governance mechanisms attempt to control the impact of fishing and aquaculture activities on the marine environment. At an international level the United Nations is a leading player with bodies established under the United Nations Convention on the Law of the Sea (UNCLOS) and United Nations Fish Stocks Agreement (UNFSA), notably the Food and Agriculture Organization (FAO) committee on fisheries and regional fisheries management organizations. The European Union also operated a number of policies aimed at governing fisheries and aquaculture across European Union territorial waters. Early European Union environmental policies like the Surfaces Water Directive and Bathing Water Directive gave way to a more comprehensive Directive in the form of the Water Framework Directive. Given the interrelated nature of freshwater aquatic systems, reaching eventually to coastal estuaries, saltmarshes and bays, even this more comprehensive directive could not stand alone if aquatic habitats and ecosystems were to be managed effectively. The Water Framework Directive, with its aim of “good ecological status”, is thus intended to operate alongside the Marine Strategy Framework Directive, which provides policy guidelines on management of the entire marine environment through the attainment of good environmental status. The Marine Strategy Framework Directive itself must then operate alongside the Common Fisheries Policy such that good environmental status can be attained. Operating in tandem with these polices is the Habitats and Birds Directive and the Natura 2000 network.

The Marine Strategy Framework Directive was adopted in June 2008 and, similarly to the Water Framework Directive, aims to achieve good environmental status of the European Union’s marine waters by 2020 (European Union, 2008). Given that one of the major indicators of good environmental status under the Directive is fishing pressure levels in European Union marine waters, it is clear that its implementation has major implications for the European Union fishing sector. In addition to the level of fishing pressure, other fishery-related indicators of good environmental status include the reproductive capacity of fishing stocks as well as their population age and size distribution. Since the main policy vehicle used to manage fisheries and improve these indicators of a fishery’s status within the European Union is the Common Fisheries Policy, the Marine Strategy Framework Directive will be required to operate alongside Common Fisheries Policy legislation. Indeed, it is likely that only through a successful application of the recent reforms of the Common Fisheries Policy the good environmental status target of the Marine Strategy Framework Directive may be realized.

European fishing waters are currently governed as part of the Common Fisheries Policy according to Council Regulation (EEC) No. 170/83. The Common Fisheries Policy is a collaborative effort by all European Union member States to ensure the sustainable governance of European Union fisheries. The policy tries to ensure sustainable fishing practice by setting “total allowable catch”, limiting the number of days at sea (fishing effort), restricting the use of certain fishing gear (technical conservation measures (TCM)) and reducing overcapacity in the European Union fishing fleet (through fleet decommissioning) (European Commission, 2011b). Total allowable catch levels are set for each European Union fishing zone. **Figure 6.11** shows the international fishing zones defined by the International Council for the Exploration of the Sea. The quantity of fish landed from each zone by the European Union fleet is recorded and quotas are set under the Common Fisheries Policy for those zones within European Union jurisdiction. The procedure for carrying this out is provided for by Council Regulation (EEC) No. 170/83 of 1983 and establishes a system for the conservation and management of fishery resources. In 2013, the European Parliament and Council of Ministers agreed on a new and reformed European Common Fisheries Policy to be implemented across all European Union marine waters in January 2014. One outcome of the agreements is that quotas and the use of species’ maximum sustainable yields will remain the primary means by which member States attempt to achieve sustainable fisheries.

Other mechanisms to achieve sustainable fisheries are also being considered. For example, closed areas are tools proposed through the ecosystem-based management approach for fisheries. These can be temporary closures or more permanent marine protected areas (Andrello *et al.*, 2015; Hynes *et al.*, 2016; Lagabrielle *et al.*, 2014). Management in marine protected areas is very diverse, with local restrictions ranging from “no-take” to zoning or gear limitations. While there is consistent evidence for the positive effects of full and partial protection on the density and biomass of protected species, it has been shown that fishers may feel alienated from the management process and may feel more comfortable with reserve managers and marine protected area regulations if they are involved in the management process (Himes, 2003).

Figure 6 11 **Ecoregions including fishing zones of the International Council for the Exploration of the Sea (subdivisions with red borders are ICES fishing zones). Source: ICES (2017).**



Elsewhere, regional fisheries management organizations are international organizations formed by countries with fishing interests in an area. Their role is to guarantee the management, conservation and sustainable exploitation of the fish and other marine species by setting catch limits, technical measures and control obligations. In Central Asia, an example of a regional fisheries management organization is the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (CACFish). The objectives of CACFish are to promote the development, conservation, rational management and best utilization of living aquatic resources, as well as the sustainable development of aquaculture in Central Asia and the Caucasus. Following the United Nations Conference on Sustainable Development (Rio+20), United Nations efforts have also focused on the launching of an Implementing Agreement under United Nations Convention on the Law of the Sea for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction.

6.5.3.3 Constraints and opportunities

Political problems with fisheries management and with maintaining the scientifically recommended maximum sustainable yield throughout the political process have been documented within the European Union (Daw & Gray, 2005). Despite these highlighted problems, the reforms of the Common Fisheries Policy indicate that the degree to which scientific recommendations of maximum sustainable yield are adhered to in practice will be far more binding than has been the case historically, such that by 2020, all stocks are to be managed at maximum sustainable yield. Negotiations that will take place on the allocation of quota in UK versus non-UK waters following Brexit are also likely to add to the complexity of fisheries management at a European level.

Further changes to the Common Fisheries Policy include a banning of all discards and the adoption of multi-annual and multi-species planning. The new landing obligation means that from 1 January 2015 onwards fishermen in certain parts of the European Union must land all the fish they catch. By 2019, all fishermen will have the same obligation. This means that the quantity of any fish stock that can be sustainably harvested will be determined on the basis of interaction with, and impacts upon, other species and marine habitats. If fisheries are to become sustainable, the impact of fishing for a single commercial species on other commercial species will be of great importance. It is foreseeable that, in waters where the by-catch of biologically sensitive species is high, quotas for any target species in question will be set lower than their potential maximum sustainable yield level would be had they been considered in isolation.

According to the European Commission, European Union legislators will only define the general framework, the basic principles and standards and the overall targets of the Common Fisheries Policy, while member States will themselves develop recommendations on the actual implementing measures (European Commission, 2016e). National policymakers will thus be charged with the responsibility of deciding on and implementing the medium-term management initiatives that will achieve the overall targets of the Common Fisheries Policy. In this new policy environment, when setting species' total allowable catches, fishery managers must pay particular attention to the multispecies impact of harvesting an individual species, not least, the impact on other commercial species within the fishery and in neighbouring fisheries.

Models assisting the management process that follows the reforms will need to assess the environmental and ecosystem impacts of commercial fishing activity. In addition, behavioural economic models have a role to play, since they offer a framework for attempting to describe the response of fishermen to any policy changes. According to Fulton and co-authors (2011), human behaviour, and in particular fishermen behaviour, is almost never explicitly considered by fisheries scientists in the assessment and management process. They posit that the uncertainty generated by unexpected resource-user behaviour is as critical as ecosystem and environmental uncertainty because it has unplanned consequences and leads to unintended management outcomes. Indeed, technical measures can lead to results which actually work directly against specific sustainability targets for which they are designed (Briand *et al.*, 2004; Dinmore *et al.*, 2003; Polacheck & Davies, 2008; White & Mace, 1988). In relation to the Marine Strategy Framework Directive, clarification is still needed as to how biodiversity and the goods and services of marine ecosystems can contribute to the Directive's good environmental status target and this needs to be further developed. For this, marine and coastal ecosystem services indicators and models for assessment (including fisheries and food webs) need to be further developed to demonstrate how they can contribute to good ecological status (Liquete *et al.*, 2013).

A recent report by the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (CACFish, 2016) highlighted a number of constraints in implementing the code of conduct for responsible fisheries in the Central Asian and Caucasus region. The main constraints highlighted were related to inadequate scientific research, statistics and access to information, insufficient budgetary resources and institutional weaknesses, insufficient fisheries monitoring, control and surveillance and overcapacity in fisheries.

The European Union Strategy for Sustainable Development of European Aquaculture sets out the European Union's policy for the development and growth of aquaculture. The original strategy of 2002 was considered to have been successful in the areas of environmental management, food safety and quality, but has not resulted in growth of production in the sector across the European Union, in contrast with the rest of the world (European Commission, 2009a). In 2009, the Commission undertook a review of the strategy. The renewed 2013 strategy sought to identify causes of the European Union stagnation and identified policy actions to address competitiveness, sustainability and governance in the sector. Following the review, the Commission published strategic guidelines for the sustainable development of aquaculture in the European Union (European Commission, 2013e). The strategic guidelines implement the new Common Fisheries Policy approach to promoting aquaculture through an open method of coordination: a voluntary process for cooperation based on strategic guidelines and multiannual national strategic plans identifying common objectives and, where possible, indicators to measure progress towards these goals. These plans have now been published, and the European Commission has produced a summary of the implementation (European Commission, 2016f).

There are also three European Commission regulations that establish a framework governing aquaculture practices in relation to alien and locally absent species to assess and minimize the possible impact of these and any associated non-target species on aquatic habitats (Council Regulation (EC) No. 708/2007 of 11 June 2007; Commission Regulation (EC) No. 506/2008 of 6 June 2008 amending Annex IV to Council Regulation (EC) No. 708/2007; Commission Regulation (EC) No. 535/2008 of 13 June 2008 laying down detailed rules for the implementation of Council Regulation (EC) No. 708/2007).

Aquaculture can also be affected by sectoral activity on land (e.g. agricultural runoff) and on the coast. The link between freshwater systems, coastal habitats and the sea at large is catered for in a policy sense via a new policy framework, which builds upon previous integrated coastal zone management legislation and incorporates marine spatial planning to account for at-sea projects and development, such as new aquaculture facilities, as well as that pertaining to areas of coastal proximity. These two sets of policy, run concurrently, are intended to allow stakeholders, coastal managers and other relevant parties to cooperate in designing coastal and marine management initiatives that promote environmental sustainability, but also allow for local economic development (Domínguez-Tejo *et al.*, 2016). It has also been shown that intensive freshwater aquaculture can deplete groundwater supplies. For example fish farming was found to be a major contributor to the depletion of underground and surface water resources in the Ararat Valley of Armenia (Trifonova, 2016).

In addition to the now extensive (and growing) legislation that exists for marine and coastal management, the European Union integrated marine policy is intended to act almost as a buffer between the various pieces of legislation in this area and a stopgap for arising maritime issues that do not fall under the jurisdiction of any of the aforementioned legislations. Furthermore, the Environmental Impact Assessment Directive, the Strategic Environmental Assessment Directive, the Habitats Directive, Water Framework Directive and Marine Strategy Framework Directive also influence the potential development of aquaculture in environmentally sensitive areas and its impact on marine ecosystems.

6.5.3.4 Summary

European Union, Eastern European and Central Asian environmental policy relating to marine and coastal areas is still very much under development, but the rate of change is rapid and transforming the face of marine environmental management. Fisheries and aquaculture management methodologies that attempt to incorporate spatial and integrated methodologies and which can help to balance the environmental and economic trade-offs of economic development and natural conservation will be important for the success of this transformation. To date, however, successful governance of marine fisheries remains elusive. In a recent article, Colloca and co-authors (2017) point to "*a worrisome picture where the effect of poorly regulated fisheries, in combination with the ongoing climate forcing and the rapid expansion of non-indigenous species are rapidly changing the structure and functioning of the ecosystem*", and add that "*the management system implemented in the region appears too slow and probably inadequate to protect biodiversity and to secure fisheries resources for future generations*". Indeed, across the European Union, the continued misalignment of short-term political objectives for jobs and revenue maximization and the scientific community's long-term objectives for the sustainability of marine biodiversity remain issues to be resolved. The practical implementation of the landing obligation under the Common Fisheries Policy is also an area that will require close monitoring and active adaption if it is to be successful. While many countries in Central Asia and the Caucasus are now employing adaptive management and conservation measures in accordance with FAO Code of Conduct for Responsible Fisheries, the region continues to face challenges caused by significant declines in total fish biomass in recent decades. According to CACFish (2016) the development of regional education and training programmes as well as a researcher exchange scheme with countries that have successfully implemented integrated approaches to fisheries management, are avenues to be explored to reverse the declines.

6.5.4 Resource extracting sectors and manufacturing

6.5.4.1 Policy objectives

Energy. As the focus on economic growth continues worldwide, energy remains a key issue in boosting production and consumption. Meanwhile, energy choices and policies are directly important for nature's contributions to people as they reshape ecological systems and the environment. This concerns both renewable and non-renewable energy systems which, as Holland and co-authors (2016) show, have considerable impacts on nature's contributions to people through extensive infrastructure and habitat loss and may thus negatively affect terrestrial, marine and freshwater realms. Low carbon development, energy efficiency and reduction of the impacts of energy are among the policy objectives in Europe and Central Asia. In addition, the European Union's Renewable Energy Directive sets a binding target of 20% renewable sources for the entire energy consumption by 2020, and at least 27% by 2030, in the European Union as a whole. Another binding directive is the 2012 Energy Efficiency Directive, which sets measures to help the European Union reach its 20% energy efficiency target by 2020. However, in Eastern Europe and Central Asia, all "environmental" targets and guidelines for the energy sector are largely focused on reducing carbon emissions and do not explicitly address the degradation of habitats and loss of species and nature's contributions to people. An extreme example can be found in Mongolia, where emission reduction targets and other energy and environment policies focus on supporting large hydropower construction. Although Mongolia falls outside the boundaries of Europe and Central Asia, such policies may adversely affect rivers of the region and Lake Baikal World Heritage Site in the Russian Federation.

Mining. Mining is most relevant to terrestrial environments. Fluvial ore mining (placer mining) has been widespread for several millennia (BRGM, 2001), and marine mining in the deep-sea (ISA, 1999) and marine shelf (United Nations, 2016) is rapidly expanding. Placer gold mining has had widespread and severe impacts on several river ecosystems in Eurasia, particularly in Russia, China and Mongolia, destroying riverine habitats, creating serious pollution and transforming sedimentation processes. This practice is often uneconomical, bringing marginal financial returns and surviving only because no fines are charged for environmental degradation in remote wilderness areas (Egidarev & Simonov, 2015). Marine mining operations may create sediment suspension which, at large scales, can harm benthic fauna and flora; and may also change the nutrient balance, causing changes in species assembly ratios. Auxiliary mining operations are also likely to damage mining sites, thus affecting local natural habitats (Van Dover *et al.*, 2011). Hence, in relation to biodiversity and nature's contributions to people, the main objective of mining policies and any particular mining activity is often to restrict both direct and indirect impacts to the site perimeter and to have an *a priori* rehabilitation programme in place. In some cases, the aim is to leave as small a footprint as possible, whereas in others a complete change of landscape may be unavoidable. Although the awareness of the negative impacts of mining is high among involved actors, and relevant international conventions and agreements are signed by most countries in Europe and Central Asia, much remains to be done to reduce the negative effects of mining on biodiversity and nature's contributions to people.

Manufacturing. Reduction of the impacts of manufacturing on nature's contributions to people is the main regulatory policy objective. Sustainable production and consumption as well as a transition towards a "circular economy" are among the emerging political goals that can contribute to achieving some of the sustainable development goals. The circular economy concept gains prominence as resources become scarcer and environmental degradation increases with increasing production and consumption of goods and services. A circular economy is considered to be a solution that harmonizes ambitions for economic growth with environmental protection (Lieder & Rashid, 2016). Its origins can be traced back in the fields of both ecology and economics (Murray *et al.*, 2017). Despite growing political will to pursue such strategies, it is important to point out that action is still needed. This idea is clearly expressed in the conclusions of the Council of the European Union on the European Union action plan for the circular economy (European Union, 2016a). The European Council (2016) recognizes that a "*circular economy offers great potential to achieve sustainable growth and boost the European Union's competitiveness, create jobs, decrease the European Union's dependency on non-renewable primary raw materials, achieve resource and energy efficiency and a smaller environmental footprint, promote locally produced goods, prevent and minimize waste generation, protect nature and natural capital, strengthen ecological resilience and mitigate greenhouse gas emissions, thus contributing to the 2030 Agenda for Sustainable Development and the world-wide efforts towards a green economy*". The Council also states "*the importance of developing a system of valuation of natural capital through appropriate indicators for monitoring economic progress and further developing ecosystem accounts*" (European Council, 2016). Still, there is a need for mainstreaming biodiversity and ecosystem services and at the same time there are many opportunities to improve the situation (see synthesis **Table 6.11**).

In Eastern Europe and Central Asia, initial decline in manufacturing after the dissolution of the Soviet Union significantly reduced pressures on natural resources. However, a challenge the regions face today is how to address environmental degradation re-emerging with the recovery and fast development of the sector.

6.5.4.2 Governance modes and policy instruments

Energy. Energy sector management is conducted mainly through national authorities dealing with energy, environment, climate and natural resources (see also Section 6.4.2 on environmental policies). Such ministries and their associated committees or agencies are responsible for managing the energy sector by developing national strategic energy plans, promoting energy efficiency, regulating energy conservation, developing alternative or renewable energy, and disseminating energy technologies. In addition, according to the Lisbon Treaty (European Union, 2007c), the European Union energy policy aims to ensure the functioning of the energy market; to ensure security of energy supply in the Union; to promote energy efficiency, energy saving, and the development of new and renewable forms of energy; and to promote the interconnection of energy networks (European Parliament, 2017). Article 194 of the Treaty on the Functioning of the European Union (European Union, 2016c) lists several specific energy provisions including energy supply, energy networks, coal and nuclear energy. Last, but not the least, the Biofuels Directive (Directive 2003/30/EC) aims to promote the use of biofuels or other renewable fuels for transport. The initial target was to ensure that biofuels and other renewable fuels are placed on European Union member State markets at a share of a minimum 2% by the year 2005, which was not attained. Later the Directive was replaced by Directive 2009/28/EC, which introduced a target of 20% by 2020. Such targets, if not coordinated with other policy areas, can easily lead to conflicts with biodiversity conservation or regulating and non-material contributions of nature to people (see **Box 6.1** and Chapter 2, Section 2.3.1.2).

There are various studies on multiple instruments that are utilized in the energy sector. Property and access rights are defined and responsibility is ensured in most of the region, to the greatest extent in Western and Central Europe, and developing in the transition economies of Eastern Europe and Central Asia. Governments can provide financial incentives, including direct payments, tax credits, payments for environmental services and grants, to different market actors (see synthesis **Table 6.11**). Besides, Governments may introduce mandates with sustainability requirements and national standards for certification. Governments can either recognize the sustainability standards that are usually developed jointly by various stakeholders or set their own standards and sustainability requirements. These standards are generally useful as they rely on local circumstances, and answer local needs and concerns. Finally, capacity building is crucial in enabling the development of a sustainable energy sector. Such programmes consist of information sharing and dissemination, education and research, and training. Rossi and Cadoni (2012) stress that several factors, such as the financial resources available and the administrative and enforcement capacity of the government, determine the success of these instruments for the bioenergy sector in any country. Similar categories of policy instruments may apply to other types of energy such as wind and solar power where sustainability is a concern. An example on Finland's bioenergy sector is provided by Makkonen and co-authors (2015), who concentrate on land-use aspects. They show that forest bioenergy, which is an asset exchanged in the market, is governed with more explicit instruments (such as financing the tending of young stands, and the energy wood harvesting from young forests) than is carbon sequestration, whose policies remain relatively abstract, possibly due to the late emergence and high uncertainty embodied in these markets.

The use of economic instruments, such as energy-related taxes and subsidies, is common in Europe and Central Asia. Environmental taxes usually cover "energy taxes" according to the definitions of the OECD, the International Energy Agency and the European Commission, and are defined as "*any compulsory, unrequited payment to general government levied on tax-bases deemed to be of particular environmental relevance*", where the "tax bases" are comprised of energy products, motor vehicles, waste, measured or estimated emissions, natural resources, etc. (OECD, 2006b). According to the OECD statistics, environmentally-related tax revenue as a share of GDP as of 2014 is the highest in Denmark (4.11%), followed by Slovenia (3.86%), Italy (3.85%), Turkey (3.83%), and Israel (2.97%), and energy taxes made the most of these tax revenues. In fact, around 70% of all environmentally related taxes are raised on energy products, including vehicle fuels. However, almost zero effective energy tax rates per tonne of CO_2 can be observed in several countries such as Russia. A study on Turkey found that the country pays among the most for fuels – especially gasoline and diesel – in the world due to a special consumption tax. Yet, it is observed that differential taxation of fuels fails to attain environmentally-friendly aims. In the absence of any viable sources of alternative energy, final consumers suffer from the very low elasticity of demand for energy sources. Without any provision of alternative sources of energy, (indirect) taxation itself does not help to reduce the utilization of fossil fuels, but leaves households and firms stuck in expensive and ecologically unsustainable patterns of consumption and production (Acar *et al.*, 2014). Meanwhile, renewable energy development is supported via financial incentives such as direct payments, tax credits, feed-in tariffs, in the European Union, Azerbaijan, Kazakhstan, and Turkey (see e.g. Acar *et al.*, 2015; IEA/IRENA, 2016; OECD, 2016b, respectively).

Substantial fossil fuel subsidies across the whole region, especially in Eastern Europe and Central Asia, pose major challenges for the environment. According to International Energy Agency statistics, Turkmenistan, Uzbekistan, Russia, Azerbaijan, and Kazakhstan were among the major provider countries of fossil fuels worldwide with the highest shares of such subsidy of GDP in 2015 (15.4%, 9.8%, 2.3%, 1.9%, and 1.8% respectively). Most of these subsidies are wastefully consumed and counter-productive to energy-efficiency as well as clean energy approaches.

Mining. While marine mining is transboundary by nature and regulated by international policies, regulations and treaties (ISA, 2002), terrestrial mining is regulated mainly by national policies, which, in the European Union, are based on European Union directives (Hámor, 2004). Mining and quarrying are regulated by policies applying to operational actions (BRGM, 2001) and through legislation regulating various types of waste that are categorized as mining waste (European Community, 1975). European Union mining operation regulations have developed since the general guidelines of the 75/442/EEC directive and currently new mining permits demand the application of the "*best available technique – integrative pollution prevention and control*" (BAT-IPPC) techniques, for mining operations as well as waste treatment. The choice of best available technique applied for tailings or waste-rock management depends mainly on an evaluation of three factors, namely cost, environmental performance and risk of failure (European Commission, 2009b). European Union directives for mining and quarrying are accordant with international regulations such as US mining laws and Australian laws of mining (Chambers, 2008).

In Central Asian countries, in general, there is no legal framework for mining regulation, which addresses its impact on biodiversity and nature's contributions to people. Moreover, since mining and quarrying are the major developing industries for most Central Asian countries, the ability to apply environmental restrictions is limited. In several countries, the lingering effects of Soviet-era hazardous ores and complex mining persist, such as the release of toxic radioactive mining waste from mining operations (USAID, 2001). As there is no evident improvement in either national mining regulations or pollution prevention infrastructures, the negative impact of mining on human environments in general, and transboundary issues in particular, are visible. Yet, several Central Asian regulative transboundary strategies for mining waste remediation are being promoted by United Nations-affiliated NGOs (UNEP, 2012). Moreover, some countries, such as Georgia and Kazakhstan, voluntarily develop "low emission development strategies" to promote the transition to climate-resilient, low emission, sustainable development (USAID, 2017) via their mining and energy industries. Hence, there are many opportunities for mainstreaming biodiversity in the mining sector (see synthesis **Table 6.11**).

In the early 21st century, the governments of China, Mongolia and several Russian provinces assessed operations of placer gold mining. In north-eastern China, placer gold mining has been fully halted as a part of comprehensive efforts to preserve and restore large forest ecosystems as well as ecosystem functions and the services they provide. In Mongolia, a similar logic led to an NGO-induced enactment in 2009 of a "*law to prohibit mining in forests, water protection zones and river sources*", but implementation has been inconsistent and largely unsuccessful. In Russian Siberia, despite being presented with overwhelming evidence of extreme harm from the placer gold mining, regional authorities continue to allow this activity on the premise that it provides local employment. As a result Russia received an influx of placer gold mining equipment and miner crews from adjacent China, where this activity is fully prohibited (Simonov *et al.*, 2013).

Manufacturing. The uptake of ecosystem services by the private sector is a growing trend following pioneer initiatives such as The Economics of Ecosystems and Biodiversity (TEEB), that dedicated one of its major reports to business (TEEB, 2012), and the Ecosystem Valuation Initiative from the World Business Council for Sustainable Development (WBCSD). The manufacturing sector is not an exception to this trend as evidenced below. In the European Union, there has been no consistent sectoral regulatory framework built upon the concept of ecosystem services or ecosystem services-based metrics applying directly to the manufacturing sector so far. The European Union Environmental Liability Directive (European Union, 2004) and the Water Framework Directive (European Community, 2000) are perhaps two of the most prominent examples of regulatory instruments applying to the manufacturing sector. Such directives can rapidly evolve into an explicit recognition of the ecosystem services concept and ecosystem services-based metrics, once considering their current wording, scope, and objectives. Despite this apparent absence of regulatory frameworks, it is important to recall that the European Union's environmental legislation is complemented by a variety of other non-binding policy instruments such as strategies, programmes, and action plans to address the wider use of terrestrial and marine resources. In this regard, the EU Biodiversity Strategy to 2020 (European Commission, 2011a) is an important step towards mainstreaming the concept of ecosystem services and associated metrics into different policies in the short term (Matzdorf & Meyer, 2014), including those regulating the manufacturing sector. The private sector is encouraged to analyze the impacts, dependencies, opportunities and risks of individual sectors as they relate to biodiversity and ecosystem services (CBD, 2012; X1/7 – Business and biodiversity).

While emerging regulatory frameworks and policy context are motivating the private sector's interest in nature's contributions to people, other factors are shaping this new corporate management paradigm, regardless of the sectors of economic activity. As pointed out by the TEEB-initiative (TEEB, 2012, p. 29), "*the idea that biodiversity and ecosystem services have economic value is scarcely reflected in the conventional measures used to assess and report on company performance, and to weigh alternative business opportunities and risks. As a result, business decisions are made based on a partial understanding of environmental costs and benefits*". Hence, the new paradigm aims to counteract business-as-usual corporate decision-making. Business activities may give rise to externalities regarding ecosystems and their services and their internalization in product value calls for different policy instruments ranging from voluntary to mandatory. The World Business Council for Sustainable Development, while recognizing that all business activities not only depend on, but also affect, nature's contributions to people, declares that corporate strategy should face this proactively and integrate the risks and opportunities arising from the interdependence in strategy and management goals (see **Table 6.10** for an overview of risks and opportunities).

Circular economy practice is gaining political support in many regions including the European Union. In December 2014, the European Parliament adopted the communication from the European Commission, "Towards a Circular Economy: a zero-waste programme for Europe" (European Commission, 2014c). This communication and the associated legislative package are related to the broad context of the European Union's 2020 strategy, "*a strategy for smart, sustainable and inclusive growth*" (European Commission, 2010).

To provide incentives for the sustainable use of natural resources in manufacturing, various legal and economic instruments have been applied. For instance, in Uzbekistan, licensing, permissions, export and import certification, and quotas have been introduced and national systems of assessment, monitoring, and environmental audit developed, to assess economic activities, which potentially have environmental impact. Environmental insurance, preferential taxation and eco-labelling systems are planned within the context of the Batumi Initiative on Green

Economy (BIG-E) (Government of Uzbekistan, 2017). Similarly, the national biodiversity strategy and action plan of Russia (CBD, 2016c) recognizes the importance of nature's contributions to people (Russian Academy of Sciences, 2001). However, biodiversity is mainly perceived from the consumption perspective (i.e. as a source of marketed products such as timber and fish) in this report, whereas the diverse values of ecosystems are not taken into account. Hence, there are many opportunities for policymakers to improve the situation (see synthesis **Table 6.11**).

6.5.4.3 Constraints and opportunities

Energy. Despite the importance of the energy sector, it is lacking coordination and regulation and, as such, it is considered inefficient. According to Florini & Sovacool (2009), there are "*enormous gaps in the international system's capacity to manage energy commodities, address their externalities, and ensure a successful transition over time to low-carbon sources*". The energy sector both at the national and the international level is thus governed in a piecemeal fashion, mostly through ad-hoc responses, involving a number of actors and creating an incoherent policy landscape of uncoordinated efforts (Dubash & Florini, 2011; Filatova, 2014; Florini, 2011; Florini & Dubash, 2011; Florini & Sovacool, 2009). Due to the extraordinary importance of energy transition and the tipping points in relation to climate change, there are, however, numerous examples of global or regional efforts to improve the governance of energy and make it more secure, affordable and sustainable, such as the European Union's Energy Union.

There are also constraints regarding the use of widely-established energy policies and policy instruments. As reviewed and demonstrated in Chapters 3 and 4, all known renewable energy sources can have consequences for biodiversity and animal migration. For aquatic and semi-aquatic fauna, hydropower presents by far the greatest array of problems in terms of diversity and severity of impacts (CMS, 2011, 2014). Environmental policy of the largest Russian hydropower company Rushydro states that further development of the sector is constrained primarily by the fact that most suitable dam locations are in wilderness areas that are known as key habitats for endangered species (PAO Rushydro, 2016). Oil, gas and coal extraction or exploration in many parts of Europe and Central Asia (e.g. Germany, Kazakhstan, Uzbekistan, Tajikistan) as well as extraction of uranium and other minerals (e.g. Kazakhstan) lead to biodiversity losses. Apart from the conventional sources of energy, mainly consisting of fossil fuels, hydraulic fracturing (or fracking) also puts pressure on the environment and ecosystems causing potential water and soil contamination from surface leaks or from improperly designed well-casing, spills of improperly treated water, and increased competition for water usage (UNEP, 2012).

Initiatives like "green economy" in Kazakhstan target clean and renewable energy development as well as water conservation; however, they embody the risk of paying more attention to energy supply and less to biodiversity. It is axiomatic that, even if an energy source is generally clean, it may still have negative implications for nature's contributions to people arising from the size or construction of power plants, the location of wind turbines on bird migration routes, the location of solar panels in agricultural land, hydropower impacts on river ecosystems, and stream restoration impacts on ecosystem functioning. Hastik and co-authors (2015) specifically focus on renewable energy policy in the Alpine region. As mountains are rich in biodiversity and provide scenic landscapes, they contribute to high non-anthropocentric and cultural value. Attempts to increase renewable energy development in these mountains creates concerns about preservation of these values and gives rise to land-use conflicts.

Substantial fossil fuel subsidies in Europe and Central Asia are another major constraint. It is significant that G20 leaders committed to "*rationalize and phase out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption*" in 2009 (G20 Information Centre, 2009) and this engagement was later endorsed by the Asia-Pacific Economic Cooperation forum. Currently the topic of fossil fuel subsidies is gaining momentum in a post-Rio+20 context. The recommendation to gradually phase out fossil fuel subsidies has ranked as one of the most highly supported recommendations (66% of support) among the Rio Dialogues and Rio Votes processes (see: http://vote.riodialogues.org/results2.html#4). The reform of environmentally harmful subsidies is also part of the European Union's 2020 strategy.

Low carbon transition entailing a switch towards cleaner fuels, renewable energies or cleaner technologies can create new opportunities in terms of reduced biodiversity impact and greenhouse gas emissions. The shift towards zero-emission energy production offers additional economic benefits.

Mining. The key issues that are addressed for the prevention of mining waste's negative environmental impact consist of tailings or waste-rock that often contain hazardous chemical compounds, leachate generation over long periods of time and acidity effects. The collapse of any type of mining facility can have short-term and long-term effects such as flooding, blanketing or suffocating, crushing, cut-off of infrastructure, poisoning in the form of metal accumulation in plants and animals, contamination of soil, and finally direct poisoning of people or animal life. In each case, adverse environmental impacts need to be kept to a minimum.

The dynamic nature of site manipulation during the excavation process prevents meticulous rehabilitation planning because, once mining operations have ended, the restoration procedure is subjected to the regulatory leverage on the perimeter as well as financing limitations. The absence of effective monitoring procedures is another hindrance to the prevention of negative impacts of mining operations on nature's contributions to people.

In principle, mining site rehabilitation and aftercare, once an operation ends, should strive to complete rehabilitation of the site. In the European Union, at least for the past few decades, plans for closure and site clean-up have been part of permitting to use a site, right from the planning stage onwards, and should therefore have undergone regular updating with every change in the operation and in negotiations with stakeholders. The concept of "design for closure" implies that the closure of a site is planned in the feasibility study of a new mining site and is updated during the mine's life cycle (European Commission, 2009b). If carefully planned, mineral extraction can positively contribute to biodiversity conservation through creation of wildlife habitats during restoration (see Chapter 4, Section 4.4.4.1).

Energy and mining activities and their policies may have adverse effects on indigenous populations (e.g. in the Russian Federation, Fennoscandinavia and Greenland - Koivurova, 2014). For instance, Lavrillier (Lavrillier, 2013, p. 263-264) notes that the nomadic and settled Evenk and Even Siberian people face pollution from local mining companies, construction of dams, roads, railways and pipelines, coal power plants and other exploitation of natural resources, which bear negative impacts on the immediate natural environment of the hunters, herders and fishermen. The United Nations special rapporteur on indigenous issues and the International Work Group for Indigenous Affairs have repeatedly monitored how the indigenous peoples in Fennoscandinavia are affected by extractive industries. Consequently, they have urged countries to ratify the International Labour Organization's Convention No. 169, and to implement the "free prior and informed consent", i.e. the principle that a community has the right to give or withhold its consent to proposed projects that may affect the lands they customarily own, occupy or otherwise use (Rohr, 2014). Norway is the first country to ratify ILO 169 (in 1990) and to implement a consultation procedure with the Sami parliament. Besides, there is an interesting governance trend emerging within the mining sector where local actors start to play an important role in governance. According to Prno and Slocombe (2012) traditional governance modes of mining are no longer sufficient for these actors. The demand for a greater share of income and participation has urged mining companies (e.g. in Norway, Finland, and Sweden) to gain a "social license to operate" from local communities to avoid conflicts (Koivurova *et al.*, 2015).

Manufacturing. **Table 6.10** presents a compilation of business-related risks and opportunities that are relevant for the manufacturing sector as well as businesses from other sectors. Risks and opportunities are classified according to five business dimensions: operational, regulatory and legal, reputational, market and product, and financing. It identifies the actions, mechanisms or institutional arrangements in place for biodiversity and nature's contributions to people, and governance that companies can undertake voluntarily. A growing number of examples illustrate how risks and opportunities are addressed and integrated in business strategies to comply with the emerging regulatory frameworks. Manufacturing industries are classified in divisions 10-33 of the International Standard Industrial Classification of economic activities (UNSTATS, 2017). Given the diversity of industries that integrate such a categorization, it is hard to imagine one division that does not depend on or affects nature's contributions to people. More often, both the impacts and dependencies are observed at different stages of supply chains ranging from resource extraction to components manufacture, transportation, packaging, use, disposal, and recycling. The use of life cycle analysis is hence being pointed out as a means to trace and identify dependencies and impacts of the manufacturing sector on biodiversity and nature's contributions to people in the academic sphere (e.g., Adams *et al.*, 2015; Bruel *et al.*, 2016; Gopalakrishnan *et al.*, 2016; Teillard *et al.*, 2016); in corporate practice or guidelines scoping (see e.g., beverage sector - Aukema & Vigerstol, 2012; the automotive sector - ten Have *et al.*, 2016; and chemical sector - Cefic, 2013). Despite the academic discussion on how to better integrate biodiversity and ecosystem services in life cycle analysis (see the references above), there is a growing recognition that life cycle thinking can play an important role in incorporating nature's contributions to people in corporate strategy. Other examples showing this life cycle system thinking in the manufacturing sector, while not necessarily explicitly adopting a life cycle thinking-based methodology, are provided in Aiama *et al.* (2016) and Kering (2015), covering different segments of the manufacturing sector.

6.5.4.4 Summary

Low carbon development, energy efficiency, sustainable production and consumption, circular economy, and reduction of the impacts of the resource extracting sectors, such as energy and mining, as well as manufacturing, are among the policy objectives in Europe and Central Asia. Sectoral policies that merely target supply, security and growth usually come at the expense of biodiversity and ecosystem services, as these policies lack sufficient integration and awareness and do not reflect the real changes in diverse values. This is easily demonstrated by the array of conflicting development policy goals and sectoral policies. An integrated approach is necessary for

Table 6 10 **Business-related risks and opportunities in relation to biodiversity and nature's contributions to people. Source: Adapted from World Resources Institute, Meridian Institute, World Business Council for Sustainable Development (Hanson *et al.*, 2012). Risks and opportunities are not exhaustive. The selection presented aims at providing insight on mechanisms to take action (on a voluntary basis).**

Business dimensions		Risks	Opportunities	Corporate action
Operational	The risks and opportunities relate to the day-to-day activities, expenditures, and processes of the company.	Higher costs for freshwater due to scarcity or water quality.	Identify the source of water scarcity or quality depletion and set up agreements to counteract the situation (water infiltration and depuration).	To design payment for ecosystem services schemes.
Regulatory & legal	The risks and opportunities relate to the laws, government policies, and court actions that can affect corporate performance.	Permit or license suspension.	In some situations, restoring or protecting an ecosystem can help a business make the case to regulators that it should be allowed to expand activities elsewhere.	To develop conservation banks.
Reputational	The risks and opportunities relate to the company's brand, image, or relationship with customers, the general public, and other stakeholders.	Damage to brand or image due to direct or indirect environmental impact.	Improve or differentiate brand.	Product certification (price premium); select suppliers based on transparency.
Market & product	The risks and opportunities relate to product and service offerings, customer preferences, and other market factors that can affect corporate performance.	Changes in private sector customer preferences.	Markets for certified products.	Product certification (price premium). Entrance fees for owned assets (recreational opportunities).
Financing	The risks and opportunities relate to the cost and availability of capital from investors.	A business may face a higher cost of capital or more rigorous lending requirements as the financial sector becomes more attuned to the implications of ecosystem degradation for borrowers or clients.	Managers may find some lenders and socially responsible investment funds becoming more interested in investing in their companies.	Environmental and social impacts disclosure.

external cost evaluation for each sector and the possible trade-offs. Evaluation of the true cost of any sectoral activity needs to consider social, health, and environmental costs together with production costs. To better govern nature's contributions to people in relation to the policies of the resource extracting sectors and manufacturing requires a well-structured assessment of the effects of these sectors on biodiversity and nature's contributions to people in different realms. As natural resources become increasingly scarce, environmental regulations become stricter and public awareness grows regarding the impacts of the extractive sectors, a new management paradigm has emerged, which focuses on managing risks and opportunities related to nature's contributions to people (depletion and conservation, respectively). Governance modes in place are diverse and reflect both top-down and bottom-up approaches. The same holds for policy instruments that can range from voluntary agreements (e.g. payment schemes) to command and control approaches. There is, nevertheless, a long way to go towards the aim of mainstreaming nature's contributions to people into corporate management and public policy.

Impacts from extractive sectors can be managed much better when decisions are made on a strategic planning level and not postponed until after an investor selects a certain project. Strategic environmental assessment presents a particularly promising tool for resolving conflict between these sectors and nature's contributions to people (see **Box 6.9**, Section 6.6.1). The assessments aim to find the best available technology alternative to satisfy certain societal needs. Recent policy advice developed by the Netherlands Commission on Environmental Assessment (NCEA, 2016) argues that decision-makers do not take an integral systems perspective through a strategic planning phase. Strategic environmental assessment may be the most promising way to decrease impacts through analysis of available resources for alternative options and the comparison of potential development outcomes (Simonov *et al.*, 2015). Apparently, there are many options for policymakers to improve the situation by raising awareness, defining clear objectives, and designing instruments as well as policies (see synthesis **Table 6.11**).

6.5.5 Services sector

6.5.5.1 Policy objectives

A service economy is considered a mature economy, having evolved from a phase of heavy reliance on natural resources, with negative local environmental impacts (Fischer-Kowalski *et al.*, 2011; Giljum *et al.*, 2005). Despite dematerialization of the economy and decoupling GDP growth from environmental impact proving to be highly unfeasible in absolute terms (e.g., Pulselli *et al.*, 2015; Ward *et al.*, 2016), there is no doubt that managing for the services sector creates opportunities for the conservation and sustainable use of biodiversity as well as the continued provision of nature's contributions to people. Trade-offs between the economy and the environment within a service economy need to be resolved as far as possible by decision-making and policies both within the private and the public spheres.

Health and education are service areas whose implementation is crucial for the realization of universal human rights. For this reason, accessible health and education have priority with respect to economic interests and this priority can be safeguarded by policy. In Europe and Central Asia, the vast majority of countries explicitly addresses health-related benefits and risks in their national biodiversity strategies and action plans (NBSAPs) and national reports to the Convention on Biological Diversity (CBD, 2016c) (see **Figure 6.12** and Chapter 2, supporting material Appendix 2.8[10]).

10. Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.8_assessment_of_health.pdf

Degraded ecosystems can jeopardize people´s health, while biodiversity and ecosystem services play a crucial role in supporting a good health status (WHO & CBD, 2015). Social health and well-being are also related to specific ecosystem services integrated into cultural motifs and practices, which are linked to concepts of sense of place, sense of identity, or sense of community. Policy objectives can be defined to regulate management of nature's contributions to people by investigating and quantifying their effects towards achieving health-related Sustainable Development Goals (i.e. Goal 3 (good health and well-being), and Goal 6 (clean water and sanitation), among others) and related targets. At the local scale, planning for urban green infrastructure and parks is more effective when coordinated with health policies and accounting for ecosystem services (Hornberg *et al.*, 2016; Lõhmus & Balbus, 2015). Improving education, capacity building and access to research and training ensures that people are becoming more aware of the importance of nature's contributions and more information is available for environmental management (see synthesis **Table 6.11**). Policy objectives to 2030 can be defined according to the Sustainable Development Goals framework, in particular Goal 4 (quality education) and its targets. Good health and quality education are conditions required to generate and diffuse sustainable behaviours that will ultimately be translated into other service areas such as sustainable tourism.

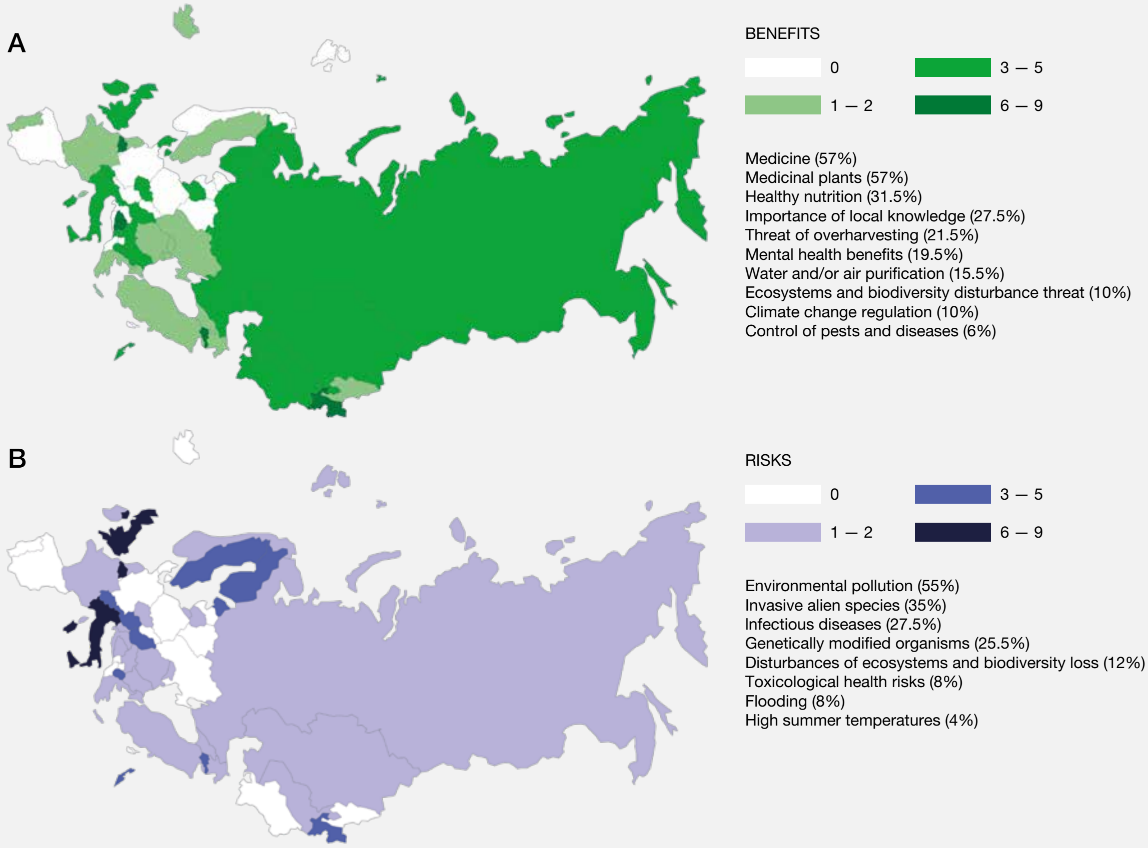
Most transport policies have a specific focus on global climate regulation and air pollution. A mandatory greenhouse gas reduction regime for international shipping was adopted by the International Maritime Organization (IMO, 2011). The current European Commission roadmap on transport, for example, follows a list of 40 initiatives, some of which have a direct effect on the environmental impacts of transport. In particular, key goals by 2050 include: a 60% cut in transport carbon emissions; 40% use of low carbon fuels in aviation; a 40% cut in shipping emissions; zero conventionally-fuelled cars in cities; and a 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport (European Commission, 2011c). Sustainable policies to reduce transport activity are usually local and diverse.

Finance is also a crucial service sector essential for achieving sustainable development. As highlighted by the overarching Goal 17 on "partnership for the goals", "*urgent action is needed to mobilize, redirect and unlock the transformative power of trillions of dollars of private resources to deliver on sustainable development objectives*".

6.5.5.2 Governance modes and policy instruments

The Convention on Biological Diversity reported, together with the World Health Organization, on the state of knowledge on the interlinkages between biodiversity and human health (WHO & CBD, 2015), highlighting the

Figure 6 12 **Number of different health-related benefits A and risks B addressed in national biodiversity strategies and action plans and national reports to the Convention on Biological Diversity. Furthermore, the insets indicate the percentage of countries in Europe and Central Asia mentioning specific health-related benefits and risks in these reports. Source: CBD (2016c); Chapter 2, supporting material Appendix 2.8*.**



* Available at https://www.ipbes.net/sites/default/files/eca_ch_2_appendix_2.8_assessment_of_health.pdf

emergence of vector-borne diseases in Europe and Central Asia and other temperate areas. Flexible "integrated vector management" of vector-borne diseases has already been successful in developing countries and such successful approaches can be taken as good examples by policymakers in Europe and Central Asia. Integrated vector management is based on the premise that effective control requires the collaboration of health, environment, and development institutions and community participation rather than exclusive action by the health sector. Integrated vector management is rarely achievable through small-scale intervention projects from actors outside local communities. Effective governance and policy instruments in this sense link to international initiatives and involve a strong participation of local communities (WHO & CBD, 2015). In developed countries, health concerns are market drivers to consider when designing relevant policy instruments. Different degrees of implementation of instruments and policy mixes can be observed in the subregions of Europe and Central Asia (see synthesis **Table 6.11**).

The role of consumer education is evident in the manifold eco-labelling and environmental certification schemes that were created through a bottom-up process of public concern about biodiversity and ecosystem services loss (e.g. the Forest Stewardship Council – FSC; the Marine Stewardship Council – MSC; Rainforest Alliance and others). Eco-labelling and certification schemes are well implemented in the European subregions (synthesis **Table 6.11**). Environmental certification is also a highly effective tool in promoting sustainable ecotourism. Sustainable tourism, both in environmental and economic terms, is achievable if regulators favour the access to biodiversity and other environmental resources exclusively to businesses with track record of good environmental stewardship (TEEB, 2012). The tourism sector is developing tools to evaluate specific risks associated with climate change, water pollution, and unsustainable tourism practices (Patterson *et al.*, 2007), and to adapt to these risks. Investments by public-private partnerships of tourism companies, governments and NGOs to establishing and maintaining natural parks can be highly beneficial for biodiversity and ecosystem services, supporting businesses and livelihoods (TEEB, 2012). Instead of viewing nature conservation and the mainstreaming of biodiversity into sectoral policies as something for which we have to sacrifice our well-being, perceiving nature as natural capital can help in the business world to better consider it as one of society's important assets (Liu *et al.*, 2010). This is also true for retailers and consumers, with an increasing share of the latter looking for certified products.

The European Union recognizes that social and environmental costs of transport are not fully borne by transport users in European Union member States. Without policy intervention, transport users are faced with incentives that may lead to uninformed travel decisions. The implementation of market-based instruments to internalize the external costs of transport could inform efficient transport pricing. This has been advocated by a series of European Commission policy documents, such as the 2011 White Paper on Transport, and the technical support study for policy analysis "IMPACT": a summary of the existing scientific and practitioner's knowledge on "*internalization measures and policies for all external cost of transport*" (Korzhenevych *et al.*, 2014). If decision-makers would like to improve the situation by promoting mainstreaming of biodiversity and nature's contributions to people, methodological guides to raise customers' awareness of CO_2 emission levels are effective tools that governments can provide and the business sector can implement (synthesis **Table 6.11**). One such example is a guide provided by the French Ministry of Ecology, Sustainable Development and Energy (Government of France, 2012) and implemented by the French National Rail Company SNCF; another is the carbon offset scheme implemented by the Portuguese National Airline Company TAP (Act Eco). Market-based and financial instruments, such as carbon cap and trade schemes and carbon taxes, are effective at incentivizing simultaneously different initiatives towards reducing environmental impacts of the transport sector (Flachsland *et al.*, 2011). Fuel taxes generate higher fuel prices that stimulate the development of more fuel-efficient vehicles, reducing travelled distances, vehicle ownership and per capita fuel expenditures (Goodwin *et al.*, 2004; Litman, 2013; IPCC, 2014).

From the 1970s onwards, infrastructure development became increasingly unbundled through forms of corporatization or privatization, spurring fragmentation and spatial inequality in many countries (UN-HABITAT, 2009). Landscape fragmentation caused by land-use change is an important driver with negative consequences for biodiversity and nature's contributions to people (Section 3.3.2; Sections 4.5 and 4.6). Transport planning and respective infrastructure development as an effect of meeting projected transport demand has proved to be unsustainable and detrimental for biodiversity and the environment (Banister *et al.*, 2011; Saleh & Sammer, 2009). More effective policies have to be based on providing high quality public transport and coordinating various land uses and transport planning. Regarding transport planning, effective regulatory instruments are based on speed limit control (that can generate a 15% reduction in daily fuel consumption) (IEA, 2014; IPCC, 2014), carpool and telecommuting, car free days and efficient and clean cars. Fuel economy (or CO_2 equivalent) standards are in force in most European and Central Asian countries. These standards are considered as an effective policy (as part of a policy mix). Their effectiveness mainly depends on their structure and level of stringency. The effective performance of single policy instruments is highly context dependent (Santos *et al.*, 2010a, 2010b). Feasible and applicable policy options depend on local history and social culture, and have equity implications (IPCC, 2014). Voluntary agreements can also be effective such as the one implemented in 2013 by the International Maritime Organization, making the "ship energy efficiency management plan" a mandatory measure for all ships (IMO, 2011). Voluntary agreements are well implemented in Western Europe while under development or started in the other subregions of Europe and Central Asia (synthesis **Table 6.11**). Effective policy intervention can thus reduce transport activity growth and fossil fuel carbon intensity. Furthermore, it generates diverse co-benefits such as improving biodiversity, urban living, energy security, and enhancing nature contributions to people and environmental quality. Despite the fact that energy efficiency improvements and a shift to hybrid vehicles are successful and important measures, reduction of overall transport activity is essential to avoid rebound effects (Goodwin, 2012; IEA, 2014; Meyer *et al.*, 2012; Millard-Ball & Schipper, 2011; IPCC, 2014; Schipper, 2011).

The finance sector increasingly responds to the wishes of a new group of investors that are willing to forego a fraction of their financial returns in exchange for positive social and environmental dividends. Novel tools and approaches such as green bonds, sustainability stock indexes or novel interpretations of pension funds' fiduciary duties to include social and environmental responsibilities are being used to direct funds away from socially and environmentally damaging projects, towards projects that are more sustainable (Paranque & Perez, 2016).

6.5.5.3 Constraints and opportunities

Economic activities of the services sector can either damage biodiversity or help to conserve it. Especially for the services sector, manifold opportunities arise when mainstreaming biodiversity and nature's contributions to people in decision-making, notwithstanding the fact that biodiversity loss and ecosystem degradation are accompanied by many constraints (synthesis **Table 6.11**, and text below).

Biodiversity loss constrains businesses that seek to exploit medicinal and other properties of wild plants and animals (e.g. in the health sector) with repercussions on society at large. In a world of declining biodiversity, the public and private health sectors, including biotechnology development, need to plan for increased raw material costs that will bring along increasing health spending and spread of infectious diseases, exacerbated by poor water quality, degraded biodiversity and ecosystem services (TEEB, 2012). Therefore, in view of these developments, the health sector is important in mainstreaming biodiversity and ecosystem services into decision-making.

Climate change and water body pollution are strong drivers altering the availability of nature's contributions to people upon which the service sector relies. For example, the tourism sector is especially affected by the loss of natural assets such as coral reefs (TEEB, 2009a). There is a high risk, mainly related to land degradation, of losing ecotourism opportunities, recreational options, specific knowledge of managing certain ecosystems, and places that are spiritually important. Land-use regulations and policies can help preserving future options as well as cultural and heritage values related to the tourism sector (Scott *et al.*, 2016).

Ultimately, the demand for ecosystem services is influenced by evolving consumer preferences and increasing consumers concerns about the environment (TEEB, 2012). An example is the decreasing acceptance of fur clothing in Europe and North America, with knock-on effects on both hunting and farming of animals for their fur (TEEB, 2012). Increasing awareness is influencing purchasing behaviour: consumers are less willing to buy products from companies that disregard ethical sourcing practices and might be willing to pay more to compensate for negative impacts of consumption on biodiversity and ecosystem services.

The field of sustainable finance is still in its infancy, and faces some risks, such as greenwashing attempts. On the one hand, the financial sector heavily impacts nature and nature´s contributions to people in cases where lenders or investors make their money available for projects that generate financial returns at the expense of social or environmental capital. On the other hand, the importance of the financial sector as a key player for moving towards sustainability is probably underappreciated, as the finance sector has the means to mobilize resources supporting the transition to sustainability when appropriately designed and implemented.

6.5.5.4 Summary

The services sector is a crucial sector for the realization of sustainable development pathways. Health, education, capacity-building and research are strong motivators for raising awareness of the importance of nature and nature's contributions to people for a good quality of life. While tourism, transport and finance continue to exert negative pressure on nature in many occasions, there are also many developments that can render these sectors more sustainable. Therefore, mainstreaming biodiversity and nature's contributions to people into decision-making and policymaking is especially important in these areas, calling for the most suitable instruments as part of the overall policy mix.

6.6 MAINSTREAMING BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE

6.6.1 Three key steps of mainstreaming

Mainstreaming biodiversity and nature's contributions to people into national sectoral and cross-sectoral strategies, policies, plans and programmes at various spatial and temporal scales is a recognized and established objective in biodiversity policies (CBD, 2016a; European Commission, 2011a), yet lacks sufficient implementation in other sectors affecting nature. Given that at most 20% of landscapes and seascapes will be protected if the Aichi Biodiversity Targets are achieved, our assessment shows that mainstreaming biodiversity and nature's contributions to people into private and public decision-making is one of the most important future tasks with regard to the remaining 80% (UNEP & UNECE, 2016). While many countries in Europe and Central Asia have, at least partially, integrated the concepts of biodiversity and nature's contributions to people into key policy documents and strategies, the uptake of these concepts, for example through concrete policy instruments, is rather weak (see Sections 6.3-6.5). Hence, there is room for improvement to protect nature effectively from the negative impacts of sectoral policies or private activities, such as consumption and production, and to support actively the integration of biodiversity and nature's contributions to people in decision-making and policymaking. The identified gaps between current practice and behavioural and policy changes needed to achieve future goals imply that existing policies and strategies are underperforming in terms of achieving the Aichi Biodiversity Targets and the Sustainable Development Goals.

This becomes even more obvious when considering future visions. In Chapter 5, four major pathways towards sustainable development have been identified (Chapter

5, Section 5.5.2). Mainstreaming by means of the three key steps listed below plays an important role in all four of these narratives. Most prominent across them is the use of awareness-raising tools, such as education and participation (Section 6.6.3). Further, a range of approaches for policy integration such as planning and environmental impact assessment is identified (Section 6.6.4). Concerning policy instruments, preferences for instrument categories differ across the mentioned narratives. While rights-based instruments and customary norms are neglected in most studies, legal, economic or social instruments are frequently applied and combined in policy mixes (Section 6.6.5). When comparing the current integration of biodiversity and nature's contributions to people into sector policies (see Sections 6.4-6.5) and potential future governance options aiming at sustainability transitions (Chapter 5, Section 5.5.2), there is a clear gap between the state of the art and desired pathways. However, it also means that there are many opportunities to close the gap by promoting more effective, efficient and equitable policies, where mainstreaming can play a prominent role.

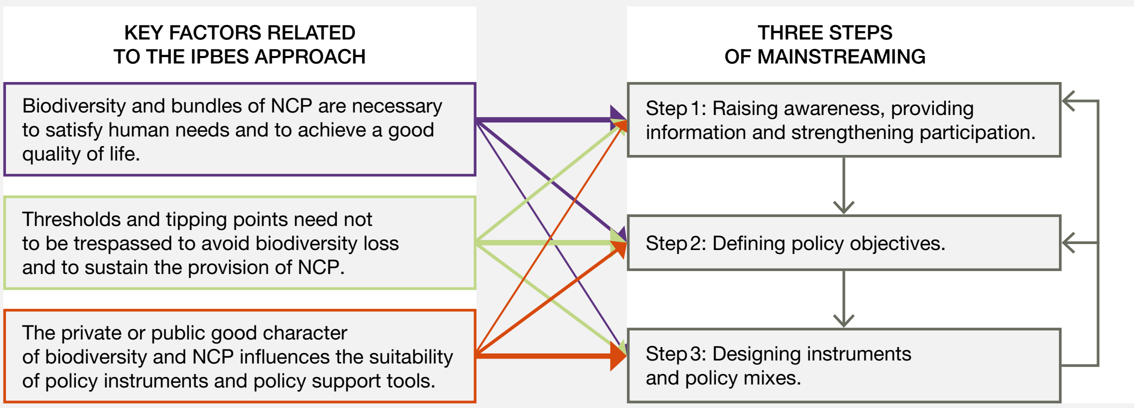
Given the importance of biodiversity and nature's contributions to people for human well-being and a good quality of life our assessment provides opportunities to increase mainstreaming efforts by considering three key steps. The first step is **raising awareness** of human dependence on natural resources and nature's contributions to people (incl. provisioning of information, enhancing capacity building and strengthening participation). The second is **defining policy objectives** related to the ecological, economic and socio-cultural requirements for achieving a sustainable living. The third is **designing instruments and policy mixes** to support the implementation of mainstreaming of biodiversity and nature's contributions to people in public and private decision-making able to achieve the satisfaction of human needs (see **Figure 6.13**). After presenting a synthesis of the assessment of mainstreaming biodiversity and nature's contributions to people across sectors in Europe and Central Asia, the remaining part of the chapter is structured based on these three steps.

6.6.2 Synthesis of the current state of mainstreaming in different sectors

Table 6.11 shows the current state of policy options and opportunities for mainstreaming biodiversity and nature's contributions to people in Europe and Central Asia subregions. It synthesizes the sector analyses in Sections 6.4 and 6.5 and identifies promising options and opportunities across the different sectors. They are based on available literature in combination with expert judgements. Enhancing research and improving access to literature especially from Eastern European and Central Asian countries would allow for a more comprehensive assessment.

Some general conclusions can be drawn from the synthesis. While only a few options are effectively implemented, there is ample room for using opportunities along all three key steps and in all sectors. Specifically in the agricultural, conservation and services sectors, there are opportunities to increase the mainstreaming efforts in most subregions. While legal and regulatory instruments are implemented quite frequently, there are opportunities to enhance the application of other instruments. Several knowledge gaps exist, therefore, there is a need to further develop and deepen the assessment to remedy these gaps in the future. For more specific results regarding the three steps, see the detailed sector analyses in previous sections.

Figure 6 13 **Three steps to link the IPBES approach to policy development and decision-making. NCP: Nature's contributions to people. Source: Own representation.**



The findings in **Table 6.11** have similar conclusions to the fourth Global Biodiversity Outlook (CBD, 2014), which summarizes the latest data on the status and trends of biodiversity and draws conclusions relevant to the further implementation of the Convention on Biological Diversity by assessing the progress towards meeting the 20 Aichi Biodiversity Targets. Public awareness concerning the importance of biodiversity and ecosystem services seems to be increasing (Target 1). Further, progress has been made in integrating biodiversity and ecosystem services in planning processes and national accounting (Target 2). However, there are still policy instruments in place that negatively affect the environment (Target 3), and even if resources are used more efficiently, it is unlikely that current production and consumption patterns are sustainable (Target 4). Therefore, mainstreaming biodiversity and ecosystem services across governments, society and economic sectors aims to address the underlying causes of biodiversity loss and environmental pressure. A crucial prerequisite – besides taking indigenous, local and scientific knowledge into account (Targets 18, 19) – is the implementation of standards concerning terminology, methods, data and reporting (Polasky *et al.*, 2015). National biodiversity strategies and action plans (Target 17) are important steps towards realizing the aims of the Strategic Plan for Biodiversity 2011-2020 at the national level, and to date most of the countries in Europe and Central Asia have compiled these plans. Integrating policy mixes is needed to address the holistic nature of socio-ecological systems. To be successful their implementation requires participatory planning, capacity building as well as mobilizing financial resources (Target 20). Based on the presented aspects current policies and initiatives can be assessed concerning their potential to reduce environmental pressures, and to capture the opportunities provided by biodiversity and ecosystem services, with the aim of enhancing benefits to all (Target 16). In a similar vein to the Global Biodiversity Outlook 4, this assessment shows that there are many options and opportunities for improvements. The following sections elaborate on the potential to accelerate progress in terms of mainstreaming of biodiversity and nature's contributions to people through various options and opportunities related to the three key steps of mainstreaming.

6.6.3 Raising awareness, providing information and strengthening participation

In the last decade substantial progress has been made in awareness raising based on (i) increasing knowledge in various scientific disciplines, (ii) disseminating results, and (iii) acknowledging their importance by governments, corporations and civil society (Kareiva *et al.*, 2015; Schröter *et al.*, 2014). **Table 6.11** shows that awareness raising is implemented or under development in several sectors. However, not all available options are applied and there is scope for improvement, especially in Eastern Europe and Central Asia. Making the diverse values of nature's contributions to people visible, for example through accounting and valuation of ecosystem services, showing trade-offs and tipping points, as well as demonstrating the impact of changing production and consumption patterns are promising opportunities to raise public awareness, participation and transparency in the decision-making process. Communication, capacity building and public participation allow individuals, communities, firms, and governments to speak the same language and to develop a common understanding of the environmental problems to be solved.

6.6.3.1 Accounting, monitoring, footprints

Making the diverse values of biodiversity and nature's contributions to people visible is a crucial prerequisite for mainstreaming. However, current economic indicators, such as GDP, are not able to reflect all dimensions of nature's contributions to people and good quality of life (Dasgupta, 2009; Schleyer *et al.*, 2015). Therefore, further options are needed to measure national welfare and sustainable development. Moving towards "measuring what we manage" will facilitate the comparison between sectors as well as interaction and coordination among them (TEEB, 2009b).

In an attempt to take natural capital and the environment explicitly into account, the "System of Environmental-Economic Accounting (SEEA) 2012-Central Framework" was developed as the first international standard for environmental-economic accounting (United Nations, 2014). However, the SEEA still falls short of providing actual total economic values. Besides, major current challenges in environmental-economic accounting necessitate improvement of the database and development and employment of extensive modelling to link services to the status of ecosystems and to the beneficiaries.

As a parallel initiative to the SEEA, the "Wealth Accounting and the Valuation of Ecosystem Services" partnership (WAVES) aims to ensure that "*natural resources are mainstreamed into development planning and national economic accounts*" by developing an ecosystem service accounting methodology, establishing a "*global platform for training and knowledge sharing*" of stakeholders, and building international consensus concerning natural capital accounting (WAVES, 2015, p. 18). These initiatives point to moving beyond measuring economic activity and growth towards a broader concept of social welfare comprising

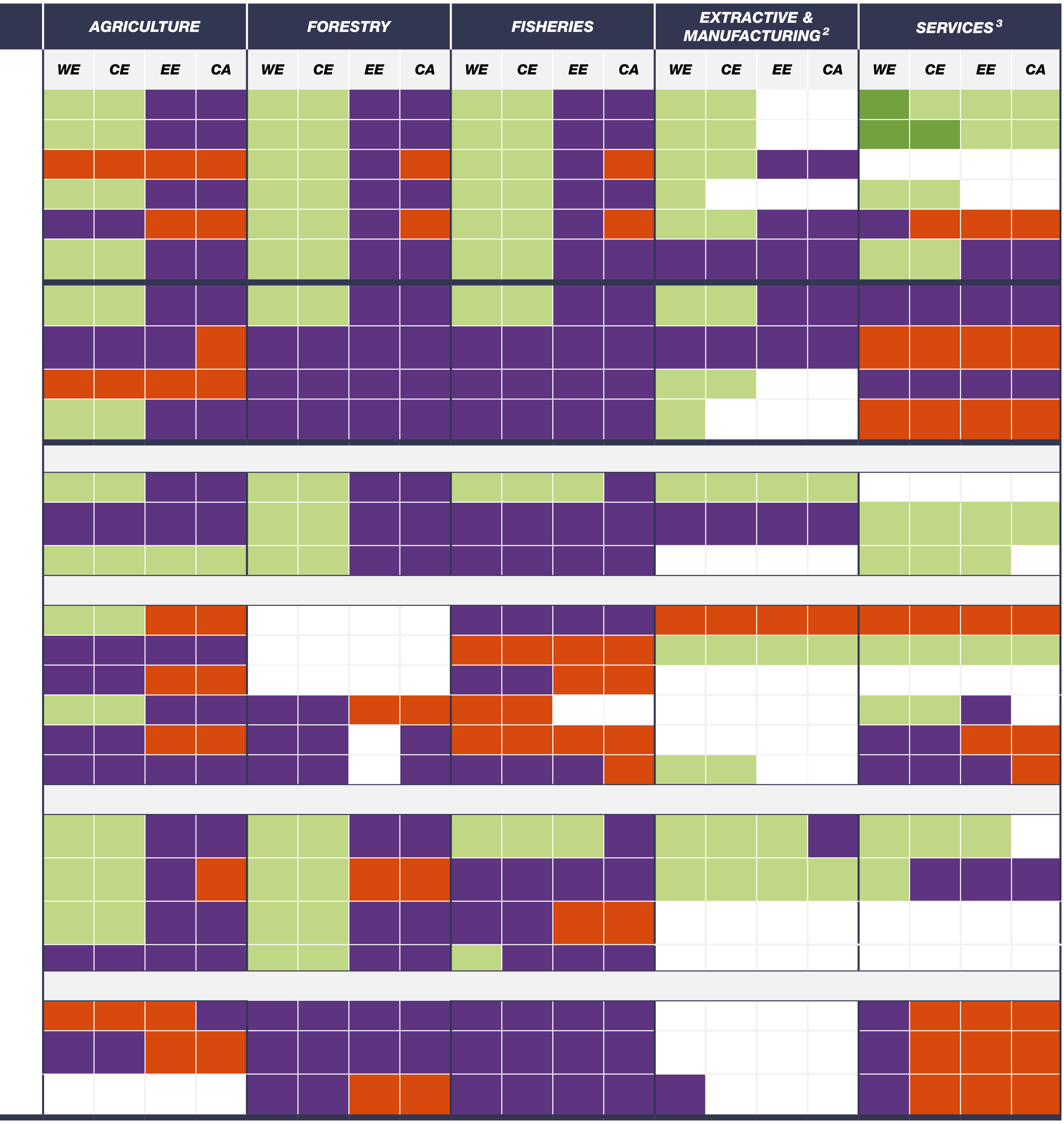
Table 6 11 **Policy options and opportunities for mainstreaming biodiversity and nature's contributions to people in Europe and Central Asia.**

Building on three key steps of mainstreaming, options and opportunities for mainstreaming are provided for seven policy and economic sectors. The evidence shows that biodiversity and nature conservation will benefit from being mainstreamed in environmental policies and all economic sectors and their policies and that nature's contributions to people will benefit from being mainstreamed in all economic sectors, as well as the conservation sector. The table synthesizes those policy options and opportunities from the sectoral analyses in chapter 6 that are relevant to all sectors. It can be used by policymakers of the

	Sectors	*CONSERVATION*				*ENVIRONMENT*[1]			
STEPS	**OPTIONS AND OPPORTUNITIES** *Subregions*	*WE*	*CE*	*EE*	*CA*	*WE*	*CE*	*EE*	*CA*
STEP 1: Raising awareness	Encourage education, joint learning and common understanding								
	Promote information sharing, transparency, knowledge management and training								
	Make trade-offs and tipping points visible at the relevant spatial scales								
	Encourage participation and dialogue among different actors								
	Make diverse values visible through national and business accounting								
	Mainstream recognition of need for profound societal transformation towards sustainability								
STEP 2: Defining policy objectives	Adopt and translate international and regional targets and standards into national and local strategies and action plans								
	Improve integration and coherence of legislation, sectoral policies and planning processes, to account for trade-offs and synergies								
	Develop context appropriate targets and objectives to stimulate positive change								
	Increase transparency and participation of a wide range of actors including indigenous peoples and local communities in decision making								
STEP 3: Designing instruments and policy mixes	***Legal and regulatory instruments***								
	Define and ensure property and access rights and responsibility								
	Set up, adjust and enforce legal and regulatory standards to sustain biodiversity and nature's contributions to people								
	Set up areas to protect biodiversity and nature's contributions to people								
	Economic and financial instruments								
	Phase out harmful subsidies	**NA**	**NA**	**NA**	**NA**				
	Tax and charge negative environmental impacts	**NA**	**NA**	**NA**	**NA**				
	Redistribute public revenues considering ecological objectives								
	Reward socio-economic activities delivering public goods								
	Secure conservation financing					**NA**	**NA**	**NA**	**NA**
	Foster sustainable technological and social innovation								
	Social and information-based instruments								
	Promote eco-labelling and certification schemes and improve their transparency and accountability								
	Promote voluntary agreements and partnerships for responsible management, which include self-enforcement mechanisms								
	Promote sense of agency and efficacy through the enhancement of public participation								
	Support social norms that promote sustainable lifestyles and practices								
	Rights-based approaches and customary norms								
	Strengthen the use of indigenous and local knowledge and practices								
	Strengthen the consideration of cultural properties and heritage in protecting sites and landscapes					**NA**	**NA**	**NA**	**NA**
	Strengthen the use of Social License to Operate or similar approaches to recognize the needs of indigenous peoples and local communities								

1. Include the following policy areas: Marine and freshwater quality and quantity, flood management, air and wider environmental pollution (including eutrophication and acidification), waste management, mitigation of and adaptation to climate change, soil management and land degradation. Options and opportunities in rows left blank have been covered by the other sectors, also in relation to their environmental outcomes.
2. Include the following policy areas: Energy, mining, manufacturing.
3. Include the following policy areas: Health, education and research, transport, tourism, finance.

subregions as a checklist to identify potential for improvement and for new policy instruments not yet initiated within the subregion. Although they have scope for improvement, legal and regulatory instruments are the most widely applied policy instrument category in all sectors and subregions, emphasizing their role as the backbone of policy mixes. Social and information-based instruments have been partly implemented in some subregions. There is also considerable scope for new or improved economic and financial instruments. Rights-based approaches and customary norms are the least developed and applied instrument category, indicating knowledge gaps (see Box SPM.5) or possibly a lack of attention or even acknowledgement to indigenous and local knowledge and practices.



WE = WESTERN EUROPE **CE** = CENTRAL EUROPE **EE** = EASTERN EUROPE **CA** = CENTRAL ASIA

EFFECTIVELY IMPLEMENTED
IMPLEMENTED WITH SCOPE FOR IMPROVEMENT
UNDER DEVELOPMENT OR STARTED
NOT YET INITIATED
NOT ASSESSED
NA = NOT APPLICABLE

multiple dimensions and perspectives (Fleurbaey, 2009). Though challenging, the opportunity exists to develop such a "*comprehensive methodological approach in which biophysical, socio-cultural and monetary value domains can be explicitly considered and integrated into decision making processes*" (Martín-López *et al.*, 2014, p. 220). Promising attempts to develop experimental statistics along these lines include the UK freshwater ecosystem assets and services accounts by Khan & Din (2015).

Griggs and co-authors (2013, p. 306) suggest redefining the term sustainability as development that meets the present needs while "*safeguarding Earth's life-support system, on which the welfare of current and future generations depends*". A major challenge, when applying this definition to policymaking, is how to decide on an appropriate set of indicators of nature's contributions to people. To fulfil Target 2 of the EU Biodiversity Strategy on maintaining ecosystems and their services, Action 5 requires member States to map and assess the state and economic value of ecosystems and ecosystem services and to promote the integration of these values into accounting and reporting systems at European Union and national level by 2020 (European Commission, 2011a). Achieving this target requires the adaptation of multiple, biophysical and economic indicators relevant for each context (Stiglitz *et al.*, 2009). Here, ecosystem service standards that "*define terminology, acceptable data and methods, and reporting requirements*" are a crucial prerequisite for mainstreaming ecosystem services into public and private sectors (Polasky *et al.*, 2015, p. 7356). Integrating the spatial dimensions of ecosystem services within decision-making at different scales would raise awareness, inform about the human dependence on diverse natural resources and enhance the recognition of their values (UK NEA, 2011).

However, a key point of attention is the interaction between environmental accounting and policy. Jakob & Edenhofer

Box 6 8 **Ecological footprint and interregional flows.**

The impact of production and trade on environment, ecosystems, and species has been demonstrated in various studies (see Chapter 2). The ecological footprint is an important tool which can be disaggregated into diverse footprints, e.g. for imports, exports and domestic production. This de-composition can be useful for policymakers in understanding the regional and international trade impact. Andersson & Lindroth (2001) list four different ways in which trade may affect ecological footprint: (i) a positive "allocation effect", which reduces the ecological footprint as trade enables specialization of countries on products with higher domestic productivity; (ii) a negative "income effect", which increases the ecological footprint as trade leads to higher domestic income, and thereby, consumption; (iii) a negative "rich-country-illusion effect", which highlights the false impression in rich countries that their lifestyle is sustainable thanks to the possibility of importing bio- and sink capacity from poorer countries; and (iv) a negative "terms-of-trade distortion effect", which hints at the tendency of poorer countries to exploit natural resources beyond sustainable levels to avoid falling terms-of-trade during boost periods in world demand.

Lenzen and co-authors (2012) argue that several species are in danger of extinction due to international trade along complex routes. The authors show evidence that international trade threatens 30% of global species. Furthermore, the consumption footprint of imported coffee, tea, sugar, textiles, fish and other manufactured items happens to be much larger abroad than in the country producing the good. Similarly, Aşıcı & Acar (2016) find that countries tend to relocate their ecological footprint as their income increases. The analysis was carried out for a panel of 116 countries by employing the production and import components of the ecological footprint data of the Global Footprint Network for the period 2004-2008. Within the income range of the selected countries, the import footprint was found to increase with income. Another study found that footprints of, for example, Turkish imports and exports increased with income during the period 1961–2008 (Acar & Aşıcı, 2017). This implies that countries tend to export the negative consequences of their consumption through imports rather than producing the environmentally harmful products domestically.

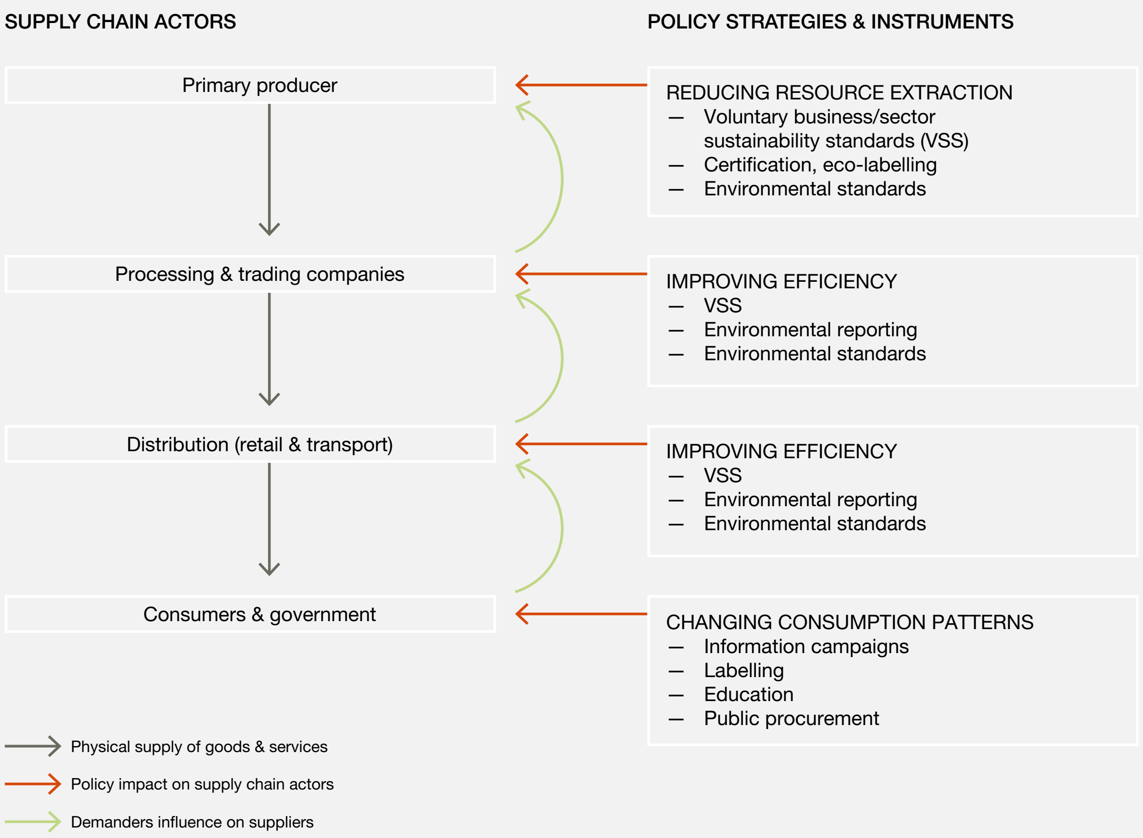
Weighell (2011) proposes biomass material flow analysis as a framework for policy implementation. His study shows that the UK's biomass imports (except from Northern America) cause around 30% of the UK's overseas land requirements, thereby leading to important environmental changes in these regions. The recognition of the original source of biomass helps to design targeted international policies in favour of biodiversity and nature's contributions to people. In addition to supply-side concerns, demand-side policies have the potential to alter the impacts of biomass flows. For instance, a more efficient use of biomass especially through a reduction in waste along the food chain, can substantially impact national and international biomass demand (Weighell, 2011). As the material flow analysis helps to identify the imports, exports and domestic extraction of environmental resources, it is also utilized in relation to sustainable development in Switzerland. The Swiss government's Sustainable Development Strategy (Swiss Federal Council, 2008) puts forward the Integrated Product Policy as a means to attain several sustainable development goals. For instance, sustainable material management targeting the reduction of consumption and environmental damage along with product quality improvements is part of the Integrated Product Policy.

(2015) conclude that, based on current green accounting systems, it is hardly possible to provide guidance for "real world-policymaking". They favour the option of a multi-dimensional concept of "welfare diagnostics", where policy should focus on establishing "minimum thresholds" or "guardrails" for critical capital stocks that matter for welfare. Oosterhuis *et al.* (2016) name three opportunities to make environmental accounting a more effective tool for policy advice: (i) to improve coordination between providers and users of environmental accounts and cooperation with other organizations both collecting and using accounts; (ii) to enhance interpretation, assessment and policy evaluation based on the accounts, which requires a different set of expertise, including integrated valuation methods, policy instruments, indicator development and modelling, and that this role requires dedicated organizations; and (iii) to use multiple channels for presenting environmental accounts in a policy relevant way. However, for environmental accounting to make a substantial contribution to mainstreaming, there is an urgent need to develop the ways in which it can effectively inform policymaking.

6.6.3.2 Sustainable consumption and production

Sustainable consumption and production is the result of actions taken by many different actors, from producers to final consumers (see **Figure 6.14**). The supply-chain perspective enables a comprehensive view on production and consumption, and provides information on relevant relations and possible opportunities for mainstreaming actions. The United Nations Environment Programme's sustainable consumption and production clearinghouse shows 149 sustainable consumption and production initiatives in Europe and Central Asia, many of which contribute to reducing pressures on biodiversity and ecosystem services as they focus on agri-food, chemicals, mining, waste, building and construction, energy, manufacturing and water. Several projects bring in the supply-chain perspective through labelling, value chains and fair trade, and in this way contribute to a global perspective on sustainable consumption and production (Leadley *et al.*, 2014; SCP Clearinghouse, 2017). Currently policies seem to focus predominantly on the production side, while

Figure 6 14 **Policy options to reduce environmental impact of consumption and production. Source: Adapted from van Oorschot *et al.* (2012).**



consumer-oriented policies are applied less frequently and mostly limited to information and nudging strategies.

The explicit aim of Sustainable Development Goal 12 is to ensure sustainable consumption and production patterns, where developed countries should take the lead (United Nations, 2015). For countries in Europe and Central Asia, this implies contributing their fair share to the global challenge of staying within safe ecological limits. In evaluating current policies and initiatives a differentiation can be made between sustainable consumption and production policies which aim (i) at reducing pressures on biodiversity and ecosystem services and (ii) at capturing the opportunities provided by natural capital and ecosystem services.

Concerning the first aim, options to reduce environmental impact or pressure can be identified by the so-called IPAT identity (IPCC, 2000): **I**mpact = **P**opulation x **A**ffluence x **T**echnology, where affluence can be approximated by production and consumption. The European Environment Agency (EEA, 2013a) identified three main environmental pressure types: material extraction, greenhouse gas emissions and air emissions. Main contributors to these impacts are agriculture and food products, forestry and fibre products, the electricity industry, water services, construction, transportation services, and basic manufacturing industries such as refinery, chemical products and basic metals; in the future possibly also bio-energy production. Food and lodging, housing and infrastructure, and mobility contribute most to the consumers' part.

Drawing on global environmental assessments (OECD, 2012b; UNEP & UNECE, 2016) five generalized types of options can be identified along the supply chain to reduce the main negative impacts on biodiversity and nature's contributions to people:

1. *Increase resource efficiency, including circular resource use (production)*
2. *Enhance sustainable resource production (production)*
3. *Design products with cradle-to-cradle-approach (production)*
4. *Promote consumption patterns with less environmental impacts (consumption)*
5. *Reduce waste at different stages (production & consumption)*

These complementary strategies for reducing the impacts of consumption and production seem to fall within the paradigm of "sustainable growth", considered an oxymoron by many (Daly & Townsend, 1993). Options for reducing consumption are worked out in Steady-State Economics (Daly, 1996), New Economics of Prosperity (Jackson, 2009; NEF, 2009; Schor, 2011); and Degrowth (Kallis *et al.*, 2012; Latouche, 2009) (see Chapter 4).

Sustainable consumption and production policies in Europe and Central Asia have so far focused (i) on the contribution of the United Nations sustainable consumption and production 10-year framework, and (ii) on resource efficiency as part of competitiveness and European Union green economy strategy. However, beyond the European Union biodiversity strategy, there are promising opportunities for raising awareness of natural capital and nature's contributions in consumption and production policies in order to mainstream biodiversity and ecosystem services.

6.6.3.3 Communication, capacity building and public participation

In recent decades, large efforts have been made to raise awareness and to integrate stakeholders and the wider public into the governance of nature's contributions to people, for example through public debate, communication and knowledge sharing as well as public participation, organizational and individual learning and capacity building. Although these efforts have led to substantial progress, there are still significant opportunities to further harness the support of a wide range of actors to raise the awareness of the need for mainstreaming (Korn *et al.*, 2004) **(Table 6.11)**. These opportunities are in line with Goal 17 of the Sustainable Development Goals, which calls to "*revitalize the global partnership for sustainable development*"; and Goal 16, aiming to "*provide access to justice for all and build effective, accountable and inclusive institutions at all levels*". Further, they are directly related to Strategic Goal E of the Strategic Plan for Biodiversity 2011-2020, namely to "*enhance implementation through participatory planning, knowledge management and capacity building*" (Aichi Biodiversity Targets 17-20). Communication, capacity building and public participation, while all playing different roles in this endeavour, are intricately linked. For example, public engagement and participation can facilitate a broader understanding of nature's contributions to people for all actors involved, but also lead to greater acceptance, legitimacy and long-term efficiency of the outcome of the process (Blackstock, 2017; Young *et al.*, 2013). Participation can also help to build the capacity of civil society to engage in governance processes (Jones-Walters & Çil, 2011; Kouplevatskaya-Yunusova, 2005).

However, to make effective use of these opportunities, one needs to know how the concepts of ecosystem services and nature's contributions to people are understood and used by stakeholders and the wider public. Essentially, this equates to the very wide-ranging and challenging question of how people understand their relationship with nature (Flint *et al.*, 2013). Especially the notion of ecosystem services, as well as cognate notions such as "natural capital" (Costanza & Daly, 1992), bear the inherent risk of "crowding out" intrinsic ideas of values (Flint *et al.*, 2013; Setten *et al.*, 2012). In addition, as with other specialist concepts such as biodiversity (Buijs *et al.*, 2008; Fischer & Young, 2007) or climate change (Fischer *et al.*, 2012a), the population is likely to have a rough understanding of the phenomena captured, even though it might not be familiar with the exact terminology (Lock & Cole, 2011). The use of a streamlined terminology might thus unduly simplify or restrict the more complex notions held by other actors. Such externally-defined frameworks are also prone to obscuring or omitting emotional and experiential dimensions of understanding nature's contributions to people (Kassam *et al.*, 2011; Verma *et al.*, 2015; Williams & Harvey, 2001).

These considerations notwithstanding, a substantial number of studies, usually framed with reference to specific ecosystems in Western and Central Europe, have assessed people's awareness of ecosystem services and perceptions of their relative importance (Agbenyega *et al.*, 2009; Hartel *et al.*, 2014; López-Santiago *et al.*, 2014; Martín-López *et al.*, 2012; Plieninger *et al.*, 2013). Generally, such studies seem to reveal widespread appreciation of nature's contributions to people. While detailed findings vary a lot between studies (Agbenyega *et al.*, 2009; Martin-Lopez *et al.*, 2012), these differences are likely related to the socio-ecological context and framing of the evaluation. In addition, people's perceptions of ecosystem services vary with their backgrounds, roles, identities and experiences and are related to socio-demographic variables (Fischer & Eastwood, 2016; Kassam *et al.*, 2011; López-Santiago *et al.*, 2014; Martín-Lopez *et al.*, 2012; Young *et al.*, 2013). Underpinning these are their broader understandings of, and relationships with, nature (Buijs, 2009; López-Santiago *et al.*, 2014), and wider discursive contexts (Kull *et al.*, 2015). The main implication of much of this literature is, as Lock & Cole (2011, p. 8) put it, that "[*greater knowledge exchange around ecosystems services is required: efforts to enhance public knowledge and understanding* […] *may improve public acceptability of interventions* […]. *In turn, such interventions could be more sensitively designed when based on a better understanding of the ways in which the public value these services and spaces (i.e. when decisions are made using both lay and expert knowledge)*" (see also a global literature review by Sterling *et al.*, 2017).

Such participation and joint learning has been increasing over recent decades, and the scientific literature on these issues is burgeoning. There has been widespread uptake of approaches such as co-management, co-governance and other collaborative arrangements (Ansell & Gash, 2008) (Section 6.4.2), as well as stakeholder participation in environmental decision-making (Young *et al.*, 2013) in many places across Europe and Central Asia. However, there is still significant scope for an expansion of these approaches across all relevant sectors, as, for example, Young *et al.* (2007) have pointed out for Central and Eastern Europe (see also Griewald *et al.*, 2017; Stringer & Paavola, 2013; Ulybina, 2014). Stakeholder participation, besides being a policy instrument in itself (Section 6.2), can be fruitfully combined with a wide range of other policy instruments, and is, in fact, already an integral part of some pieces of legislation such as the European Union Water Framework Directive (Sections 6.3 and 6.4) (Blackstock *et al.*, 2012). But even where no explicit provision for the use of participatory methods exists, participation and joint learning can, in many cases, improve the governance of biodiversity and nature's contributions to people (Jones-Walters & Çil, 2011).

For example, in some areas in Germany, NGOs and civil society have relatively recently gained influence in decision-making processes in the forestry sector, which previously only involved traditional forestry actors (Maier *et al.*, 2014). Conversely, the process of establishing and drawing up management plans for designated areas such as marine protected areas (Ruiz-Frau *et al.*, 2015), Biosphere Reserves under the United Nations Educational, Scientific and Cultural Organization (Bridgewater & Babin, 2017) or European Union Natura 2000 sites (Brescancin *et al.*, 2017; Young *et al.*, 2013) can also be an opportunity for joint learning and participatory decision-making. Studies show the main effect of stakeholder participation in processes around three Natura 2000 sites in Scotland was an increase in trust (Young *et al.*, 2013). Their findings also highlight that local views have to be taken seriously, rather than participation being just a token exercise. As a result perspectives that deprioritize ecosystem services might also have to be accepted (Maier *et al.*, 2014). Institutional processes need to be designed such that there are clear ways in which the outcomes of participatory activities can be fed into decision-making (Kouplevatskaya-Yunusova, 2005; Reed, 2008). Participatory approaches also run the risk of privileging certain perspectives over others – often those by "*high income, well-educated and time-rich*" stakeholders (Blackstock, 2017, p. 343) or those that use specialist language and knowledge to dominate the decision-making process (Maier *et al.*, 2014). Cultural differences in terms of discussion styles and willingness to allow conflictive encounters might also act as barriers to successful participatory processes (Kouplevatskaya-Yunusova, 2005). This is particularly true for countries in Eastern Europe and Central Asia that may lack experience in deliberative democracy and collaborative decision-making. Non-state actors are keen to participate, but their transformative capacity is often severely constrained (Ulybina, 2014). Furthermore, attempts to increase participation in policy development often result in the re-appropriation of power by traditionally powerful stakeholders (Kouplevatskaya-Yunusova, 2005).

Finally, repeated stakeholder involvement – especially if outcomes and actual policy uptake are unclear – can lead to stakeholder fatigue and withdrawal (Blackstock, 2017; Reed, 2008). Far from being a panacea (Blanchard, 2015), participation is thus a social process that has risks and costs as well as benefits. Not least because of these challenges, participatory approaches require skilled facilitators (Blackstock, 2017; Reed, 2008), drawing on the large amount of collective experience to further enhance the mainstreaming of biodiversity and nature´s contribution to people.

6.6.4 Defining policy objectives

The ecosystem service concept and the further developed concept of nature´s contributions to people offer a framework to identify policy objectives and contribute to identifying limits for trading off one service for another, beyond which intended substitution can lead to catastrophic results (Bastian, Corti, & Lebboroni, 2007; Jax, 2014; Mace *et al.*, 2014; Rockström *et al.*, 2009; Simoncini, 2009). Given that the same ecosystem processes and components often provide bundles of diverse services simultaneously, a comprehensive assessment of the ecological, economic and social conditions is needed. Policy integration and spatial planning are two important options to consider synergies and trade-offs when defining policy objectives.

6.6.4.1 Policy integration

The status of biodiversity and the quality and quantity of ecosystem services are often determined by economic, trade, agricultural, forestry and other sectors (MEA, 2005b). Improved coordination across sectors, actors and scales offers opportunities for effective action to address problems related to biodiversity and ecosystem services for human well-being. Although this has been recognized by the European Union for more than a decade, only few countries make intensive efforts to develop integration strategies (EEA, 2005). Thus, mainstreaming biodiversity and the multiple values of nature's contributions to people remains an essential task (MEA, 2005b; PBL, 2014; UNEP, 2011a). In this context, identifying synergies to conserve and enhance multiple services is as important as recognizing potential trade-offs between ecosystem services (Vira *et al.*, 2011).

The identification and analysis of relationships among multiple levels of socio-ecological systems at different spatial and temporal scales is a core challenge to achieve sustainability (Ostrom, 2009). This includes the need to recognize the holistic nature of socio-ecological systems. More specifically, integrated policies have to be designed and implemented, requiring policy integration within and across different economic, policy and societal sectors. Coordination needs to be improved among international institutions and across decision-making levels, taking due account of scientific insights, local communities' and indigenous peoples' knowledge, as well as different socio-cultural contexts and related value systems. A core task in this context is integrating biodiversity and ecosystem services into poverty reduction and development strategies. Drawing on the sector policy analyses earlier in this chapter, conflicts of forestry with other sector policies have been highlighted as one of the major challenges for the integration of nature conservation into forest policy (Winkel *et al.*, 2015). The relation between the forestry sector and Sami reindeer herders in Sweden can be seen as an example, where neglecting the holistic character (including biological, geographical and climatic, as well as linguistic, socio-economic and management issues) and a missing mutual understanding can aggravate conflicting situations (Kitti *et al.*, 2006; Roturier & Roué, 2009). Improving information tools for decision-makers is one important strategy to follow.

Integrated policies are necessary to consider consumption and production processes at different scales, at local, regional and national levels, and relating to impacts displaced to foreign countries (see Section 6.6.2.1). Some examples are (i) land-use policies to enforce and regulate transnational land acquisitions ("land-grabbing") (Rulli *et al.*, 2013); (ii) regulation and monitoring of conflict-free mineral trade (Young *et al.*, 2014); and (iii) the adoption of "*principles for responsible agro-investment*" (Deininger & Byerlee, 2011).

Besides individual policy instruments and their interaction in policy mixes, which are dealt with in Section 6.6.5 below, there are a number of policy-support tools specifically dedicated to checking for consistency between objectives, instruments and potentially adverse impacts from one to another strategy, policy, programme or individual project (see IPBES web portal on policy support tools: IPBES, 2017). Strategic environmental assessment (SEA) and environmental impact assessment (EIA) provide promising options to improve mainstreaming attention for biodiversity and ecosystem services across a wider range of sectors, beyond environment and conservation (Geneletti, 2013; Helming *et al.*, 2013; Lamorgese & Geneletti, 2013).

6.6.4.2 Integration through spatial planning

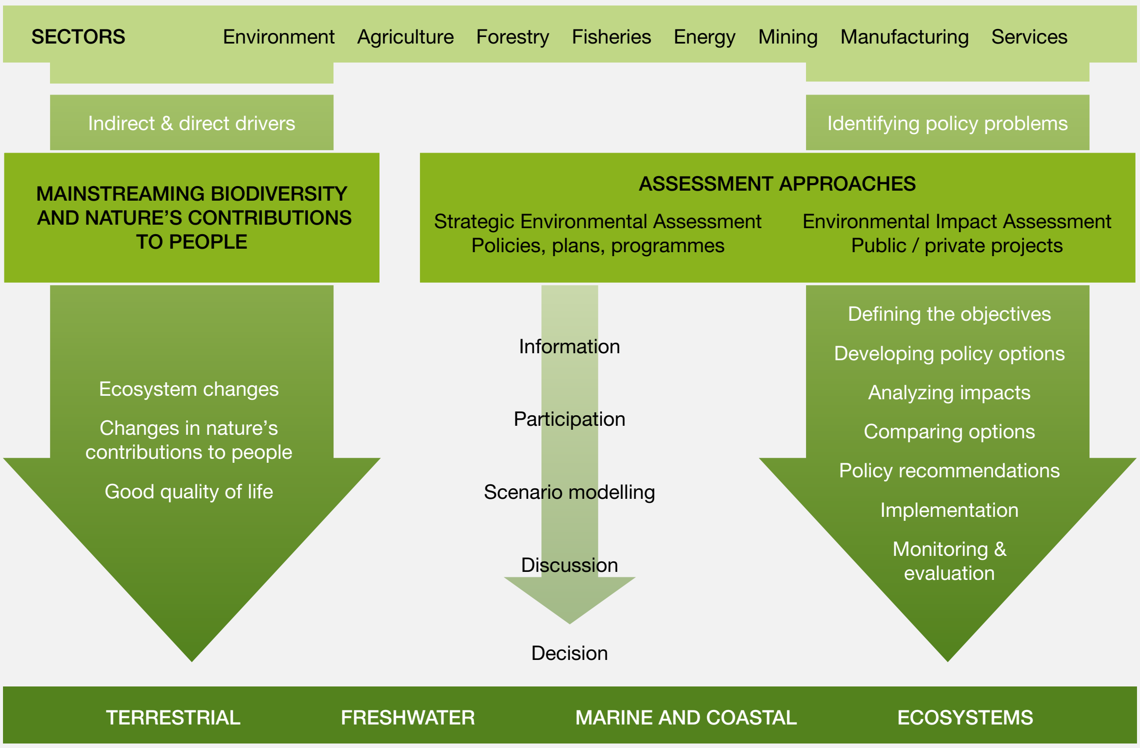
Spatial planning is a "[…] *key instrument for establishing long-term, sustainable frameworks for social, territorial and economic development both within and between countries. Its primary role is to enhance the integration between sectors such as housing, transport, energy and industry, and to improve national and local systems of urban and rural development, also taking into account environmental considerations.* […]" (UNECE, 2008, p. vii). It usually combines legal and regulatory instruments with more informal instruments. These can be complemented

Box 6 9 Policy support tools to integrate across sectors and scales: strategic environmental assessment and environmental impact assessment.

As a key instrument to ensure good quality of policies, planning and programmes, strategic environmental assessment (SEA) has been established in most countries, for example at European Union level through directive 2001/42/EC. In addition, environmental impact assessment (EIA, 2014/52/European Union) performs an appraisal of the effects of environmentally relevant public or private projects. Both assessment tools take account of spatial and temporal scales, and provide options for conceptualizing the diverse values of biodiversity. They have a great potential to mainstream biodiversity and nature's contributions to people by applying assessment, decision and monitoring criteria, and they can highlight development opportunities and potentially warn about negative biodiversity and nature's contributions to people impacts (Geneletti, 2013) **(Figure 6.15)**. Providing a process-oriented assessment framework, strategic environmental assessment could contribute to evaluation of the coherence, synergies and conflicts between different policy sectors using biodiversity and ecosystem services standards and indicators to enable a multidimensional and multi-scale trade-off analysis. Another challenge consists in considering biodiversity and nature's contributions to people in a transboundary context. Here, the Espoo Convention on Environmental Impact Assessment in a Transboundary Context (Glasson *et al.*, 2013; OECD, 2005; United Nations, 1991) obliges the 45 ratifying countries to perform an environmental impact assessment of proposed activities on the environment at an early stage of planning. States are obliged to inform and consult others on all major projects that might have a significant adverse environmental impact across boundaries. The integration of biodiversity and ecosystem services in such mutual assessment and information processes could greatly contribute to set standards for critical thresholds or tipping points, delineate impact areas and identify appropriate instruments and actions to avoid environmental degradation.

Strategic environmental assessment and environmental impact assessment frameworks could provide suitable instruments to assess and improve the coherence between different policy sectors and to create synergies considering their direct or indirect impacts on terrestrial, freshwater, marine and coastal systems. Further, they could promote and integrate stakeholder views on the importance of biodiversity and nature's contributions to people (Slootweg *et al.*, 2009), and may be combined with information tools and scenario modelling (see Chapter 5) to provide tailored information for different types of

Figure 6 15 Mainstreaming biodiversity and ecosystem services in strategic environmental assessment and environmental impact assessment. Source: Own representation.



Box 6 9

actors. However, formal and informal participation needs to be implemented more concisely. Adapted participatory instruments could help to consider different socio-cultural contexts of public and private decision-making in planning and natural resource management. However, the effectiveness of strategic environmental assessment to enhance the consideration of environmental aspects in planning is still debated and seems to be context dependent (Cashmore *et al.*, 2010; Hilding-Rydevik & Bjarnadóttir, 2007) (see Section 6.6.1). Further, caution is warranted regarding who assesses policies or projects for whom. As holds for any assessment, independence of those who assess from those who finance, or investors whose projects are being assessed, as well as transparency, legitimacy and credibility, are crucial for the outcomes to be widely accepted (Lebel, 2006).

by financial instruments such as the common agricultural policy (CAP), rural development policy[11] and LEADER[12] (see Section 6.4). Spatial planning can both positively and negatively influence the conservation and sustainable use of biodiversity and nature's contributions to people (von Haaren *et al.*, 2016), the key opportunity being its integrative potential through providing a cross-disciplinary view towards more sustainable development (Goodstadt *et al.*, 2012; Niemelä *et al.*, 2010; UNECE, 2008). It is increasingly recognized that a social-ecological perspective is key in effective planning due to its potential to include resilience into spatial recommendations (Folke, 2006) and thus to identify and address impacts and trade-offs of policy options and ensure informed decisions for sustainable development (Chan *et al.*, 2006; Goodstadt *et al.*, 2012; Zisenis, 2009).

If implemented without consideration of social-ecological implications, planning development can have a substantial negative impact on biodiversity and nature's contributions to people, for example if ecosystem processes and functions are destroyed, landscapes are fragmented or soils are sealed (Forman & Collinge, 1997; Opdam *et al.*, 2002; Scolozzi *et al.*, 2012). Conversely, a well-balanced social-ecological spatial planning framework positively affects the provision of biodiversity and nature's contributions to people and subsequently quality of life, for example by reducing the ecological footprint of cities; enhancing accessibility to, and the cooling effect of, green spaces in urban agglomerations; and overcoming trade-offs from single-sector focused decisions (Bateman *et al.*, 2013; TEEB, 2011a). A case in point are urban areas, which illustrate contrasting urbanization trends and examples of emerging science–policy linkages for improving urban landscapes for human health and quality of life. Cities increasingly engage in protecting and enhancing the capacity of their ecosystems to meet urban resident needs, for example through novel management systems in Stockholm, civic engagement in Berlin, and a shift towards nature-based flood mitigation in Rotterdam (Schewenius *et al.*, 2014). Urban planning has particular responsibilities to ensure biodiversity protection and nature's contributions to people delivery today and in the future to enhance the quality of life of an increasing number of urban dwellers (Gómez-Baggethun & Barton, 2013). It can help to avoid costs in nature's contributions to people impairments and identifying safe-to-fail strategies or probes that will allow the nature of emergent possibilities to become more visible (Ahern *et al.*, 2014; Grêt-Regamey *et al.*, 2013; Niemelä *et al.*, 2010). Concepts such as green infrastructure help to identify and communicate the benefits which conserving and sustainably using biodiversity and nature's contributions to people have for nature and human well-being (Tzoulas *et al.*, 2007) (see Chapter 3). As shown in Section 6.3.2 marine spatial planning has also proved successful in considering biodiversity and nature's contributions to people (Flannery & Ó Cinnéide, 2008).

Targeted spatial planning that integrates across sectors and scales can substantially enhance the conservation and sustainable use of biodiversity and nature's contributions to people (Bateman *et al.*, 2013). The particular opportunity for spatial planning exists in its capacity to make explicit, and support the integration of, diverse interests and policy fields. Spatial planning addresses multiple scales, incorporating the local and regional scale, the different policy scales as well as sectoral and infrastructural aspects. Hierarchies and the level of detail at which topics are addressed, as well as institutional responsibilities, vary considerably among countries (OECD, 2001). Spatial planning has the capacity to safeguard sensitive areas, enhancing the state of ecosystems, minimizing current and potential future impacts, and identifying synergistic land-use options. For example, Swedish forest policy has gradually picked up science-based biodiversity conservation in line with the Convention of Biodiversity (Angelstam *et al.*, 2011). Informed planning can furthermore enhance the engagement and experience of nature among citizens, facilitate public participation, enhance environmental behaviour and stewardship, and provide the basis for targeted investments in nature's contributions to people, for example by designating specific areas for results-oriented agri-environmental measures (Beatley & London, 2011; Hartig *et al.*, 2001; Wells & Lekies, 2006).

11. https://enrd.ec.europa.eu/policy-in-action/policy-framework_en
12. https://enrd.ec.europa.eu/leader-clld_en

Important challenges remain for an enhanced consideration of biodiversity and nature's contributions to people in spatial planning in Europe and Central Asia (EEA, 2009). The sectoral nature of policies leads to fragmented spatial strategies that fall short of a comprehensive consideration of environmental issues. Spatial proposals to improve biodiversity and nature's contributions to people need to be developed and better implemented. Delivery mechanisms for proposed actions are poor, since separate actors often administer planning and implementation. The uptake of environmental considerations is further complicated by limitations in political support and financial resources, spatial misfits between planning constituencies and ecosystems (Trepel, 2010), and distributed responsibilities in federal systems (von Haaren & Reich, 2006).

If the consideration of biodiversity and nature's contributions to people is to be enhanced in spatial planning, a multi-scale approach needs to be applied to decision-making and to ensure that public interests and the benefits provided by functioning ecosystems are considered in decision-making (TEEB, 2011a). Trade-offs between different contributions by nature to people, as well as between biodiversity and nature's contributions to people, need to be accounted for in decision-making about preferable spatial planning strategies and implementation actions. Key issues that would benefit from a better consideration of biodiversity and nature's contributions to people are, among others, human health and quality of life, issues of water and energy security, climate adaptation and mitigation, and flood control, recreation and locational quality (cf. Chapters 2, 4, 5). Several studies illustrate options for better integration of biodiversity and nature's contributions to people in planning, for example landscape planning (Albert *et al.*, 2016a; Albert *et al.*, 2014; van Oudenhoven *et al.*, 2012), urban planning and economic valuation (Gómez-Baggethun & Barton, 2013; Schewenius *et al.*, 2014), or Strategic Environmental Assessment (Geneletti, 2013). Successful examples for integrating biodiversity and nature's contributions to people in spatial planning include river restoration in Vitoria-Gasteiz (Kopperoinen, 2015) and protected area management in Doñana, Spain (Palomo *et al.*, 2011).

Three methodological challenges for a systematic assessment can be pointed out: (i) an assigning problem related to difficulties in detecting cause-effect relations between planning measures and outcomes; (ii) an indicator problem because it is not possible to quantitatively measure the qualitative impact; and (iii) a time framing problem due to the long time span between implementation and impact of a measure (Fürst, 2005). Knowledge gaps exist concerning a comparative overview of spatial planning throughout Europe and Central Asia. Comparative studies on spatial planning and its effectiveness across such a diverse group of countries is particularly challenging: most literature on planning is only available in national languages and often differences exist between planning as described in the legislation, and applied practices. Further knowledge is needed on how particular planning modes and planning instruments affect biodiversity and nature's contributions to people and how respective information could best be integrated and communicated in planning processes so that it is understood and appropriately considered in decision-making (Albert *et al.*, 2016a; de Groot *et al.*, 2010).

6.6.5 Designing, implementing and assessing instruments and policy mixes

Nature contributes in diverse ways to human well-being. Depending on the character as private or public goods or services, various institutional failures concerning their provision can lead to biodiversity loss and ecosystem degradation (TEEB, 2010). Mainstreaming can contribute to overcoming these failures by designing and implementing different policy instruments and tools (Costanza *et al.*, 2014; Kenter *et al.*, 2015; Muradian & Rival, 2012; Parks & Gowdy, 2013). The assessment of specific policy instruments in the realm of biodiversity and nature's contributions to people is, however, a major challenge. On the one hand it comprises quite heterogeneous and complex systems involving multiple actors and governance levels (Buizer *et al.*, 2011; Paloniemi *et al.*, 2015). On the other hand, instruments have to be applied and assessed under uncertainty due to severe information gaps (e.g., concerning scientific knowledge about ecological production functions or bio-physical trade-offs). Further, different future pathways (see Chapter 5) often call for a policy mix embedded in specific institutional settings, which makes it difficult to assess them in an isolated way. Such a policy mix could start top-down with the design of regulatory instruments based on socio-ecological indicators in the proximity of tipping points, in order to assure a minimum sustainable provision of nature's contributions to people. Beyond this point, ecosystem service delivery could be further enhanced by applying economic, financial and information-based instruments, including bottom-up approaches. By adopting this architecture for policy design, it is possible to envisage promising opportunities to enable a re-thinking of the decision-making process particularly for policies envisioning specific pathways.

6.6.5.1 Legal and regulatory instruments

In principle, regulatory instruments can contribute to all policy strategies, including mainstreaming of biodiversity and nature's contributions to people, and **Table 6.11** shows that they are widely applied in Europe and Central Asia. However, a balancing of practical flexibility and legal certainty in the design and implementation of these instruments is necessary to ensure their effectiveness and efficiency (Garmestani *et al.*, 2013; IPBES, 2015b). Recent research has shown that traditional environmental monitoring and enforcement are still dominant when the aim is to improve environmental quality in many countries (Gray & Shimshack, 2011). However, direct regulations are discussed controversially at the same time. For example, Santos *et al.* (2015a) emphasize the limited ability to have an impact on broader land-use patterns and pressures undermining biodiversity and ecosystem services, while others doubt that regulations are flexible enough and able to appropriately deal with current environmental problems (Harring, 2014). As an example, enhancing landscape diversity is sometimes hindered by regulations that forbid or strongly limit converting woodland to agricultural land (Agnoletti, 2006). Kenward *et al.* (2011) found that there is a lack of empirical evidence concerning the performance of particular governance strategies. Based on a novel analytical framework they analyzed 34 case studies and conclude that, while biodiversity conservation was positively associated with regulation, ecosystem service provisioning and regulation are negatively correlated. Their results seem to support a multiple-option approach, including both regulatory and market-based measures.

6.6.5.2 Economic and financial instruments

Beside taxation, economic and financial instruments currently play a minor role in mainstreaming biodiversity and nature's contributions to people **(Table 6.11)**. However, there are further opportunities, such as price-based and quantity-based mechanisms, to incentivize environmentally friendly behaviour.

Price-based mechanisms

In the context of agricultural landscapes, Pascual & Perrings (2007) point out that changes in biodiversity are ultimately the result of decentralized decisions at the farm level, where land owners or users decide on the uptake of environmentally advantageous management practices. The correction of market failures is thus a necessary, but insufficient condition for effectively reducing biodiversity loss. Here, appropriate institutions can contribute to creating favourable conditions and incentives for farmers to act accordingly. However, for economic mechanisms to be effective, diverse environmental values have to be demonstrated, captured, and distributed to the individuals who actually bear the costs of conservation measures (TEEB, 2010). Furthermore, taking local traditional knowledge into account avoids a weakening of the traditionally strong relationship between human and natural systems (Babai & Molnár, 2014).

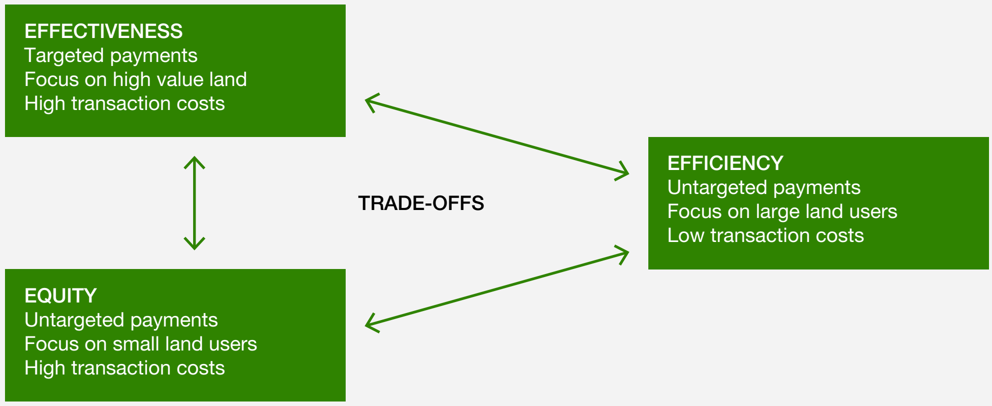
The effectiveness of price-based instruments is called into question given the often highly complex relationships between land-use practices and their actual impact on biodiversity and ecosystem services (Porras *et al.*, 2011). To develop this mechanism to an operational and efficient degree, the following conditions should ideally be fulfilled: (i) assuring clear and enforceable property rights; (ii) increasing the number of buyers and sellers; (iii) providing complete information; (iv) reducing transaction costs and (v) avoiding entry and exit barriers to markets (Alvarado-Quesada *et al.*, 2014). However, even if these conditions are met, it is still uncertain how to ensure conservation in the long run, given that governmental policies might change and insufficient future funding might reduce the credibility of market-based instruments and environmental governance as a whole. Further problems are related to leakage effects if negative effects are displaced instead of being reduced, and to lacking additionality in case that payments are made for practices that would have been adopted anyway (Porras *et al.*, 2011).

In general, there are two options for financing conservation; targeted and untargeted payments. Cudlínová *et al.* (1999) analyzed environmental subsidies in the Czech Republic and found they may be ineffective if the payments are not directed towards the appropriate target groups. By contrast, when appropriately targeted, subsidies can be very effective and essential for the continuity of traditional land-use systems (e.g. herding in the Pyrenees); up to an extent that herders substantially rely on such payments, which makes them particularly vulnerable to policy changes (Fernández-Giménez & Estaque, 2012). Mayrand & Paquin (2004) emphasize possible trade-offs between effectiveness, efficiency and equity (see **Figure 6.16**). While targeted payments might be effective, untargeted payments might be more equitable by including small scale land owners and more efficient by reducing transaction costs (Jack *et al.*, 2008; Runhaar, 2016).

Quantity-based mechanisms

Tradable permits and habitat banking provide further opportunities for mainstreaming. They aim to offset environmental damages in one place by restoring habitats of equivalent ecological characteristics elsewhere (Wissel & Wätzold, 2010). The underlying principle of such biodiversity offsets is that of "no net loss" of biodiversity (Bull *et al.*, 2013; Gardner *et al.*, 2013). Due to their flexible character, such instruments are becoming increasingly popular. One of their advantages is seen in the ability to reduce information asymmetries: by using trading opportunities land owners reveal private information, that would otherwise not be available to public decision-makers, which can be used to enhance the effectiveness of the applied mechanism (Ring *et al.*, 2010). Further, ensuring competitive conditions among potential service providers can lead to environmental solutions at lowest costs (Pirard, 2012). However, several

Figure 6 16 **Trade-offs in implementing payment schemes. Source: Adapted from Mayrand & Paquin (2004).**



practical drawbacks and weaknesses have to be taken into account. Besides management and compliance problems, such concepts suffer from a flawed logical basis of the offset mechanism and "*immature, imprecise and complex science, which results in difficulties in determining biodiversity values*" (Burgin, 2008, p. 807). There are several dimensions in which destroyed and replaced habitat might differ: (i) the suitability of a site for certain species (dimension of type), (ii) the size and configuration of a site as well as distance and connectivity of sites (dimension of space), and (iii) the time it takes for a habitat to regenerate or for a species to recolonize (dimension of time) (Wissel & Wätzold, 2010). These differences might hinder the establishment of tradable permit markets, due to high transactions costs and difficulties in finding matching trading partners. Similar to the case of price-based instruments, there is a need for an appropriate institutional framework given that property rights are to be transferred. Furthermore, scientific expertise as well as local and indigenous knowledge are required. In contrast to carbon credits, where quantities are measured in a single and global metric (tonnes of CO_2 equivalents), other nature's contributions to people comprise more complex aspects which can hinder trade at local and at coarser scales. This might be the reason why tradable right approaches in conservation are less successful in reality than corresponding mechanisms in markets for pollution and water rights (Reeson, 2015).

According to Santos and co-authors (2015b), it is hardly possible to draw a general conclusion on the effectiveness of quantity-based mechanisms. First, because the concept of "biodiversity markets" is still at an initial stage and there are only very few programmes developing, mainly in Western Europe (European Union, France, Germany, Sweden, and UK) (Madsen *et al.*, 2010, 2011). Second, available studies often refer to output-based indicators, such as area covered or credits traded, but it remains uncertain whether the goal of "no net loss" of biodiversity has actually been achieved. Under certain conditions, such as substantial ecological uncertainty or lack of legal safeguards for compliance (Bull *et al.*, 2013), a precautionary approach by avoiding damages and protecting non-fungible habitats seems more appropriate.

6.6.5.3 Social and information-based instruments

The potential opportunities of social and information-based instruments are widely underutilized in Europe and Central Asia. While eco-labelling and environmental certification are quite frequently used approaches and private environmental reporting is increasing, the transparency and accountability of these voluntary instruments could be enhanced **(Table 6.11)**.

Certification of resource production and trade

Producing and extracting resources in a more sustainable manner is an important strategy for sustainable production and consumption. To achieve this aim, social instruments such as voluntary market standards are increasingly being used (Potts *et al.*, 2014). These standards contain a range of criteria for more efficient operational management and for production practices that positively affect environmental and socio-economic conditions. When production is verified for compliance to the standards' criteria, the produced and traded resources are certified and labelled with well-known sustainability logos such as Forest Stewardship Council (FSC) for wood, Marine Stewardship Council (MSC) for caught fish and UTZ Certified for cacao. Further, the Fairtrade initiative addresses the imbalance of power in trading relationships and is based on a partnership of producers and consumers, including Central Asian countries, such as Kyrgyzstan and Uzbekistan (Fairtrade.net, 2012).

As a result of enhanced consumer awareness, business commitment and sustainable government procurement, the market shares of certified products have risen considerably on consumer good markets during the last decade (Potts *et al.*, 2014). Concerning Europe and Central Asia, the only sector with major certification activities is forestry. In 2013 the share of certified forested area (Forest Stewardship Council and Programme for the Endorsement of Forest Certification) in the most forested countries differed substantially, from less than 5% in the Russian Federation to about 80% in Poland and more than 90% in Finland, Norway and Croatia (Potts *et al.*, 2014). Special effort in further countries and additional products is necessary, if voluntary standards are to operate effectively as tools for environmental conservation and poverty reduction. Furthermore, sector-specific certification standards, e.g. in forestry, do not consider the conservation of cultural landscapes as a whole. Maintaining landscape mosaics by using traditional production patterns can increase the competitiveness of goods, such as cheese or fruits, on national and international markets, while contributing to local biodiversity and autonomy (Agnoletti, 2006; Demeulenaere & Bonneuil, 2010).

In principle, market standards can be beneficial for conserving and enhancing ecosystem services (CBD & UNEP-WCMC, 2012). A desk-study on the monetary costs and benefits of certified production that takes the value of ecosystem services explicitly into account showed that certified production systems may offer effective and cost-efficient solutions for protecting and safeguarding ecosystem services. However, a quick scan of a selection of standards reveals that not all services are as yet equally well addressed and treated (van Oorschot *et al.*, 2016). Furthermore, an analysis of standard criteria suggests that newer, mainstream-oriented standards apply criteria of reduced depth and breadth as a means to allow a more rapid market uptake (Potts *et al.*, 2014).

Although certification holds the promise of creating positive impacts in resource producing regions, convincing proof on the positive impacts of certification on environmental and socio-economic conditions is scarce and results are mixed (Blackman & Rivera, 2011; SCSKASC, 2012). A comprehensive research agenda for standards has been developed (Milder *et al.*, 2012, 2015), spurred by cross-standard platforms for discussion and improving credibility, such as the International Social and Environmental Accreditation and Labelling Alliance (ISEAL) (Loconto & Fouilleux, 2014). Up to now, the protection of nature's contributions to people has not been routinely and explicitly addressed. Wider promotion of sustainable production standards, improving the ability of standards to address ecosystem services, and conducting better impact research are all options to be pursued for improving the outreach and effectiveness of this instrument. This might motivate private firms to take proactive measures ahead of legislation, while later regulatory decisions will possibly be aligned to the already developed practice (Lyon & Maxwell, 2002).

Social and environmental reporting

Social and environmental reporting is defined as all forms of non-financial reporting by business to external stakeholders that focus on environmental, social and governance issues. Such reporting is intended to measure consequences of economic activity not covered by traditional accounting systems (Gray, 2010) and has grown and developed over the past decades (van der Esch & Steurer, 2014). Although at present mainly focused on businesses, there is an emerging trend to extend it to other institutions such as NGOs and government agencies at different levels (Owen, 2008). Non-financial reporting is most often based on specific guidelines such as developed by the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB) or the Natural Capital Coalition (NCC, 2015). Those in turn may have a base in, or link to, more general, global principles.

There are different internal and external drivers that may incentivize companies to engage in sustainability reporting (see **Figure 6.17**). On top of that there are semi-mandatory rules, such as intending as a company to comply with certain principles or guidelines that require reporting, and in many countries legal obligations. In Europe and Central Asia, governments have created policies to stimulate or to mandate sustainability reporting by companies in their jurisdictions (van der Esch & Steurer, 2014).

Characteristically, policies that stimulate non-financial reporting by companies are indirect. They use transparency as a tool that aims to set other changes in motion. This indirectness makes it complex to find evidence of the effectiveness and efficiency of environmental reporting policies, as additionality is hard to proof. At the user end, the data collected through non-financial reporting can be used for management, engagement and dialogue within the company, as well as by external stakeholders **(Figure 6.17)**. Rating agencies use this information increasingly to guide and support investors, with large investors by now routinely incorporating this information in their decision-making framework.

6.6.5.4 Rights-based instruments and customary norms

The current state of mainstreaming through rights-based instruments and customary norms has a huge potential for improvement. Despite the fact that rights-based approaches are at the very centre of the recently adopted Sustainable Development Goals, which aim at integrating human

Figure 6 17 **Company drivers for sustainability reporting and engagement of raters. Source: van der Esch & Steurer (2014).**

INTERNAL ORIENTATION	EXTERNAL ORIENTATION
Internal (i.e. employees) stakeholder communication	Anticipation of regulation
Product and process innovation	Competitive edge and public image
Internal management (effiency, costs)	Attract investors
Risk management	External (i.e. community) stakeholder communication

Source: PBL

pbl.nl

rights into all three dimensions of sustainable development (United Nations, 2015), our assessment shows that these types of instruments are rarely implemented and there are huge knowledge gaps in several sectors **(Table 6.11)**. However, following the 2030-Agenda, we assume that the rights-based approach will be emphasized as an option to contribute to mainstreaming biodiversity and nature´s contributions to people. To implement the Sustainable Development Goals agenda including the rights-based approach there is a need to develop more explicit guidelines for public and private decision-makers on how to contribute to e.g. the financing of development, an equitable trading system and a renewed and strengthened global partnership (Kindornay & Twigg, 2015).

The rights-based approach also offers opportunities to identify problems and prospects related to, for example, the implementation of conservation policies in line with the Aichi Biodiversity Targets and the Sustainable Development Goals. The conservation of biodiversity has, on the one hand, contributed to the recognition of both procedural rights by safeguarding the right to participate in decision-making, and substantive rights by supporting sustainable natural resources and human well-being (Borrini-Feyerabend *et al.*, 2004b). Conservation measures have, on the other hand, undermined or violated human rights, through human translocations, abolishment of traditional practices, centralization of governance and management or the prioritization of one industry (e.g., wildlife tourism) over traditional industries (e.g. live-stock herding) (Dowie, 2009).

The application of the rights-based approach implies a need (i) to transform systemic and structural imbalances in power and (ii) to ensure participation in the governance and management of biodiversity and nature's contributions to people, thereby generating an opportunity to avoid such problems related to conservation polices. However, there is also a need to further develop and implement policy instruments such as "free, prior, and informed consent" and the United Nations "protect, respect and remedy" framework (Campese *et al.*, 2009; Hill & Lillywhite, 2015) for States to avoid violating the rights of indigenous peoples (Adams & Hutton, 2007; Anaya, 2015; Otis & Laurent, 2013; Reimerson, 2013) and to take diverse world views, trust issues, imbalance of power or hidden historical issues into consideration (Redpath *et al.*, 2015). Through the promotion of a rights-based approach, instead of being the source of conflicts, indigenous peoples and local communities can often provide opportunities for learning about more sustainable natural resource uses. One positive example is the development of the joint knowledge generation by Hungarian herders and scientists (Molnár *et al.*, 2017).

6.6.5.5 Policy mix

Basically, a policy mix aims to overcome the flaws of single instruments with respect to effectiveness, efficiency and equity, while highlighting the functional role of the relevant instrument in the mix (Schröter-Schlaack & Ring, 2011). The different pathway narratives presented in Chapter 5, Section 5.5.2 emphasize the opportunities of specific instrument mixes to achieve future developments. Several additional aspects call for an analysis and assessment of instruments within a broader policy mix: There are quite different ecosystems with different actors and multiple objectives involved. Furthermore, multiple drivers, sectors and governance levels have to be taken into account. In addition, existing policy regimes and sectoral policies already in place have decisive impact on the effectiveness and efficiency of new instruments to be implemented. Thus, there is a need for more systematic comparative analyses and empirical evidence to specify the interaction between new and traditional measures (Jordan *et al.*, 2013).

Policy analysis considering the role of individual instruments in the real-world policy mix, including interactions with instruments within the same or from other policy sectors, has been mostly dealt with in climate and energy policies (Gawel *et al.*, 2014; Lehmann, 2012; OECD, 2007; Sorrell & Sijm, 2003). Besides a few exceptions in the past (Barton *et al.*, 2014; Gunningham & Young, 1997; Howlett & Rayner, 2006; Ring & Barton, 2015; Ring & Schröter-Schlaack, 2015; Schröter-Schlaack & Ring, 2011), policy mix analysis in biodiversity and ecosystem governance still holds some potential for further research and policy implementation, especially in a cross-sectoral perspective and spatially explicit analysis on the ground.

Direct regulations have often been the first choice for dealing with environmental problems, especially in the case of safeguarding against irreversible developments and overstepping ecological tipping points. In addition, they are seen as a precondition for the effectiveness of other instruments, for example by determining property rights before applying market-based instruments. However, given that direct regulation often neglects opportunity costs and equity aspects (including disregard of traditional and informal rights), their appropriateness can be questioned, and their acceptance can possibly be increased in combination with other instruments. In this regard, regulation and incentive-based instruments are seen as complements in a dual or multiple approach rather than substitutes (Kenward *et al.*, 2011). Designing such policy mixes provides opportunities to mainstreaming biodiversity and nature's contributions to people.

Taking the agricultural sector as an example **(Box 6.10)**, the European Union's cross-compliance mechanism combines direct payments with the compliance by farmers with basic regulatory standards concerning the environment, climate change, public health, food safety, animal and plant health and animal welfare, as well as the requirement of maintaining land in good agricultural and environmental condition (European Union, 2013b). In addition, farmers may qualify for agri-environmental payments for agricultural practices, which go beyond cross-compliance and greening requirements (European Commission, 2013c). This policy design could be further adapted to mainstream and implement the concept of nature's contributions to people in sectors such as agriculture, forestry, fisheries and environmental policy and land-use planning. Legal and regulatory instruments in the form of environmental standards and requirements could be fine-tuned to approximate as much as possible the level of ecological thresholds or tipping points not to be trespassed. These standards can then be combined with economic and financial instruments to further promote the provision of selected contributions of nature to people by land users or fishermen.

Policy mix analysis is also essential from a cross-sectoral perspective where policies in one sector (e.g., climate, fisheries, energy or agriculture) may jeopardize policies in other sectors (e.g., nature conservation). A comprehensive policy mix also comprises the integration of environmental aspects in non-environmental policy sectors, with the aims (i) to reduce conflicts between sectoral policies and (ii) to directly target the drivers of environmental pressures and degradation (Runhaar *et al.*, 2014). For example, publicly financed support programmes for biodiversity measures on farmland can hardly be effective if, at the same time and in the same area, public subsidies favour agricultural intensification and monocultures to increase bioenergy production (TEEB-DE, 2015). However, scientific insight is scarce concerning the reasons for hindering or favouring policy integration (Biesbroek *et al.*, 2013; Brouwer *et al.*, 2013). This calls for the development of a systematic framework for the analysis of effective policy integration strategies (Runhaar *et al.*, 2014).

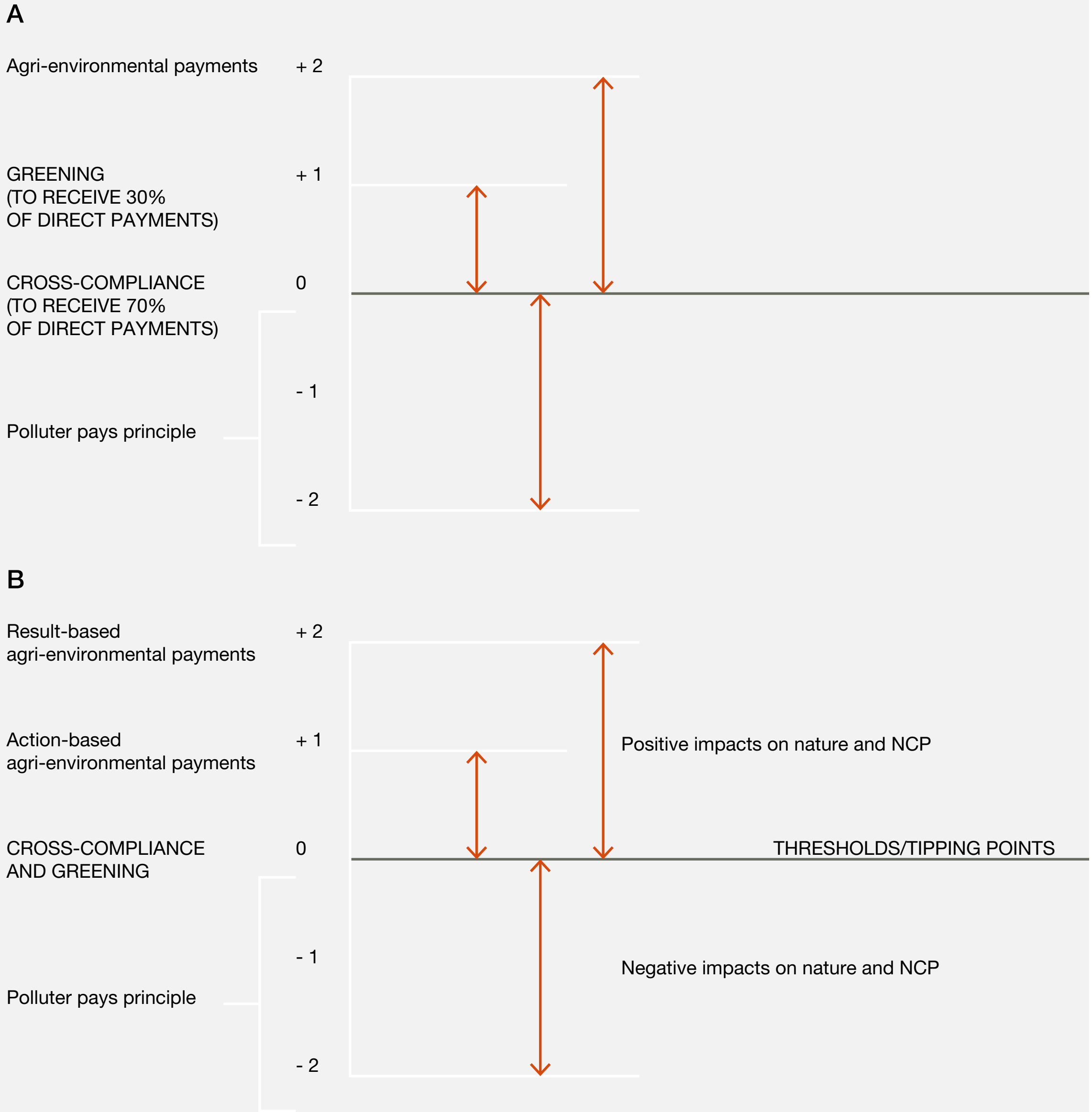
For environmental policy instruments to be effective, they have to be supported by the general public (Harring, 2014). Here, attitudes and judgements concerning specific instruments vary substantially across countries. Combining scientific evidence with legal, political and social institutions can be a promising approach for balancing environmental protection and development. Further, economic instruments should not only focus on private actors but also include the role of public actors and promote a "*mindset of cooperation and shared responsibility*" (Santos *et al.*, 2015a, p. 94). Such a mindset could also contribute to overcoming aspects of procedural and distributive justice and comprise an equitable integration of scientific insights and lay knowledge (Paloniemi *et al.*, 2015).

Box 6 10 Mix of instruments in agri-environmental policy.

Despite being criticized for setting too loose and general criteria for cross-compliance and greening (see also Section 6.5.1.3; Hauck *et al.*, 2014; Hodge *et al.*, 2015; Pe'er *et al.*, 2014), the 2013 Common Agricultural Policy reform has made explicit the rationale underlying the policy design to achieve the delivery of public goods by both pillars of the policy (European Commission, 2013c). This policy architecture envisages the use and integration of different policy instruments **(Figure 6.18 A)**. This strategy is implemented by requiring farmers to respect cross-compliance requirements (some of which are based on European Union environmental legislation such as the Water Framework Directive and Nitrates Directive) to be eligible for 70% of direct payments, and of greening requirements to be eligible for the remaining 30% of direct payments under pillar 1. Once farmers have respected both cross-compliance and greening requirements they are eligible to enroll in voluntary agri-environmental measures with payments under pillar 2 for agricultural practices which go beyond cross-compliance and greening requirements (European Commission, 2013c). Furthermore, administrative penalties may be applied as in cases of non-compliance with eligibility criteria, commitments or other obligations resulting from the application of agricultural legislation (European Union, 2013b) **(Figure 6.18 A)**.

Box 6 10

Figure 6 18 A Integration of different agri-environmental policy instruments by the 2013 reform of the European Union's Common Agricultural Policy; B Example of integrating further policy instruments with additional benefits for biodiversity conservation and the sustained delivery of nature's contributions to people (NCP) in the policy mix. Source: Own representation.



This policy architecture could be adapted to mainstream and to implement the concept of nature's contributions to people **(Figure 6.18 B)**. This can be done by fine tuning cross-compliance and greening requirements to approximate as much as possible the level of ecological thresholds or tipping points not to be trespassed in a specific agro-ecosystem to achieve the delivery of selected contributions of nature to people. Above this reference level payments for agri-environment-climate measures could be tailored to specific nature's contributions to people or local conditions by allowing farmers to choose between action- or result-based agri-environmental payments (Section 6.5.1.3) to enhance the nature's contributions to people delivery beyond thresholds or tipping points **(Figure 6.18 B).** The effectiveness and efficiency of result-oriented agri-environmental measures could be further enhanced by issuing territorial contracts for groups of farmers to reach the critical mass necessary to deliver selected nature's contributions to people and at the same time reducing transaction costs.

The dialogue and engagement of different actors in the political process is not a novel phenomenon (EUFORGEN, 2017). The important issues are how actors cooperate and which combination of actors is most effective in providing successful governance (Peters, 2014). The policy outcomes concerning non-governmental certification in the forestry and fishery sector are examples of public-private policy interaction at multiple levels. However, more research is needed to identify causal mechanisms and to explore whether sector-specific solutions are successfully applicable within and across other sectors (Gulbrandsen, 2014). Concerning Central Asia, a recently finished European Union FP7-research project assessed the policy mix in the field of science and innovation (IncoNet Central Asia, 2016). The applied peer-review exercise could serve as an example for a similar initiative related to nature's contributions to people.

Box 6.11 presents a policy-mix analysis for the Norwegian system of fisheries management based on the IPBES categories of policy instruments and families of policy support tools and methodologies (IPBES, 2015b; Lasson, 2016). Norway's experience has shown that it is possible to drastically reduce subsidies without destroying the industry (Lehmann *et al.*, 2011; OECD, 2006a) and it provides a best-practice example of how considering relevant actors and various policy instruments in a mix can lead to effective outcomes. Therefore, integrating and mainstreaming biodiversity into key sectors and policies is a major strategic goal, at national, regional and global levels (CBD, 2010; European Commission, 2011a).

6.6.6 Safeguarding biodiversity, nature's contributions to people and good quality of life in a changing world

The design of promising governance options and smart institutional arrangements is central to the conservation and sustainable use of biodiversity and nature's contributions to people. Mainstreaming biodiversity and nature's

Box 6 11 Policy mix analysis of the Norwegian system of fisheries management.

Today's system of fisheries management in Norway is often cited as best practice of effective and well-coordinated policymaking, which is, however, the result of decades of gradual reforms. As a major paradigm shift, sustainable resource management instead of state support to industry became the main management priority. The ecosystem approach is now a central principle in fisheries management, which at the same time is increasingly coordinated with other marine uses. Since the 1990s, the negative trend in stock levels has been reversed: major stocks have been rebuilt or are still in the rebuilding phase, and catches and profitability of the sector increased (Gullestad *et al.*, 2014; Misund, 2014).

Within the policy mix, legal and regulatory instruments naturally play a key role. Limiting access to fisheries and reducing the number of vessels was the starting point of reforms in the 1970s (Misund, 2014; OECD, 2013a, p. 369). Also, overall quotas were cut and are mostly set according to scientific advice (Diamond & Beukers-Stewart, 2011). Limiting access to fisheries by licenses is a form of rights-based instruments and customary norms: today, all offshore and most coastal fisheries are access-regulated. To mitigate social impacts, a number of free access licenses are granted to young fishermen in small-scale coastal fisheries (Eliasen *et al.*, 2009, p. 31). In 2011, an agreement was reached with the indigenous Sami population regarding their fishing rights and increased involvement in decision-making (Government of Norway, 2012, p. 114; OECD, 2013a, p. 369).

One of the main economic and financial instruments in fisheries management are subsidies. In the mid-1960s, Norwegian fisheries started to be heavily subsidized, which counteracted both conservation and profitability objectives. It took until the early 1980s when the problem was addressed and subsidies started to be reduced. Since then, they have been temporarily increased to buffer short-term crisis in the sector but have been cut to a negligible level since the mid-1990s. Another economic instrument concerns the discard ban: to increase compliance of fishermen – which is arguably hard to enforce on the high seas – they can keep, under certain conditions, a percentage of the sales value of their landed bycatch.

Transparency is considered an important element of social and information-based instruments. A database containing the fishing licenses and quotas for each vessel is publicly available; an instrument that is assumed to enhance compliance with regulations. The same effect is attributed to the fact that the fishing industry is given responsibility in terms of monitoring and self-control. Environmental education and awareness campaigns are carried out by agencies which are also involved in fisheries management, for example in the development of the integrated ocean management plans.

The overall effectiveness of the policy mix is closely tied to a range of policy support tools and methodologies. Namely a trustful and well-established cooperation with the fishing industry and increasingly also other stakeholders, and extensive monitoring of both ecosystems and fisheries in combination with strict enforcement contribute to the viability of policy instruments. **Table 6.12** shows an exemplary overview of these and other support tools.

Box 6 11

Table 6 12 **Examples of policy support tools and methodologies in Norwegian fisheries management.**

Assembling data and knowledge	Scientific surveys increasingly run as “ecosystem cruises”, collecting data not only on fish but also on plankton, benthos, marine mammals and seabirds as well as on oceanographic conditions. Additional data are collected by the Norwegian Reference Fleet, a group of commercial fishing vessels performing scientific sampling of their catch.
Assessment and evaluation	Biophysical ecosystem considerations in stock assessments, for example modeling predator-prey relationships.
Public discussion, involvement and participatory process	Formal and informal involvement of fishermen’s associations and other stakeholders in quota setting, allocation and other management issues, with positive effects on legitimacy and compliance.
Selection and design of policy instruments	Fisheries legislation mainly as enabling acts, delegating decision-making power to administration and de-coupling it from shifting political agendas; strong commitment to conservation goals. ”Stock and Fisheries tables” as tool to prioritize policy requirements and as basis for discussion with stakeholders.
Implementation, outreach and enforcement	High coverage of Coast Guard inspections, carried out in respectful and non-provocative manner.
Training and capacity building	Training of scientists and Coast Guard inspectors in international collaboration, especially with Russia.
Social learning, innovation and adaptive governance	Regular formal and informal meetings between stakeholders and managers at national and local scales (Gullestad *et al.,* 2017; Mikalsen & Jentoft, 2003). General openness of system to innovation and testing of new policies (Gullestad *et al.,* 2015).

contributions to people into different sectors at multiple scales is a crucial precondition to achieving long-term human well-being and sustainable development (CBD, 2016a; Meadowcroft *et al.*, 2012; UNEP & UNECE, 2016; United Nations, 2015). How we choose to organize our societies – both the public and the private spheres - is key for the realization of pathways towards a world with ecosystems capable of meeting future human needs (see Chapter 5). Hence, the literature on governance towards sustainability focuses in particular on finding promising governance modes (or mixes of modes) suitable to promote sustainable development (Lange *et al.*, 2013). Our assessment shows that new modes of governance, such as decentralization, public-private partnerships or private forms of governance, increasingly emerge in parallel to traditional hierarchical governance. They allow better involvement of different actors in policy and decision-making with the aim of promoting shared responsibility for our common future. However, due to the intrinsic complexity of human societies, there is no single panacea for successful governance of biodiversity and nature’s contributions to people (Ostrom *et al.*, 2007).

To govern complexity or complex adaptive systems (see Chapter 4), which often includes various forms of incomplete knowledge, and involves risk, uncertainty, ambiguity or even ignorance (Leach *et al.*, 2010), it is frequently argued that the design of promising governance options should aim at building robustness, enhancing resilience, and considering risk. While robustness refers to the maintenance of system performance to avoid disruption (Anderies & Janssen, 2013), resilience measures the maximum disturbance of a system before flipping to a different state (Walker *et al.*, 2004), and can be characterized as “*a kind of insurance against reaching a non-desired state*.” (Mäler & Li, 2010, p. 708). A risk approach has a slightly different focus of enabling societies to benefit from change while minimizing the negative consequences of associated risks (Lidskog *et al.*, 2010). While the concepts are appealing, resilience in particular can be difficult to apply to designed or managed systems (Rist & Moen, 2013), while robustness and risk, which explicitly build on designed systems, often fail to make necessary trade-offs (Barnett & Anderies, 2014). Nevertheless, the various approaches to governance of complexity share important characteristics, since they all promote policy processes that stimulate adaptation and learning. Hence, to take up the challenge of successfully governing complexity and better adapting policies and instruments to specific contexts, approaches of biodiversity conservation and mainstreaming into sectoral policies, programmes and strategies need to be seen as experiments that require (i) governance and management for change, rather than against change, and (ii) systematic continuous monitoring and evaluation (Rist & Moen, 2013). This can be achieved incrementally through adaptive governance and management and the systematic improvement of policy implementation (Hasselman, 2017), or via transition governance and management, and the organization of evolutionary processes of societal change (Mårald *et al.*, 2017).

Over the last three decades promising governance modes have emerged that support biodiversity conservation and mainstreaming in Europe and Central Asia. However, our assessment shows that there are underutilized opportunities for policy integration and mainstreaming that might facilitate the transition towards an inclusive green economy (see e.g. “Greening Economies in the Eastern Neighbourhood Programme” (EaP-Green) (UNEP & UNECE, 2016, p. 154). Developing and improving governance systems to promote adaptive or transition management is therefore essential, if public and private actors are to achieve the overarching objective of safeguarding biodiversity, nature’s contributions to people and good quality of life. Mainstreaming biodiversity and nature’s contributions to people along the three key steps of raising awareness, defining policy objectives, and designing policies and instruments **(Figure 6.13)** is crucial to the success of this endeavour.

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ANNEXES

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ANNEX I

Glossary

A

Abundance (ecological)
The size of a population of a particular life form in a given area.

Acceptance
Acceptance of IPBES outputs at a session of its Plenary signifies that the material has not been subjected to line-by-line discussion and agreement, but nevertheless presents a comprehensive and balanced view of the subject matter.

Acidification
Ongoing decrease in pH away from neutral value of 7. Often used in reference to oceans, freshwater or soils, as a result of uptake of carbon dioxide from the atmosphere.

Actor
Individual person or group representative that is involved in a specific decision-making context.

Adaptation
Adjustment in natural or human systems to a new or changing environment, whether through genetic or behavioural change.

Adaptive capacity
The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences.

Adaptive management
A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. In active adaptive management, management is treated as a deliberate experiment for purposes of learning.

Afforestation
Converting grasslands or shrublands into tree plantations. Afforestation is sometimes suggested as a tool to sequester carbon, but it can have negative impacts on biodiversity and ecosystem function, for example by reducing runoff and so decreasing water production.

Agenda setting
One of four phases in the policy cycle. Agenda setting motivates and sets the direction for policy design and implementation.

Agri-environmental schemes
Schemes that provide funding to farmers and land managers to farm in ways that support biodiversity, enhance the landscape, and improve the quality of water, air and soil (see also agroecology as integral to such schemes).

Agricultural intensification
An increase in agricultural production per unit of input (which may be labour, land, time, fertilizer, seed, feed or cash).

Agrobiodiversity
Agrobiodiversity or agricultural biodiversity is the biological diversity that sustains key functions, structures and processes of agricultural ecosystems. It includes the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels.

Agroecology
The science and practice of applying ecological concepts, principles and knowledge (i.e., the interactions of, and explanations for, the diversity, abundance and activities of organisms) to the study, design and management of sustainable agroecosystems. It includes the roles of human beings as a central organism by way of social and economic processes in farming systems. Agroecology examines the roles and interactions among all relevant biophysical, technical and socioeconomic components of farming systems and their surrounding landscapes.

Agroecosystem
An ecosystem, dominated by agriculture, containing assets and functions such as biodiversity, ecological succession and food webs. An agroecosystem is not restricted to the immediate site of agricultural activity (e.g. the farm), but rather includes the region that is impacted by this activity, usually by changes to the complexity of species assemblages and energy flows, as well as to the net nutrient balance.

Agroforestry
A collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence.

Aichi Biodiversity Targets
The 20 targets set by the Conference of the Parties to the Convention for Biological Diversity (CBD) at its tenth meeting, under the Strategic Plan for Biodiversity 2011-2020.

Alien species
See “invasive alien species”.

Annual
In botany, refers to plants that grow from seed to maturity, reproduction and death in one year. Related terms are biennial (plants that take two years to complete their life cycles), and perennial (plants that take several many years to complete their life cycles).

Anthropocentric value
See “values”.

Anthropogenic assets
Built-up infrastructure, health facilities, or knowledge - including indigenous and local knowledge systems and technical or scientific knowledge - as well as formal and non-formal education, work, technology (both physical objects and procedures), and financial assets. Anthropogenic assets have been highlighted to emphasize that a good quality of life is achieved by a co-production of benefits between nature and people.

Approval
Approval of IPBES outputs signifies that the material has been subject to detailed, line-by-line discussion and agreement by consensus at a session of the Plenary.

Aquaculture
The farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants, involving interventions such as regular stocking, feeding, protection from predators, to enhance production. (In contrast, aquatic organisms which are exploitable by the public as a common property resource, are classed as fisheries, not aquaculture).

Archetypes
In the context of scenarios, an over-arching scenario that embodies common characteristics of a number of more specific scenarios.

Aridification
A chronic reduction in soil moisture caused by an increase of mean annual temperature or a decrease in yearly precipitation.

Assessment reports
Assessment reports are published outputs of scientific, technical and socioeconomic issues that take into account different approaches, visions and knowledge systems, including global assessments of biodiversity and ecosystem services with a defined geographical scope, and thematic or methodological assessments based on the standard or the fast-track approach. They are composed of two or more sections including a summary for policymakers, an optional technical summary, and individual chapters and their executive summaries. Assessments are the major output of IPBES, and they contain syntheses of findings on topics that have been selected by the IPBES Plenary.

B

Baseline
A minimum or starting point to which to compare other information (e.g. for comparisons between past and present or before and after an intervention).

Beneficiary
Different social actors and groups who may be benefiting from nature and its contributions to people in different ways and to different degrees, including individual, household or collective levels.

Benefit sharing
Distribution of benefits between stakeholders.

Benefits
Advantage that contribute to well-being from the fulfilment of needs and wants. In the context of nature's contributions to people.

Benthic
Occurring at the bottom of a body of water; related to benthos.

Benthos
A group of organisms, including invertebrates, that live in or on the bottom in aquatic habitats.

Biocapacity
The capacity of a country, a region, or the world, to produce useful biological materials for its human population and to absorb waste materials.

Biocentric perspectives
Recognizing the importance of non-human life.

Biocultural diversity
The diversity exhibited collectively by natural and cultural systems. It incorporates three concepts: firstly, that the diversity of life includes human cultures and languages; secondly, that links exist between biodiversity and human cultural diversity; and finally, that these links have developed over time through mutual adaptation and possibly co-evolution between humans, plants and animals.

Biodiversity
The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems.

Biodiversity hotspot
A generic term for an area high in such biodiversity attributes as species richness or endemism. It may also be used in assessments as a precise term applied to geographic areas defined according to two criteria: (i) containing at least 1,500 species of the world's 300,000 vascular plant species as endemics, and (ii) being under threat, in having lost 70% of its primary vegetation.

Biodiversity loss
The reduction of any aspect of biological diversity (i.e. diversity at the genetic, species and ecosystem levels) is lost in a particular area through death (including extinction), destruction or manual removal; it can refer to many scales, from global extinctions to population extinctions, resulting in decreased total diversity at the same scale.

Biodiversity offset
A biodiversity offset is a tool proposed by developers and planners for compensating for the loss of biodiversity in one place by biodiversity gains in another.

Biofuel
Fuel made from biomass.

Biological diversity
See "biodiversity".

Biomass
The mass of non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms in a given area or volume.

Biome
Biomes are global-scale zones, generally defined by the type of plant life that they support in response to average rainfall and temperature patterns. For example, tundra, coral reefs or savannas.

Biosphere
The sum of all the ecosystems of the world. It is both the collection of organisms living on the Earth and the space that they occupy on part of the Earth's crust (the lithosphere), in the oceans (the hydrosphere) and in the atmosphere. The biosphere is all the planet's ecosystems.

Biota
All living organisms of an area; the flora and fauna considered as a unit.

Biotic homogenization
See "homogenization".

Bureau
The IPBES Bureau is a subsidiary body established by the Plenary which carries out the governance functions of IPBES. It is made up of representatives nominated from each of the United Nations regions, and is chaired by the Chair of IPBES.

Bushmeat
Meat for human consumption derived from wild animals.

Bycatch
The commercially undesirable species caught during a fishing process.

C

Cap-and-trade
An economic policy instrument in which the State sets an overall environmental target (the cap) and assigns environmental impact allowances (or quotas) to actors that they can trade among each other.

Capacity-building (or capacity development)
Defined by the United Nations Development Programme as "the process through which individuals, organisations and societies obtain, strengthen and maintain their capabilities to set and achieve their own development objectives over time". IPBES promotes and facilitates capacity-building, to improve the capacity of countries to make informed policy decisions on biodiversity and ecosystem services.

Carbon cycle
The carbon cycle is the process by which carbon is exchanged among the ecosystems of the Earth.

Carbon sequestration
The long-term storage of carbon in plants, soils, geologic formations, and the ocean. Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas.

Carbon storage
The technological process of capturing waste carbon dioxide from industry or power generation, and storing it so that it will not enter the atmosphere.

Carrying capacity
In ecology, the carrying capacity of a species in an environment is the maximum population size of the species that the environment can sustain indefinitely. The term is also used more generally to refer to the upper limit of habitats, ecosystems, landscapes, waterscapes or seascapes to provide tangible and intangible goods and services (including aesthetic and spiritual services) in a sustainable way.

Catalogue of policy support tools and methodologies
The IPBES catalogue of policy support tools and methodologies is an evolving online resource with two main goals. The first goal is to enable decision-makers to gain easy access to information on policy support tools and methodologies to better inform and assist the different phases of policymaking and implementation. The second goal is to allow a range of users to provide input to the catalogue and assess the usability of tools and methodologies in their specific contexts, including resources required and types of outputs that can be obtained, thus helping to identify and bridge gaps with respect to available tools and methodologies.

Certainty
In the context of IPBES, the summary terms to describe the state of knowledge are the following:

- Well established (certainty term): comprehensive meta-analysis or other synthesis or multiple independent studies that agree.
- Established but incomplete (certainty term): general agreement although only a limited number of studies exist but no comprehensive synthesis and, or the studies that exist imprecisely address the question.
- Unresolved (certainty term): multiple independent studies exist but conclusions do not agree.
- Inconclusive (certainty term): limited evidence, recognising major knowledge gaps.

Citizens/laypeople
Actors living in the area / context of interest that are directly or indirectly impacted by decisions / recommendations and hold their own (subjective) interest.

Climate change
As defined in Article 1 of the UNFCCC, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

Co-management
Process of management in which government shares power with resource users, with each given specific rights and responsibilities relating to information and decision-making.

Co-production
In the context of the IPBES conceptual framework, this is the joint contribution by nature and anthropogenic assets in generating nature's contributions to people.

Community based monitoring and information systems (CBMIS)
Initiatives by indigenous peoples and local community organizations to monitor their community's well-being and the state of their territories and natural resources, applying a mix of traditional knowledge and innovative tools and approaches. It is a system that promotes evidence-based policymaking while empowering communities to participate in the process.

Community-based natural resource management
Community-based natural resource management: an approach to natural resource management that involves the full participation of indigenous peoples' and local communities and resource users in decision-making activities, and the incorporation of local institutions, customary practices, and knowledge systems in management, regulatory, and enforcement processes. Under this approach, community-based monitoring and information systems are initiatives by indigenous peoples and local community organizations to monitor their community's well-being and the state of their territories and natural resources, applying a mix of traditional knowledge and innovative tools and approaches.

Confidence
See "certainty".

Conservation agriculture
Approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. It is characterized by three linked principles, namely: 1) continuous minimum mechanical soil disturbance; 2) permanent organic soil cover; and 3) diversification of crop species grown in sequences and/or associations. This covers a wide range of approaches from minimum till to permaculture/"mimicking nature".

Corridor
A geographically defined area which allows species to move between landscapes, ecosystems and habitats, natural or modified, and ensures the maintenance of biodiversity and ecological and evolutionary processes.

Cost-benefit analysis
A technique designed to determine the feasibility of a project or plan by quantifying its costs and benefits.

Cropland
A land cover/use category that includes areas used for the production of crops for harvest.

Cross-scale analysis
Cross-scale effects are the result of spatial

and/or temporal processes interacting with other processes at another scale. These interactions create emergent effects that can be difficult to predict.

Cross-sectoral
Relating to interactions between sectors (that is, the distinct parts of society, or of a nation's economy), such as how one sector affects another sector, or how a factor affects two or more sectors.

Customary law
Law consisting of commonly repeated customs, practices and beliefs that are accepted as legal requirements or obligatory rules of conduct.

D

Decomposition
Breakdown of complex organic substances into simpler molecules or ions by physical, chemical and/or biological processes.

Deforestation
Human-induced conversion of forested land to non-forested land. Deforestation can be permanent, when this change is definitive, or temporary when this change is part of a cycle that includes natural or assisted regeneration.

Degraded land
Land in a state that results from persistent decline or loss of biodiversity and ecosystem functions and services that cannot fully recover unaided.

Denitrification
Reduction of nitrates and nitrites to nitrogen by microorganisms.

Desertification
Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification does not refer to the natural expansion of existing deserts.

Direct driver
See "driver".

Distributional equity/justice
Allocation of costs, benefits, risks and responsibilities as well as of the products of nature requiring the disaggregation of values to highlight who benefits and who loses, and to demonstrate the consequences for those affected.

Double counting of services
Erroneously including the same ecosystem service more than once in an economic analysis.

Downscaling
The transformation of information from coarser to finer spatial scales through statistical modelling or spatially nested linkage of structural models.

Driver
In the context of IPBES, drivers of change are all the factors that, directly or indirectly, cause changes in nature, anthropogenic assets, nature's contributions to people and a good quality of life.

Drylands
Arid, semi-arid and dry sub-humid areas. The term excludes hyper-arid areas, also known as deserts. Drylands are characterized by water scarcity and cover approximately 40% of the world's terrestrial surface.

E

Ecoregion
A large area of land or water that contains a geographically distinct assemblage of natural communities that: (a) Share a large majority of their species and ecological dynamics; (b) Share similar environmental conditions, and; (c) Interact ecologically in ways that are critical for their long-term persistence (source: WWF). In contrast to biomes, an ecoregion is generally geographically specific, at a much finer scale. For example, the "East African Montane Forest" ecoregion of Kenya (WWF ecoregion classification) is a geographically specific and coherent example of the globally occurring "tropical and subtropical forest" biome.

Ecological community
An assemblage or association of populations of two or more different species occupying the same geographical area and in a particular time.

Ecological footprint
A measure of the amount of biologically productive land and water required to support the demands of a population or productive activity. Ecological footprints can be calculated at any scale: for an activity, a person, a community, a city, a region, a nation or humanity as a whole.

Ecological infrastructure
Ecological infrastructure refers to the natural or semi-natural structural elements of ecosystems and landscapes that are important in delivering ecosystem services. It is similar to "green infrastructure", a term sometimes applied in a more urban context. The ecological infrastructure needed to support pollinators and improve pollination services includes patches of semi-natural habitats, including hedgerows, grassland and forest, distributed throughout productive agricultural landscapes, providing nesting and floral resources. Larger areas of natural habitat are also ecological infrastructure, although these do not directly support agricultural pollination in areas more than a few kilometres away from pollinator-dependent crops.

Economic and financial instruments
Economic and financial instruments can be used to change people's behaviour towards desired policy objectives. Instruments typically encompass a wide range of designs and implementation approaches. They include traditional fiscal instruments, including for example subsidies, taxes, charges and fiscal transfers. Additionally, instruments such as tradable pollution permits or tradable land development rights rely on the creation of new markets. Further instruments represent conditional and voluntary incentive schemes such as payments for ecosystem services. All these can in principle be used to correct for policy or/and market failures and reinstate full-cost pricing. They aim at reflecting social costs or benefits of the conservation and use of biodiversity and ecosystem services of a public good nature ("getting the price right"). Financial instruments, in contrast, are often extra-budgetary and can be financed from domestic sources or foreign aid, external borrowing, debt for nature swaps, etc. Economic instruments do not necessarily imply that commodification of environmental functions is promoted. Generally, they are meant to change behaviour of individuals (e.g., consumers and producers) and public actors (e.g., local and regional governments).

Economic valuation
See "values".

Ecosystem
A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Ecosystem accounting
The process of constructing formal accounts for ecosystems.

Ecosystem degradation
A persistent (long-time) reduction in the capacity to provide ecosystem services.

Ecosystem function
The flow of energy and materials through the biotic and abiotic components of an ecosystem. It includes many processes such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer.

Ecosystem health
Ecosystem health is a metaphor used to describe the condition of an ecosystem, by analogy with human health. Note that there is no universally accepted benchmark for a healthy ecosystem. Rather, the apparent health status of an ecosystem can vary, depending upon which metrics are employed in judging it, and which societal aspirations are driving the assessment.

Ecosystem management
An approach to maintaining or restoring the composition, structure, function, and delivery of services of natural and modified ecosystems for the goal of achieving sustainability. It is based on an adaptive, collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework, and defined primarily by natural ecological boundaries.

Ecosystem services
The benefits people obtain from ecosystems. In the Millennium Ecosystem Assessment, ecosystem services can be divided into supporting, regulating, provisioning and cultural. This classification, however, is superseded in IPBES assessments by the system used under "nature's contributions to people." This is because IPBES recognises that many services fit into more than one of the four categories. For example, food is both a provisioning service and also, emphatically, a cultural service, in many cultures.

Ecotourism
Sustainable travel undertaken to access sites or regions of unique natural or ecological quality, promoting their conservation, low visitor impact, and socio-economic involvement of local populations.

Endangered species
A species at risk of extinction in the wild.

Endemic species
Plants and animals that exist only in one geographic region.

Endemism
The ecological state of a species being unique to a defined geographic location, such as an island, nation, country or other defined zone, or habitat type; organisms that are indigenous to a place are not endemic to it if they are also found elsewhere.

Energy security
Access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses.

Equity
Fairness of rights, distribution, and access. Depending on context, this can refer to resources, services, or power.

Eutrophic
A condition of an aquatic system in which increased nutrient loading leads to progressively increasing amounts of algal growth and biomass accumulation. When the algae die off and decompose, the amount of dissolved oxygen in the water becomes reduced. The term is sometimes applied more broadly than just to aquatic systems.

Eutrophication
Nutrient enrichment of an ecosystem, generally resulting in increased primary production and reduced biodiversity. In lakes, eutrophication leads to seasonal algal blooms, reduced water clarity, and, often, periodic fish mortality as a consequence of oxygen depletion. The term is most closely associated with aquatic ecosystems but is sometimes applied more broadly.

Exclusive economic zone
An exclusive economic zone (EEZ) is a concept adopted at the Third United Nations Conference on the Law of the Sea (1982), whereby a coastal State assumes jurisdiction over the exploration and exploitation of marine resources in its adjacent section of the continental shelf, taken to be a band extending 200 miles from the shore. The exclusive economic zone comprises an area which extends either from the coast, or in federal systems from the seaward boundaries of the constituent states (3 to 12 nautical miles, in most cases) to 200 nautical miles (370 kilometres) off the coast. Within this area, nations claim and exercise sovereign rights and exclusive fishery management authority over all fish and all continental shelf fishery resources.

Externality
A positive or negative consequence (benefit or cost) of an action that affects someone other than the agent undertaking that action and for which the agent is neither compensated nor penalized through the markets.

Extinction debt
The future extinction of species due to events in the past, owing to a time lag between an effect such as habitat destruction or climate change, and the subsequent disappearance of species.

F

Feedback
The modification or control of a process or system by its results or effects.

Food security
The World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life".

Formal institutions
Include law and policies e.g., regulations and directives, and fiscal, agricultural or planning policies, to name just a few examples. These are typically based on legal instruments, treaties and customary laws. Informal institutions in turn include social norms and rules, such as those related to collective action.

Functional diversity
The range, actual values, relative abundance and distribution of functional trait attributes in a given community.

Functional traits
Any feature of an organism, expressed in the phenotype and measurable at the individual level, which has demonstrable links to the organism's function. As such, a functional trait determines the organism's response to external abiotic or biotic factors (response trait), and/or its effects on ecosystem properties or benefits or

detriments derived from such properties (effect trait). In plants, functional traits include morphological, ecophysiological, biochemical and regeneration traits. In animals, these traits include e.g. body size, litter size, age of sexual maturity, nesting habitat, time of activity.

G

Generalist species
A species able to thrive in a wide variety of environmental conditions and that can make use of a variety of different resources (for example, a flower-visiting insect that lives on the floral resources provided by several to many different plants).

Good quality of life
Within the context of the IPBES conceptual framework – the achievement of a fulfilled human life, a notion which may vary strongly across different societies and groups within societies. It is a context-dependent state of individuals and human groups, comprising aspects such as access to food, water, energy and livelihood security, and also health, good social relationships and equity, security, cultural identity, and freedom of choice and action. “Living in harmony with nature”, “living-well in balance and harmony with Mother Earth” and “human well-being” are examples of different perspectives on a “good quality of life”.

Governance
The way the rules, norms and actions in a given organization are structured, sustained, and regulated.

Grassland
Type of ecosystem characterized by a more or less closed herbaceous (non-woody) vegetation layer, sometimes with a shrub layer, but – in contrast to savannas – without, or with very few, trees. Different types of grasslands are found under a broad range of climatic conditions.

H

Habitat
The place or type of site where an organism or population naturally occurs. Also used to mean the environmental attributes required by a particular species or its ecological niche.

Habitat connectivity
The degree to which the landscape facilitates the movement of organisms (animals, plant reproductive structures, pollen, pollinators, spores, etc.) and other environmentally important resources (e.g., nutrients and moisture) between similar habitats. Connectivity is hampered by fragmentation.

Habitat degradation
A general term describing the set of processes by which habitat quality is reduced. Habitat degradation may occur through natural processes (e.g. drought, heat, cold) and through human activities (forestry, agriculture, urbanization).

Habitat fragmentation
A general term describing the set of processes by which habitat loss results in the division of continuous habitats into a greater number of smaller patches of lesser total and isolated from each other by a matrix of dissimilar habitats. Habitat fragmentation may occur through natural processes (e.g., forest and grassland fires, flooding) and through human activities (forestry, agriculture, urbanization).

Habitat service
The importance of ecosystems to provide living space for resident and migratory species (thus maintaining the gene pool and nursery service).

Harmonization
The process of bringing something together, and comparing (e.g., models or scenarios) to facilitate compatibility or consistency.

Hedgerow
A row of shrubs or trees that forms the boundary of an area such as a garden, field, farm, road or right-of-way.

Hedonic pricing
An economic valuation approach that utilizes information about the implicit demand for an environmental attribute of marketed commodities.

Homogenization
When used in the ecological sense “homogenization” means a decrease in the extent to which communities differ in species composition.

Human appropriation of net primary production (HANPP)
The aggregate impact of land use on biomass available each year in ecosystems.

I

Impact assessment
A formal, evidence-based procedure that assesses the economic, social, and environmental effects of public policy or of any human activity.

Important Bird & Biodiversity Areas
A Key Biodiversity Area identified using an internationally agreed set of criteria as being globally important for bird populations.

Indicators
A quantitative or qualitative factor or variable that provides a simple, measurable and quantifiable characteristic or attribute responding in a known and communicable way to a changing environmental condition, to a changing ecological process or function, or to a changing element of biodiversity.

Indigenous and community conserved areas
Natural and modified ecosystems including significant biodiversity, ecological services and cultural values voluntarily conserved by indigenous and local communities through customary laws or other effective means.

Indigenous and local knowledge systems
Indigenous and local knowledge systems are social and ecological knowledge practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments. Such knowledge can provide information, methods, theory and practice for sustainable ecosystem management.

Indigenous peoples and local communities
Indigenous peoples and local communities (IPLCs) are, typically, ethnic groups who are descended from and identify with the original inhabitants of a given region, in contrast to groups that have settled, occupied or colonized the area more recently. IPBES does not intend to create or develop new definitions of what constitutes “indigenous peoples and local communities.

Indirect driver
See “driver”.

Indirect use value
See “values”.

Institutional failure
These are often catalogued as (i) law and policy failures (e.g., perverse subsidies), (ii) market failures (externalities in the use of public goods and services), (iii) organizational failure (e.g., lack of transparency and political legitimacy in decision-making) and (iv) informal institutional failures (e.g., break of collective action norms due to erosion of trust.

Institutions
Encompasses all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed.

Instrumental value
See "values".

Integrated assessment models
Interdisciplinary models that aim to describe the complex relationships between environmental, social, and economic drivers that determine current and future state of the ecosystem and the effects of global change, in order to derive policy-relevant insights. One of the essential characteristics of integrated assessments is the simultaneous consideration of the multiple dimensions of environmental problems.

Integrated pest management
Also known as integrated pest control. It is a broadly-based approach that integrates various practices for economic control of pests. Integrated pest management (or IPM) aims to suppress pest populations below the economic injury level (i.e., to below the level that the costs of further control outweigh the benefits derived). It involves careful consideration of all available pest control techniques and then integration of appropriate measures to discourage development of pest populations while keeping pesticides and other interventions to economically justifiable levels with minimal risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

Integrated valuation
See "values".

Intrinsic value
See "values".

Invasive alien species
Species whose introduction and/or spread by human action outside their natural distribution threatens biological diversity, food security, and human health and well-being. "Alien" refers to the species having been introduced outside its natural distribution ("exotic", "non-native" and "non-indigenous" are synonyms for "alien"). "Invasive" means "tending to expand into and modify ecosystems to which it has been introduced". Thus, a species may be alien without being invasive, or, in the case of a species native to a region, it may increase and become invasive, without actually being an alien species.

Invasive species
See "invasive alien species".

IPBES conceptual framework
The IPBES conceptual framework has been designed to build shared understanding across disciplines, knowledge systems and stakeholders of the interplay between biodiversity and ecosystem drivers, and of the role they play in building a good quality of life.

IUCN protected area category
IUCN protected area management categories classify protected areas according to their management objectives.

K

Key biodiversity areas
Sites contributing significantly to the global persistence of biodiversity. They represent the most important sites for biodiversity worldwide, and are identified nationally using globally standardized criteria and thresholds.

Knowledge systems
A body of propositions that are adhered to, whether formally or informally, and are routinely used to claim truth. They are organized structures and dynamic processes (a) generating and representing content, components, classes, or types of knowledge, that are (b) domain-specific or characterized by domain-relevant features as defined by the user or consumer, (c) reinforced by a set of logical relationships that connect the content of knowledge to its value (utility), (d) enhanced by a set of iterative processes that enable the evolution, revision, adaptation, and advances, and (e) subject to criteria of relevance, reliability, and quality.

L

Land degradation
Refers to the many processes that drive the decline or loss in biodiversity, ecosystem functions or services and includes the degradation of all terrestrial ecosystems.

Land sharing
A situation where low-yield farming enables biodiversity to be maintained within agricultural landscapes.

Land sparing
Land sparing, also called "land separation" involves restoring or creating non-farmland habitat in agricultural landscapes at the expense of field-level agricultural production - for example, woodland, natural grassland, wetland, and meadow on arable land. This approach does not necessarily imply high-yield farming of the non-restored, remaining agricultural land.

Land use
The human use of a specific area for a certain purpose (such as residential, agriculture, recreation, industrial, etc.). Influenced by, but not synonymous with, land cover. Land-use change refers to a change in the use or management of land by humans, which may lead to a change in land cover.

Land-use change
See "land use".

Landscape
An area of land that contains a mosaic of ecosystems, including human-dominated ecosystems.

Landscape configuration
The distribution, size and abundances of patch types represented within a landscape. Configuration is spatially explicit because it refers not only to the variety and abundance of patch types, but also to their placement or location (dispersion) in the landscape.

Leaching
The dissolution and movement of dissolved substances by water.

Living in harmony with nature
Within the context of the IPBES conceptual framework – a perspective on good quality of life based on the interdependence that exists among human beings, other living species and elements of nature. It implies that we should live peacefully alongside all

other organisms even though we may need to exploit other organisms to some degree.

M

Mainstreaming biodiversity
Mainstreaming, in the context of biodiversity, means integrating actions or policies related to biodiversity into broader development processes or policies such as those aimed at poverty reduction, or tackling climate change.

Mangrove
Group of trees and shrubs that live in the coastal intertidal zone. Mangrove forests only grow at tropical and subtropical latitudes near the equator because they cannot withstand freezing temperatures.

Meta-analysis
A quantitative statistical analysis of several separate but similar experiments or studies in order to test the pooled data for statistical significance.

Millennium Ecosystem Assessment
The Millennium Ecosystem Assessment is a major assessment of the human impact on the environment published in 2005.

Mitigation
In the context of IPBES, an intervention to reduce negative or unsustainable uses of biodiversity and ecosystems.

Models
Qualitative or quantitative representations of key components of a system and of relationships between these components. Benchmarking (of models) is the process of systematically comparing sets of model predictions against measured data in order to evaluate model performance. Validation (of models) typically refers to checking model outputs for consistency with observations. However, since models cannot be validated in the formal sense of the term (i.e. proven to be true), some scientists prefer to use the words "benchmarking" or "evaluation". A dynamic model is a model that describes changes through time of a specific process. A process-based model (also known as "mechanistic model") is a model in which relationships are described in terms of explicitly stated processes or mechanisms based on established scientific understanding, and model parameters therefore have clear ecological interpretation, defined beforehand. Hybrid models are models that combine correlative and process-based modelling approaches. A correlative model (also known as "statistical model") is a model in which available empirical data are used to estimate values for parameters that do not have predefined ecological meaning, and for which processes are implicit rather than explicit. Integrated assessment models are interdisciplinary models that aim to describe the complex relationships between environmental, social, and economic drivers that determine current and future state of the ecosystem and the effects of global change, in order to derive policy-relevant insights. One of the essential characteristics of integrated assessments is the simultaneous consideration of the multiple dimensions of environmental problems.

Monitoring
The repeated observation of a system in order to detect signs of change.

Monoculture
The agricultural practice of producing or growing a single crop, plant, or livestock species, variety, or breed in a field or farming system at a time.

Mosaic landscape
A pattern of landscapes with multiple patches and corridors.

Mother Earth
An expression used in a number of countries and regions to refer to the planet Earth and the entity that sustains all living things found in nature with which humans have an indivisible, interdependent physical and spiritual relationship (see "nature").

Multidisciplinary expert panel
The IPBES multidisciplinary expert panel is a subsidiary body established by the IPBES Plenary which oversees the scientific and technical functions of the Platform, a key role being to select experts to carry out assessments.

N

Native species
Indigenous species of animals or plants that naturally occur in a given region or ecosystem.

Natural capital
An economic metaphor for the limited stocks of physical and biological resources found on Earth.

Nature
In the context of IPBES, nature refers to the natural world with an emphasis on its living components. Within the context of Western science, it includes categories such as biodiversity, ecosystems (both structure and functioning), evolution, the biosphere, humankind's shared evolutionary heritage, and biocultural diversity. Within the context of other knowledge systems, it includes categories such as Mother Earth and systems of life, and it is often viewed as inextricably linked to humans, not as a separate entity (see "Mother Earth").

Nature's contributions to people (NCP)
Nature's contributions to people (NCP) are all the contributions, both positive and negative, of living nature (i.e. diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life of people. Beneficial contributions from nature include such things as food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include disease transmission and predation that damages people or their assets. Many NCP may be perceived as benefits or detriments depending on the cultural, temporal or spatial context.

Non-anthropocentric
A non-anthropocentric value is a value centred on something other than human beings. These values can be non-instrumental (e.g. a value ascribed to the existence of specific species for their own sake) or instrumental to non-human ends (e.g. the instrumental value a habitat has for the existence of a specific species).

Non-indigenous or non-native or alien species
See "invasive alien species".

O

Ocean acidification
See "acidification".

Organic agriculture
Any system that emphasises the use of techniques such as crop rotation, compost or manure application, and biological pest control in preference to synthetic inputs. Most certified organic farming schemes prohibit all genetically modified organisms and almost all synthetic inputs. Its origins are in a holistic management system that avoids off-farm inputs, but some organic

agriculture now uses relatively high levels of off-farm inputs.

Overexploitation
Harvesting species from the wild at rates faster than natural populations can recover. Includes overfishing, and overgrazing.

P

Participatory mapping
A key method that many indigenous communities apply in order to collect data, information and monitoring and to use it in science- policy- society interface processes.

Participatory scenario development (and planning)
Approaches characterized by more interactive, and inclusive, involvement of stakeholders in the formulation and evaluation of scenarios. Aimed at improving the transparency and relevance of decision-making, by incorporating demands and information of each stakeholder, and negotiating outcomes between stakeholders.

Particulate and gaseous pollutants
Air pollutants such as ozone, nitrogen oxides and ammonia.

Particulate matter
A mixture of solid particles (dust, dirt, soot, or smoke) and liquid droplets.

Pastoralism
Extensive livestock production in rangelands.

Peatlands
Wetlands which accumulate organic plant matter in situ because waterlogging prevents aerobic decomposition and the much slower rate of the resulting anaerobic decay is exceeded by the rate of accumulation.

Pelagic
Organisms that live in the water column.

Perennial
See “annual”.

Permafrost
Perennially frozen ground that occurs wherever the temperature remains below 0°C for several years.

Phytophilia
The positive effect of green vegetation in landscapes on human beings.

Plankton
Typically microscopic aquatic organisms that drift or swim weakly. Phytoplankton are the plant forms of plankton (e.g., diatoms), and are the dominant plants in the sea. Zooplankton are the animal forms of plankton.

Plenary
Within the context of IPBES – the decision-making body comprising all of the members of IPBES.

Policy instrument
Set of means or mechanisms to achieve a policy goal.

Policy mix
A combination of policy instruments which has evolved to influence the quantity and quality of biodiversity conservation and ecosystem service provision in public and private sectors.

Policy support tools
Approaches and techniques based on science and other knowledge systems that can inform, assist and enhance relevant decisions, policymaking and implementation at local, national, regional and global levels to protect nature, thereby promoting nature’s benefits to people and a good quality of life.

Policy/policy tools
Instruments used by governance bodies at all scales to implement their policies. Environmental policies, for example, could be implemented through tools such as legislation, economic incentives or dis-incentives, including taxes and tax exemptions, or tradable permits and fees.

Polycentric governance
An organizational structure where multiple independent actors mutually order their relationships with one another under a general system of rules.

Poverty
A state of economic deprivation. Its manifestations include hunger and malnutrition, limited access to education and other basic services. Other corollaries of poverty are social discrimination and exclusion as well as the lack of participation in decision-making.

Precautionary principle
Pertains to risk management and states that if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is not harmful, the burden of proof that it is not harmful falls on those taking an action. The principle is used to justify discretionary decisions when the possibility of harm from making a certain decision (e.g., taking a particular course of action) is not, or has not been, established through extensive scientific knowledge. The principle implies that there is a social responsibility to protect the public from exposure to harm, when scientific investigation has found a plausible risk or if a potential plausible risk has been identified.

Process-based model
See “models”.

Protected area
A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.

R

Ramsar site(s)
A Ramsar site is a wetland site designated of international importance especially as Waterfowl Habitat under the Ramsar Convention, an intergovernmental environment treaty established in 1975 by UNESCO, coming into force in 1975. Ramsar site refers to wetland of international significance in terms of ecology, botany, zoology, limnology or hydrology. Such a site meets at least one of the criteria of identifying wetlands of international importance set by Ramsar Convention and is designated by appropriate national authority to be added to Ramsar list.

Rangeland
Natural grasslands used for livestock grazing.

REDD+
Reducing emissions from deforestation and forest degradation (REDD+) is a mechanism developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It creates a financial value for the carbon stored in forests by offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. Developing countries would

receive results-based payments for results-based actions. REDD+ goes beyond simply deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

Regime shift(s)
Substantial reorganization in system structure, functions and feedbacks that often occurs abruptly and persists over time.

Rehabilitation
Restoration activities that move a site towards a natural state baseline in a limited number of components (i.e. soil, water, and/or biodiversity), including natural regeneration, conservation agriculture, and emergent ecosystems.

Relational value
See "values".

Remediation
Any action taken to rehabilitate ecosystems.

Resilience
The level of disturbance that an ecosystem or society can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on factors such as ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.

Resolution (spatial or temporal)
See "scale".

Restoration
Any intentional activities that initiates or accelerates the recovery of an ecosystem from a degraded state.

Richness
The number of biological entities (species, genotypes, etc.) within a given sample. Sometimes used as synonym of species diversity.

Rights-based instruments and customary norms
Synergizing rights and norms for the conservation and protection of systems of Mother Earth can foster complementarity with human well-being. International and national human rights instruments whether binding or non-binding can be creatively interpreted to fit socio-ecological systems and foster resilience. Strengthening of collective rights, customary norms and institutions of indigenous peoples and local communities, can promote adaptive governance including the equitable and fair management of natural resources.

S

Salinization
The process of increasing the salt content in soil is known as salinization. Salinization can be caused by natural processes such as mineral weathering or by the gradual withdrawal of an ocean. It can also come about through artificial processes such as irrigation.

Savanna
Ecosystem characterized by a continuous layer of herbaceous plants, mostly grasses, and a discontinuous upper layer of trees that may vary in density.

Scale
The spatial, temporal, quantitative and analytical dimensions used to measure and study any phenomenon. The temporal scale is comprised of two properties: 1) temporal extent – the total length of the time period of interest for a particular study (e.g. 10 years, 50 years, or 100 years); and 2) temporal grain (or resolution) – the temporal frequency with which data are observed or projected within this total period (e.g. at 1-year, 5-year or 10-year intervals). The spatial scale is comprised of two properties: 1) spatial extent – the size of the total area of interest for a particular study (e.g. a watershed, a country, the entire planet); and 2) spatial grain (or resolution) – the size of the spatial units within this total area for which data are observed or predicted (e.g. fine-grained or coarse-grained grid cells).

Scenarios
Representations of possible futures for one or more components of a system, particularly for drivers of change in nature and nature's contributions, including alternative policy or management options.

Seascape(s)
Seascape can be defined as a spatially heterogeneous area of coastal environment (i.e. intertidal, brackish) that can be perceived as a mosaic of patches, a spatial gradient, or some other geometric patterning. The tropical coastal "seascape" often includes a patchwork of mangroves, seagrass beds, and coral reefs that produces a variety of natural resources and ecosystem services.

Sector
A distinct part of society, or of a nation's economy.

Semi-natural habitat(s)
An ecosystem with most of its processes and biodiversity intact, though altered by human activity in strength or abundance relative to the natural state.

Socioecological system
An ecosystem, the management of this ecosystem by actors and organizations, and the rules, social norms, and conventions underlying this management.

Soil compaction
Defined as an increase in density and a decline of porosity in a soil that impedes root penetration and movements of water and gases.

Soil degradation
The diminishing capacity of the soil to provide ecosystem goods and services as desired by its stakeholders.

Soil organic matter
Matter consisting of plant and/or animal organic materials, and the conversion products of those materials in soils.

Soil quality
Soil quality is a measure of the soil's ability to provide ecosystem and social services through its capacities to perform its functions under changing conditions. Soil quality reflects how well a soil performs the functions of maintaining biodiversity and productivity, partitioning water and solute flow, filtering and buffering, nutrient cycling, and providing support for plants and other structures.

Species
An interbreeding group of organisms that is reproductively isolated from all other organisms, although there are many partial exceptions to this rule in particular taxa. Operationally, the term species is a generally agreed fundamental taxonomic unit, based on morphological or genetic similarity, that once described and accepted is associated with a unique scientific name.

Species composition
The array of species in a specific sample, community, or area.

Species distribution mode
Species distribution models relate field observations of the presence/absence of a species to environmental predictor variables, based on statistically or theoretically derived response surfaces, for prediction and inference. The predictor variables are often climatic but can include other environmental variables.

Species richness
The number of species within a given sample, community, or area.

Stakeholders
Any individuals, groups or organizations who affect, or could be affected (whether positively or negatively) by a particular issue and its associated policies, decisions and action.

Storylines (or scenario storylines)
Qualitative narratives which provide the descriptive framework from which quantitative exploratory scenarios can be formulated.

Summary for policymakers
Is a component of any report, providing a policy-relevant but not policy prescriptive summary of that report.

Sustainability
A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

Sustainable Development Goals (SDGs)
A set of goals adopted by the United Nations in 2015 to end poverty, protect the planet, and ensure prosperity for all, as part of the 2030 Agenda for Sustainable Development.

Sustainable use (of biodiversity and its components)
The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

Synergies
See “trade-off”.

T

Taxon
A category applied to a group in a formal system of nomenclature, e.g., species, genus, family etc. (plural: taxa).

Telecoupling
Refers to socioeconomic and environmental interactions over distances. It involves distant exchanges of information, energy and matter (e.g., people, goods, products, capital) at multiple spatial, temporal and organizational scales.

Threatened species
In the IUCN Red List terminology, a threatened species is any species listed in the Red List categories, critically endangered, endangered, or vulnerable.

Tipping point
A set of conditions of an ecological or social system where further perturbation will cause rapid change and prevent the system from returning to its former state.

Trade-off
A trade-off is a situation where an improvement in the status of one aspect of the environment or of human well-being is necessarily associated with a decline in or loss of a different aspect. Trade-offs characterize most complex systems, and are important to consider when making decisions that aim to improve environmental and/or socio-economic outcomes. Trade-offs are distinct from synergies (the latter are also referred to as “win-win” scenarios): synergies arise when the enhancement of one desirable outcome leads to enhancement of another.

Transformation
A change in the fundamental attributes of natural and human systems that reflect strengthened, altered, or aligned paradigms, goals, or values towards promoting adaptation that supports sustainable development, including poverty reduction.

Transhumance
Form of pastoralism or nomadism organized around the migration of livestock between mountain pastures in warm seasons and lower altitudes the rest of the year. The seasonal migration may also occur between lower and upper latitudes. A traditional farming practice based on indigenous and local knowledge.

Transitional pathways
A course of actions and strategies that aim to achieve the vision. They are closely related to “policy or target-seeking scenarios”.

Trophic cascades
The chain of knock - on extinctions observed or predicted to occur following the loss of one or a few species that play a critical role (e.g. as a pollinator) in ecosystem functioning.

Trophic level
The level in the food chain in which one group of organisms serves as a source of nutrition for another group of organisms (e.g. primary producers, primary or secondary consumers, decomposers).

U

Units of analysis
Units of analysis result from subdividing the Earth’s surface into units solely for the purposes of analysis. The terrestrial and aquatic units of analysis serve as a framework for comparison within and across IPBES assessments and represent a pragmatic solution. The terrestrial and aquatic units of analysis used by IPBES are not intended to be prescriptive for purposes other than those of IPBES assessments. They are likely to evolve as the work of IPBES develops.

V

Values
- Value systems: Set of values according to which people, societies and organizations regulate their behaviour. Value systems can be identified in both individuals and social groups.
- Value (as principle): A value can be a principle or core belief underpinning rules and moral judgments. Values as principles vary from one culture to another and also between individuals and groups.
- Value (as preference): A value can be the preference someone has for something or for a particular state of the world. Preference involves the act of making comparisons, either explicitly or implicitly. Preference refers to the importance attributed to one entity relative to another one.
- Value (as importance): A value can be the importance of something for itself or for others, now or in the future, close by or at a distance. This importance can be considered in three broad classes.
  1. The importance that something has

subjectively, and may be based on experience. 2. The importance that something has in meeting objective needs. 3. The intrinsic value of something.
- Value (as measure): A value can be a measure. In the biophysical sciences, any quantified measure can be seen as a value.
- Non-anthropocentric value: A non-anthropocentric value is a value centred on something other than human beings. These values can be non-instrumental or instrumental to non-human ends.
- Intrinsic value: The value inherent to nature, independent of human experience and evaluation, and therefore beyond the scope of anthropocentric valuation approaches.
- Anthropocentric value: Human-centred, the value that something has for human beings and human purposes.
- Instrumental value: The direct and indirect contribution of nature's benefits to the achievement of a good quality of life. Within the specific framework of the total economic value, instrumental values can be classified into use (direct and indirect use values) on the one hand, and non-use values (option, bequest and existence values) on the other. Sometimes option values are considered as use values as well.
- Non-instrumental value: The value attributed to something as an end in itself, regardless of its utility for other ends.
- Relational value: The values that contribute to desirable relationships, such as those among people and between people and nature, as in "living in harmony with nature".
- Integrated valuation: The process of collecting, synthesizing, and communicating knowledge about the ways in which people ascribe importance and meaning of nature's contributions, to facilitate deliberation and agreement for decision-making and planning.

Vision
A desirable future (an endpoint in time) which we want to achieve. Visions usually consist of statements depicting the explicit desires, assumptions, beliefs and paradigms that underlie the desired future.

W

Water security
The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.

Water stress
Water stress occurs in an organism when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use.

Well-being
A perspective on a good life that comprises access to basic resources, freedom and choice, health and physical well-being, good social relationships, security, peace of mind and spiritual experience. Well-being is achieved when individuals and communities can act meaningfully to pursue their goals and can enjoy a good quality of life. The concept of human well-being is used in many Western societies and its variants, together with living in harmony with nature, and living well in balance and harmony with Mother Earth. All these are different perspectives on a good quality of life.

Western science
Also called modern science, Western scientific knowledge or international science, and used in the context of the IPBES conceptual framework as a broad term to refer to knowledge typically generated in universities, research institutions and private firms following paradigms and methods typically associated with the "scientific method" consolidated in Post-Renaissance Europe on the basis of wider and more ancient roots. It is typically transmitted through scientific journals and scholarly books. Some of its central tenets are observer independence, replicable findings, systematic scepticism, and transparent research methodologies with standard units and categories.

Wetlands
Areas that are subject to inundation or soil saturation at a frequency and duration, such that the plant communities present are dominated by species adapted to growing in saturated soil conditions, and/or that the soils of the area are chemically and physically modified due to saturation and indicate a lack of oxygen; such areas are frequently termed peatlands, marshes, swamps, sloughs, fens, bogs, wet meadows, etc.

Worldviews
Defined by the connections between networks of concepts and systems of knowledge, values, norms and beliefs. Individual person's worldviews are moulded by the community the person belongs to. Practices are embedded in worldviews and are intrinsically part of them (e.g. through rituals, institutional regimes, social organization, but also in environmental policies, in development choices, etc.).

ANNEX II

Acronyms

ABTs	Aichi Biodiversity Targets
AR	Assessment Report (specifically in the context of the Intergovernmental Panel on Climate Change)
BPA	Bisphenol A; Biodiversity Promotion Areas
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMIP	Coupled Model Intercomparison Project Phase
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COP	Conference of the Parties / Conference of the Contracting Parties
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
ECA	Europe and Central Asia
ECOLEX	A partnership of three organizations compiling environmental, (ECO), law (LEX) related information
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization (of the United Nations)
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Ha	Hectare(s)
HELCOM	Helsinki Commission
HWSD	Harmonized World Soil Database
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions Programme
ILK	Indigenous and Local Knowledge
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LRTAP	Long-range Transboundary Air Pollution (Convention)
MEA	Millennium Ecosystem Assessment
MPA	Marine Protected Area
NASA	National Aeronautics and Space Administration
NBSAP	National Biodiversity Strategy and Action Plan
NCP	Nature's Contributions to People
NEC Directive	National Emissions Ceiling Directive
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
OPERAs	OPerationalising Ecosystem Research Applications
OSPAR	Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
PAHs	Polycyclic Aromatic Hydrocarbons
PBT	Polybutylene Terephthalate
PCB	Polychrorinated Byphenil
POP	Persistent Organic Pollutant
RCP	Representative Concentration Pathway
RED	Renewable Energy Directive
REDD+	Reducing Emissions from Deforestation and Degradation
SDG	Sustainable Development Goal
SRES	Special Report on Emissions Scenarios
SSP	Shared Socioeconomic Pathways
TEEB	The Economics of Ecosystems and Biodiversity
TgC	Teragrams of Carbon
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme (now also known as UN Environment)
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USLE	Universal Soil Loss Equation
USSR	Union of Soviet Socialist Republics
WFD	Water Framework Directive
WG	Working Group
WHO	World Health Organization
WTO	World Trade Organization
WWF	World Wide Fund for Nature

ANNEX III

List of authors and review editors

Fischer, Markus
Chair
University of Bern,
Switzerland

Rounsevell, Mark
Chair
University of Edinburgh/Karlsruhe Institute of Technology,
United Kingdom of Great Britain and Northern Ireland/Germany

Chapter 1

Rounsevell, Mark
Coordinating Lead Author
University of Edinburgh/Karlsruhe Institute of Technology,
United Kingdom of Great Britain and Northern Ireland/Germany

Fischer, Markus
Coordinating Lead Author
University of Bern,
Switzerland

Jacobs, Sander
Lead Author
Research Institute for Nature and Forest INBO,
Belgium

Liekens, Inge
Lead Author
VITO,
Belgium

Marques, Alexandra
Lead Author
German Centre for Integrative Biodiversity Research (iDiv),
Germany

Molnár, Zsolt
Lead Author
Centre for Ecological Research, Hungarian Academy of Sciences,
Hungary

Osuchova, Jana
Lead Author
Global Change Research Centre,
Czech Republic

Shkaruba, Anton
Lead Author
Central European University/NGO "Ekapraekt",
Belarus/Hungary

Whittingham, Mark
Lead Author
Newcastle University,
United Kingdom of Great Britain and Northern Ireland

Zlinszky, András
Lead Author
Centre for Ecological Research, Hungarian Academy of Sciences,
Hungary

Boeraeve, Fanny
Fellow
Gembloux Agro Bio-Tech, University of Liege,
Belgium

Brucet, Sandra
Contributing Author
University of Vic/Catalan Institution for Research and Advanced Studies (ICREA),
Spain

Davletova, Sholpan
Contributing Author
Kazakhstan

Eggermont, Hilde
Contributing Author
Belgian Biodiversity Platform,
Belgium

Fürst, Christine
Contributing Author
Martin Luther-University Halle,
Germany

Grainger, Matthew
Contributing Author
School of Natural & Environmental Sciences, Newcastle University,
United Kingdom of Great Britain and Northern Ireland

Jetz, Walter
Contributing Author
Ecology and Evolutionary Biology, Yale University,
United States of America

Leroy, Boris
Contributing Author
Muséum National d'Histoire Naturelle,
France

Lipka, Oksana
Contributing Author
WWF Russia,
Russian Federation

Lucy, Frances
Contributing Author
Institute of Technology, Sligo,
Ireland

Schlaepfer, Martin
Contributing Author
University of Geneva,
Switzerland

Snethlage, Mark
Contributing Author
University of Bern,
Switzerland

Sousa Pinto, Isabel
Contributing Author
CIIMAR, University of Porto,
Portugal

Viard, Frédérique
Contributing Author
Centre National de la Recherche Scientifique (CNRS),
France

Whitehorn, Penelope
Contributing Author
Karlsruhe Institute of Technology (KIT),
Germany

Wilson, Meriwether
Contributing Author
University of Edinburgh,
United Kingdom of Great Britain and
Northern Ireland

Hilding-Rydevik, Tuija
Review Editor
Swedish Biodiversity Center, Swedish
University of Agricultural Sciences and
Uppsala University,
Sweden

Podmaniczky, László
Review Editor
Szent István University,
Hungary

Chapter 2

Martín López, Berta
Coordinating Lead Author
Leuphana University Lüneburg,
Germany

Church, Andrew
Coordinating Lead Author
University of Brighton,
United Kingdom of Great Britain and
Northern Ireland

Başak Dessane, Esra
Lead Author
Project House Cooperative,
Turkey

Berry, Pam
Lead Author
University of Oxford,
United Kingdom of Great Britain and
Northern Ireland

Chenu, Claire
Lead Author
AgroParisTech,
France

Christie, Mike
Lead Author
Aberystwyth University,
United Kingdom of Great Britain and
Northern Ireland

Gerino, Magali
Lead Author
Université P. Sabatier - Toulouse 3,
France

Keune, Hans
Lead Author
Research Institute for Nature and Forest
INBO,
Belgium

Oteros Rozas, Elisa
Lead Author
University Pablo de Olavide,
Spain

Paillard, Sandrine
Lead Author
Future Earth Secretariat,
France

Rossberg, Axel G.
Lead Author
Queen Mary University of London/Centre
for Environment, Fisheries and Aquaculture
Science,
United Kingdom of Great Britain and
Northern Ireland

Schröter, Matthias
Lead Author
Helmholtz Centre for Environmental
Research – UFZ/German Centre for
Integrative Biodiversity Research (iDiv) Halle-
Jena-Leipzig,
Germany

van Oudenhoven, Alexander P.E.
Lead Author
Leiden University,
The Netherlands

Osipova, Elena
Fellow
International Union for Conservation of
Nature (IUCN), World Heritage Programme,
Switzerland

Aloe Karabulut, Armağan
Contributing Author
Ministry of Food Agriculture and Livestock,
Ankara,
Turkey

Avcıoğlu Çokçalışkan, Başak
Contributing Author
The Research Association of Rural
Environment and Forestry, Ankara,
Turkey

Bilgin, Adem
Contributing Author
Turkish Ministry of Forestry and Water
Affairs,
Turkey

Breeze, Tom
Contributing Author
School of Agriculture, Policy and
Development, University of Reading,
United Kingdom of Great Britain and
Northern Ireland

Bukvareva, Elena
Contributing Author
Biodiversity Conservation Center, Moscow,
Russian Federation

Duez, Pierre
Contributing Author
Unit of Therapeutic Chemistry and
Pharmacognosy, University of Mons
(UMONS),
Belgium

Faith, Daniel P.
Contributing Author
The Australian Museum,
Australia

Geijzendorffer, Ilse
Contributing Author
Tour du Valat, Research Institute for the
conservation of Mediterranean Wetlands,
France

Gosal, Arjan
Contributing Author
University of Leeds,
United Kingdom of Great Britain and
Northern Ireland

Haider, L. Jamila
Contributing Author
Stockholm Resilience Centre, Stockholm
University,
Sweden

Kretsch, Conor
Contributing Author
Co-Operation On Health And Biodiversity,
United Kingdom of Great Britain and
Northern Ireland

Lozano, Jorge
Contributing Author
Leuphana University of Lüneburg,
Germany

Meire, Patrick
Contributing Author
Ecosystem Management Research Group (ECOBE), University of Antwerp,
Belgium

Mena Sauterel, Jasmin
Contributing Author
Leuphana University Lüneburg,
Germany

Meyer, Markus
Contributing Author
Research Group on Agricultural and Regional Development Triesdorf,
Germany

Moleón, Marcos
Contributing Author
Department of Zoology, University of Granada,
Spain

Morales-Reyes, Zebensui
Contributing Author
Department of Applied Biology, Miguel Hernández University,
Spain

Oosterbroek, Bram
Contributing Author
International Centre for Integrated Assessment and Sustainable Development, Maastricht University,
The Netherlands

Potts, Simon G.
Contributing Author
School of Agriculture, Policy and Development, University of Reading,
United Kingdom of Great Britain and Northern Ireland

Povilaityte-Petri, Vitalija
Contributing Author
Unit of Therapeutic Chemistry and Pharmacognosy, University of Mons (UMONS),
Belgium

Ruiz Almeida, Adriana
Contributing Author
Sustainability Measurement and Modeling Lab (SUMMLab), Polytechnic University of Catalonia,
Spain

Sánchez-Zapata, José A.
Contributing Author
Department of Applied Biology, University Miguel Hernández,
Spain

Sievers-Glotzbach, Stefanie
Contributing Author
Department of Business Administration, Economics and Law, University of Oldenburg,
Germany

Siwicka, Ewa
Contributing Author
Aberystwyth University,
United Kingdom of Great Britain and Northern Ireland

Sorokin, Alexey
Contributing Author
Lomonosov Moscow State University,
Russian Federation

Sousa Pinto, Isabel
Contributing Author
CIIMAR, University of Porto,
Portugal

Stange, Erik
Contributing Author
Norwegian Institute for Nature Research (NINA),
Norway

Szymonczk, Pawel
Contributing Author
Aberystwyth University,
United Kingdom of Great Britain and Northern Ireland

Vugdelic, Marija
Contributing Author
University of Donja Gorica,
Montenegro

Turkelboom, Francis
Review Editor
Research Institute for Nature and Forest INBO,
Belgium

Urbanc, Mimi
Review Editor
Research Centre of the Slovenian Academy of Sciences and Arts,
Slovenia

Chapter 3

Visconti, Piero
Coordinating Lead Author
University College London/Zoological Society of London,
United Kingdom of Great Britain and Northern Ireland

Elias, Victoria
Coordinating Lead Author
WWF Russia,
Russian Federation

Sousa Pinto, Isabel
Coordinating Lead Author
CIIMAR, University of Porto,
Portugal

Fischer, Markus
Coordinating Lead Author
University of Bern,
Switzerland

Ali-Zade, Valida
Lead Author
Azerbaijan National Academy of Sciences,
Azerbaijan

Báldi, András
Lead Author
Centre for Ecological Research, Hungarian Academy of Sciences,
Hungary

Brucet, Sandra
Lead Author
University of Vic/Catalan Institution for Research and Advanced Studies (ICREA),
Spain

Bukvareva, Elena
Lead Author
Biodiversity Conservation Center, Moscow,
Russian Federation

Byrne, Kenneth
Lead Author
University of Limerick,
Ireland

Caplat, Paul
Lead Author
Lund University,
Sweden

Feest, Alan
Lead Author
University of Bristol/Ecosulis,
United Kingdom of Great Britain and
Northern Ireland

Gozlan, Rodolphe
Lead Author
Institut de Recherche pour le
Développement,
France

Jelić, Dušan
Lead Author
Croatian Herpetological Society,
Croatia

Kikvidze, Zaal
Lead Author
Institute of Ecology, Ilia State University,
Georgia

Lavrillier, Alexandra
Lead Author
University of Versailles-Saint-Quentin
(OVSQ, UVSQ),
France

Le Roux, Xavier
Lead Author
National Institute of Agronomic Research
(INRA),
France

Lipka, Oksana
Lead Author
WWF Russia,
Russian Federation

Petřík, Petr
Lead Author
The Czech Academy of Sciences, Institute
of Botany,
Czech Republic

Schatz, Bertrand
Lead Author
Centre of Evolutionary and Functional
Ecology (CEFE, CNRS),
France

Smelansky, Ilya
Lead Author
NGO SibEcoCenter,
Russian Federation

Viard, Frédérique
Lead Author
Centre National de la Recherche Scientifique
(CNRS),
France

Guerra, Carlos
Fellow
German Centre for Integrative Biodiversity
Research (iDiv),
Germany

Anker, Yaakov
Contributing Author
Ariel University the Department of Chemical
Engineering (Biotechnology & Materials) and
the Eastern R&D Center, Department of
Environmental Research,
Israel

Bellard, Céline
Contributing Author
Unité Biologie des organismes et
écosystèmes aquatiques, Muséum National
d'Histoire Naturelle, Sorbonne Universités,
Université Pierre et Marie Curie, Université
de Caen Normandie, Université des Antilles,
France

Boch, Steffen
Contributing Author
University of Bern/Swiss Federal Research
Institute WSL Birmensdorf,
Switzerland

Böhm, Monika
Contributing Author
Institute of Zoology, Zoological Society of
London,
United Kingdom of Great Britain and
Northern Ireland

Dahlberg, Anders
Contributing Author
Swedish University of Agricultural Sciences/
Department of Forest Mycology and Plant
Pathology,
Sweden

Dobrolyubova, Ksenia
Contributing Author
Institute of Geology, Russian Academy of
Science,
Russian Federation

Ekroos, Johan
Contributing Author
Centre for Environmental and Climate
Research, Lund University,
Sweden

Faith, Daniel P.
Contributing Author
The Australian Museum,
Australia

Feldman, Anat
Contributing Author
Tel Aviv University,
Israel

Galil, Bella
Contributing Author
The Steinhardt Museum of Natural History,
Tel Aviv University,
Israel

García Criado, Mariana
Contributing Author
International Union for Conservation of
Nature (IUCN),
Belgium

Geltman, Dmitry
Contributing Author
Komarov Botanical Institute of the Russian
Academy of Sciences, St Peterburg,
Russian Federation

Guisan, Antoine
Contributing Author
University of Lausanne,
Switzerland

Joosten, Hans
Contributing Author
Greifswald Mire Centre/Greifswald University,
Germany

Karimov, Bakhtiyor
Contributing Author
Department of Ecology and Water
Resources Management, Tashkent institute
of irrigation and agricultural mechanization
engineers,
Uzbekistan

Korotenko, Vladimir
Contributing Author
Kyrgyz National University of name
Balasagin/Ecological Movement "BIOM",
Kyrgyzstan

Kotta, Jonne
Contributing Author
Estonian Marine Institute, University of Tartu,
Estonia

Kreuzberg, Elena
Contributing Author
Holarctic Bridges Pvt.,
Canada

Krylenko, Marina
Contributing Author
Russian Federation, Shirshov Institute of Oceanology RAS, Southern Branch,
Russian Federation

Kurokhtin, Aleksei
Contributing Author
Bishkek Financial and Economic Academy/ Ecological Movement "BIOM",
Kyrgyzstan

Kuznetsova, Daria
Contributing Author
Russian Federation

Leroy, Boris
Contributing Author
Muséum National d'Histoire Naturelle,
France

Lukić Bilela, Lada
Contributing Author
Faculty of Science, University of Sarajevo,
Bosnia and Herzegovina

Meiri, Shai
Contributing Author
Tel Aviv University,
Israel

Minayeva, Tatiana
Contributing Author
Care for Ecosystems,
Germany

Molau, Ulf
Contributing Author
University of Gothenburg,
Sweden

Morato, Telmo
Contributing Author
IMAR/OKEANOS/MARE,
Departamento de Oceanografia e Pescas,
Universidade dos Açores, Horta,
Portugal

Nakhutsrishvili, George
Contributing Author
Institute of Botany Ilia State University,
Georgia

Nieto, Ana
Contributing Author
International Union for Conservation of Nature (IUCN),
Belgium

Nikitina, Oxana
Contributing Author
WWF Russia,
Russian Federation

Novitsky, Ruslan
Contributing Author
National Academy of Science of Belarus,
Belarus

Nurkse, Kristiina
Contributing Author
Estonian Marine Institute, University of Tartu,
Estonia

Pérez-Ruzafa, Angel
Contributing Author
University of Murcia,
Spain

Raab, Kristina
Contributing Author
Helmholtz Centre for Environmental Research, UFZ,
Germany

Roll, Uri
Contributing Author
Ben Gurion University,
Israel

Rossberg, Axel G.
Contributing Author
Queen Mary University of London/Centre for Environment, Fisheries and Aquaculture Science,
United Kingdom of Great Britain and Northern Ireland

Selimov, Resad
Contributing Author
Institute of Botany Azerbaijan National Academy of Sciences,
Azerbaijan

Shukurov, Emil
Contributing Author
Ecological Movement of Kyrgyzstan "Aleyne +",
Kyrgyzstan

Sirin, Andrey
Contributing Author
Institute of Forest Science, Russian Academy of Sciences,
Russian Feederation

Smith, Henrik G.
Contributing Author
Centre for Environmental and Climate research & Department Biology, Lund University,
Sweden

Snethlage, Mark
Contributing Author
University of Bern,
Switzerland

Solovyev, Boris
Contributing Author
A.N. Severtsov Institute of Ecology and Evolution Russian Academy of Sciences,
Russian Federation

Svetasheva, Tatyana
Contributing Author
Komarov Botanical Institute, St-Petersburg, Tula State Lev Tolstoy Pedagogical University,
Russian Federation

Tanneberger, Franziska
Contributing Author
Greifswald Mire Centre/Greifswald University/Michael Succow Foundation,
Germany

Thuiller, Wilfried
Contributing Author
CNRS-University of Grenoble Alpes,
France

Tuniyev, Boris
Contributing Author
Sochi National Park,
Russian Federation

van der Plas, Fons
Contributing Author
Department of Systematic Botany and Functional Biodiversity, University of Leipzig,
Germany

Vandvik, Vigdis
Contributing Author
University of Bergen,
Norway

Venn, Stephen
Contributing Author
Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, University of Helsinki/Department of Architecture, Aalto University/Kone Foundation,
Finland

Vershinin, Vladimir
Contributing Author
Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences (Yekaterinburg)/Ural Federal University, Russian Federation

Winter, Marten
Contributing Author
German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Germany

Zadereev, Egor
Contributing Author
Institute of Biophysics, Krasnoyarsk Research Center, Siberian Branch of Russian Academy of Science, Russian Federation

Zazanashvili, Nugzar
Contributing Author
WWF Caucasus Programme Office, Georgia

Brūmelis, Guntis
Review Editor
Faculty of Biology, University of Latvia, Latvia

Troumbis, Andreas
Review Editor
University of the Aegean, Greece

Chapter 4

Elbakidze, Marine
Coordinating Lead Author
Swedish University of Agricultural Sciences, Sweden

Hahn, Thomas
Coordinating Lead Author
Stockholm University, Stockholm Resilience Centre, Sweden

Niklaus E. Zimmerman
Coordinating Lead Author
Swiss Federal Research Institute WSL, Switzerland

Cudlín, Pavel
Lead Author
Global Change Research Centre CAS, Czech Republic

Friberg, Nikolai
Lead Author
Norwegian Institute for Water Research, Norway

Genovesi, Piero
Lead Author
Institute for Environmental Protection and Research (ISPRA), Italy

Guarino, Riccardo
Lead Author
University of Palermo, Italy

Helm, Aveliina
Lead Author
University of Tartu, Estonia

Jonsson, Bengt-Gunnar
Lead Author
Society for Conservation Biology/Mid Sweden University, Sweden

Lengyel, Szabolcs
Lead Author
Hungarian Academy of Sciences, Centre for Ecological Research, Hungary

Leroy, Boris
Lead Author
Muséum National d'Histoire Naturelle, France

Luzzati, Tommaso
Lead Author
University of Pisa, Italy

Milbau, Ann
Lead Author
Research Institute for Nature and Forest INBO, Belgium

Pérez-Ruzafa, Ángel
Lead Author
University of Murcia, Spain

Roche, Philip
Lead Author
Research Institute on Science and Technology for Agriculture and Environment (IRSTEA), France

Roy, Helen
Lead Author
Centre for Ecology & Hydrology (CEH), United Kingdom of Great Britain and Northern Ireland

Vanbergen, Adam
Lead Author
Centre for Ecology & Hydrology (CEH), United Kingdom of Great Britain and Northern Ireland

Vandvik, Vigdis
Lead Author
University of Bergen, Norway

Sabyrbekov, Rahat
Fellow
American University of Central Asia, Kyrgyzstan

Dawson, Lucas
Contributing Author
Department of Physical Geography, Stockholm University, Sweden

Andersen, Jesper H.
Contributing Author
NIVA Denmark Water Research, Denmark

Andreev, Alexei
Contributing Author
Institute of Zoology of Academy Sciences of Moldova and BIOTIICA Ecological Society, Republic of Moldova

Angelstam, Per
Contributing Author
School for Forest Management, Faculty of Forest Sciences, Sweden

Ayata, Sakina-Dorothée
Contributing Author
Sorbonne Université, CNRS, Laboratoire d'Océanographie de Villefanche, France

Azam, Clémentine
Contributing Author
Center for Ecology and Conservation Science, Muséum National d'Histoire Naturelle,
France

Beaugrand, Grégory
Contributing Author
Centre National de la Recherche Scientifique, Laboratoire d'Océanologie et de Géosciences,
France

Begeja, Fjoralba
Contributing Author
Institute for Nature Conservation in Albania,
Albania

Bellard, Céline
Contributing Author
Unité Biologie des organismes et écosystèmes aquatiques, Muséum National d'Histoire Naturelle, Sorbonne Universités, Université Pierre et Marie Curie, Université de Caen Normandie, Université des Antilles,
France

Conrad, Elisabeth
Contributing Author
Institute of Earth Systems, University of Malta,
Malta

Cotté, Cédric
Contributing Author
Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN-IPSL), Muséum National d'Histoire Naturelle,
France

Dubos, Nicolas
Contributing Author
Muséum National d'Histoire Naturelle,
France

Elias, Victoria
Contributing Author
WWF Russia,
Russian Federation

Eycott, Amy Elizabeth
Contributing Author
Department of Biology, University of Bergen,
Norway

Forsius, Martin
Contributing Author
Finnish Environment Institute (SYKE),
Finland

Frances, Lucy
Contributing Author
Institute of Technology, Sligo,
Ireland

Galil, Bella
Contributing Author
The Steinhardt Museum of Natural History, Tel Aviv University,
Israel

García Criado, Mariana
Contributing Author
International Union for Conservation of Nature (IUCN),
Belgium

Herrmann, Marine
Contributing Author
LEGOS, IRD/CNRS/CNES/Universite de Toulouse and University of Sciences and Technology of Hanoi (USTH),
France/Vietnam

Irvine, R. Justine
Contributing Author
The James Hutton Institute,
United Kingdom of Great Britain and Northern Ireland

Kallbekken, Steffen
Contributing Author
CICERO Center for International Climate Research,
Norway

Kobyakov, Konstantin
Contributing Author
WWF Russia,
Russian Federation

Kulenbekov, Zheenbek
Contributing Author
Department of Environmental Management & Sustainable Development, American University of Central Asia,
Kyrgyzstan

Lewis, Edward
Contributing Author
UN Environment World Conservation Monitoring Centre,
United Kingdom of Great Britain and Northern Ireland

Lyche Solheim, Anne
Contributing Author
Norwegian Institute for Water Research (NIVA),
Norway

Malmaeus, Mikael
Contributing Author
IVL Swedish Environmental Research Institute,
Sweden

Marcos, Concepción
Contributing Author
Departamento de Ecología e Hidrología, Facultad de Biología, Campus de excelencia internacional Mare Nostrum, Universidad de Murcia,
Spain

Minchin, Dan
Contributing Author
Klaipeda University,
Lithuania

Molnár, Zsolt
Contributing Author
Centre for Ecological Research, Hungarian Academy of Sciences,
Hungary

Mulder, Jan
Contributing Author
Norwegian University of Life Sciences,
Norway

Murashko, Olga
Contributing Author
The Research Institute and the Anthropology Museum of Moscow State University, Center for Assistance to Indigenous Minorities of the North,
Russian Federation

Nieto, Ana
Contributing Author
International Union for Conservation of Nature (IUCN),
Belgium

van Oldenborgh, Geert Jan
Contributing Author
Royal Netherlands Meteorological Institute (KNMI),
The Netherlands

Prishchepov, Alexander
Contributing Author
Department of Geosciences and Natural Resource Management (IGN), University of Copenhagen/Institute of Environmental Sciences, Kazan Federal University,
Denmark/Russian Federation

Prots, Bohdan
Contributing Author
State Museum of Natural History, National Academy of Sciences of Ukraine and WWF International Danube-Carpathian Programme,
Ukraine

Réverdin, Gilles
Contributing Author
Centre National de la Recherche Scientifique (CNRS),
France

Samakov, Aibek
Contributing Author
Aigine Cultural Research Center,
Kyrgyzstan

Seebens, Hanno
Contributing Author
Senckenberg Biodiversity and Climate Research Centre,
Germany

Shmatkov, Nikolay
Contributing Author
WWF Russia,
Russian Federation

Smelansky, Ilya
Contributing Author
NGO SibEcoCenter,
Russian Federation

Sousa Pinto, Isabel
Contributing Author
CIIMAR, University of Porto,
Portugal

Spinova, Yuliia
Contributing Author
Environmental Studies Department of National University of "Kyiv-Mohyla Academy", Ukrainian Nature Conservation Group (UNCG),
Ukraine

Sultanaliev, Kanat
Contributing Author
American University of Central Asia,
Kyrgyzstan

Sverdrup-Thygeson, Anne
Contributing Author
Norwegian University of Life Sciences (NMBU),
Norway

Vasyliuk, Oleksiy
Contributing Author
I.I. Schmalhausen Institute of Zoology, NAS Ukraine/NGO Ukrainian Nature Conservation Group,
Ukraine

Visconti, Piero
Contributing Author
University College London/Zoological Society of London,
United Kingdom of Great Britain and Northern Ireland

Winter, Marten
Contributing Author
German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig,
Germany

Wüest, Rafael
Contributing Author
Swiss Federal Institute for Forest, Snow and Landscape Research WSL,
Switzerland

Yamelynets, Taras
Contributing Author
Faculty of Geography, Ivan Franko National University of Lviv and WWF Danube-Carpathian Programme,
Ukraine

Zimenko, Alexey
Contributing Author
Biodiversity Conservation Center,
Russian Federation

Saarikoski, Heli
Review Editor
Finnish Environment Institute (SYKE),
Finland

van der Sluis, Theo
Review Editor
Wageningen Environmental Research (Alterra),
The Netherlands

Chapter 5

Harrison, Paula A.
Coordinating Lead Author
Centre for Ecology & Hydrology (CEH),
United Kingdom of Great Britain and Northern Ireland

Hauck, Jennifer
Coordinating Lead Author
Helmholtz Center for Environmental Research – UFZ/CoKnow Consulting,
Germany

Austrheim, Gunnar
Lead Author
Norwegian University of Science and Technology,
Norway

Brotons, Lluís
Lead Author
Spanish Research Council (CSIC) at CTFC-CREAF,
Spain

Cantele, Matthew
Lead Author
International Institute for Applied Systems Analysis,
Austria

Claudet, Joachim
Lead Author
Centre National de la Recherche Scientifique (CNRS),
France

Fürst, Christine
Lead Author
Martin Luther-University Halle,
Germany

Guisan, Antoine
Lead Author
University of Lausanne,
Switzerland

Lavorel, Sandra
Lead Author
Centre National de la Recherche Scientifique (CNRS),
France

Olsson, Gunilla Almered
Lead Author
University of Gothenburg,
Sweden

Proença, Vânia
Lead Author
Instituto Superior Técnico, Universidade de Lisboa,
Portugal

Rixen, Christian
Lead Author
Swiss Federal Institute for Forest, Snow and Landscape Research WSL,
Switzerland

Santos-Martín, Fernando
Lead Author
Universidad Autonoma de Madrid,
Spain

Schlaepfer, Martin
Lead Author
University of Geneva,
Switzerland

Solidoro, Cosimo
Lead Author
Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS),
Italy

Takenov, Zharas
Lead Author
Freelance consultant,
Kazakhstan

Turok, Jozef
Lead Author
Technical University in Zvolen,
Slovakia

Harmáčková, Zuzana V.
Fellow
Global Change Research Centre of the Czech Academy of Sciences,
Czech Republic

Aloe Karabulut, Armağan
Contributing Author
Ministry of Food Agriculture and Livestock, Ankara,
Turkey

Boeraeve, Fanny
Contributing Author
Gembloux Agro Bio-Tech (University of Liege),
Belgium

Coll Monton, Marta
Contributing Author
Institut de Recherche pour le Développement,
France

Dunford, Robert
Contributing Author
Environmental Change Institute, University of Oxford and Centre of Ecology and Hydrology,
United Kingdom of Great Britain and Northern Ireland

Frantzeskaki, Niki
Contributing Author
DRIFT, Erasmus University Rotterdam,
The Netherlands

Griewald, Yuliana
Contributing Author
Humboldt-Universität zu Berlin,
Germany

Grigulis, Karl
Contributing Author
Laboratoire d'Ecologie Alpine, CNRS,
France

Jacobs, Sander
Contributing Author
Research Institute for Nature and Forest INBO,
Belgium

Janse, Jan
Contributing Author
PBL-Netherlands Environmental Assessment Agency,
The Netherlands

Kireyeu, Viktar
Contributing Author
Siberian Federal University,
Russian Federation

Kok, Kasper
Contributing Author
Wageningen University & Research,
The Netherlands

Lobanova, Anastasia
Contributing Author
Potsdam Institute for Climate Impact Research,
Germany

Morán-Ordóñez, Alejandra
Contributing Author
InForest Joint Research Unit (CTFC-CREAF),
Spain

Pedde, Simona
Contributing Author
Wageningen University & Research,
The Netherlands

Shkaruba, Anton
Contributing Author
Central European University/NGO "Ekapraekt",
Belarus/Hungary

Sonrel, Anthony
Contributing Author
Department of Ecology and Evolution, University of Lausanne,
Switzerland

Viñegla, Fernando
Contributing Author
Fundación Internacional para la Restauración de Ecosistemas,
Spain

Winter, Marten
Contributing Author
German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig,
Germany

Zinngrebe, Yves
Contributing Author
Department for Agricultural Economics and Rural Development, University of Göttingen,
Germany

Holman, Ian
Review Editor
Cranfield University,
United Kingdom of Great Britain and Northern Ireland

Plieninger, Tobias
Review Editor
University of Göttingen/University of Kassel,
Germany

Chapter 6

Ring, Irene
Coordinating Lead Author
Technische Universität Dresden,
International Institute Zittau,
Germany

Sandström, Camilla
Coordinating Lead Author
Department of Political Science, Umeå University,
Sweden

Acar, Sevil
Lead Author
Istanbul Kemerburgaz University,
Turkey

Adeishvili, Malkhaz
Lead Author
UNIDO,
Georgia

Albert, Christian
Lead Author
Leibniz Universität Hannover,
Germany

Allard, Christina
Lead Author
Luleå University of Technology,
Sweden

Anker, Yaakov
Lead Author
Ariel University the Department of Chemical Engineering (Biotechnology & Materials) and the Eastern R&D Center, Department of Environmental Research,
Israel

Arlettaz, Raphaël
Lead Author
University of Bern,
Switzerland

Bela, Györgyi
Lead Author
Szent István University/ESSRG Ltd.,
Hungary

ten Brink, Ben
Lead Author
PBL-Netherlands Environmental Assessment Agency,
The Netherlands

Fischer, Anke
Lead Author
James Hutton Institute,
United Kingdom of Great Britain and Northern Ireland

Fürst, Christine
Lead Author
Martin Luther-University Halle,
Germany

Galil, Bella
Lead Author
The Steinhardt Museum of Natural History,
Tel Aviv University,
Israel

Hynes, Stephen
Lead Author
National University of Ireland, Galway,
Ireland

Kasymov, Ulan
Lead Author
Humboldt-Universität zu Berlin,
Kyrgyzstan

Marta-Pedroso, Cristina
Lead Author
Instituto Superior Técnico, Universidade de Lisboa,
Portugal

Mendes, Ana
Lead Author
University of Évora,
Portugal

Molau, Ulf
Lead Author
University of Gothenburg,
Sweden

Olschewski, Roland
Lead Author
Swiss Federal Research Institute WSL,
Switzerland

Pergl, Jan
Lead Author
Institute of Botany, Charles University,
Czech Republic

Simoncini, Riccardo
Lead Author
International Union for Conservation of Nature (IUCN), European Sustainable Use Group,
Belgium

Coscieme, Luca
Fellow
Trinity College Dublin,
Italy

Adem, Çiğdem
Contributing Author
Public Administration Institute for Turkey & the Middle East (TODAIE),
Turkey

Blackstock, Kirsty
Contributing Author
The James Hutton Institute,
United Kingdom of Great Britain and Northern Ireland

Hauck, Jennifer
Contributing Author
Helmholtz Center for Environmental Research – UFZ/CoKnow Consulting,
Germany

Johansson, Johanna
Contributing Author
Södertörn University, School of Natural Sciences, Technology and Environmental Studies,
Sweden

Lasson, Caroline
Contributing Author
University of Leipzig,
Germany

Minchenko, Natalya
Contributing Author
NGO “Bagna”/UNDP in Belarus,
Belarus

Reimerson, Elsa
Contributing Author
Department of Political Science, Umeå University,
Sweden

Schlaepfer, Martin
Contributing Author
University of Geneva,
Switzerland

Simonov, Eugene A.
Contributing Author
Daursky Biosphere Reserve/Dauria International Protected Area (DIPA) and The Rivers without Boundaries International Coalition (RwB),
China/Mongolia/Russian Federation

Snethlage, Mark
Contributing Author
University of Bern,
Switzerland

Söderasp, Johanna
Contributing Author
Luleå University of Technology, Department of Business Administration, Technology and Social Sciences,
Sweden

Baker, Susan
Review Editor
Cardiff University,
United Kingdom of Great Britain and Northern Ireland

Matczak, Piotr
Review Editor
Adam Mickiewicz University,
Poland

Primmer, Eeva
Review Editor
Finnish Environment Institute (SYKE),
Finland

Multidisciplinary Expert Panel/Bureau

Watson, Robert T.
Chair/Bureau
University of East Anglia,
United Kingdom of Great Britain and Northern Ireland

Barudanovic, Senka
Bureau
Faculty of Science, Zmaja od Bosne,
Bosnia and Herzegovina

Novitsky, Ruslan
MEP
National Academy of Science of Belarus,
Belarus

Stenseke, Marie
MEP
Gothenburg University,
Sweden

IPBES Secretariat

Larigauderie, Anne
IPBES Secretariat,
Germany

Van der Plaat, Felice
IPBES Secretariat,
Germany

Technical Support Unit

Torre-Marin Rando, Amor
University of Bern,
Switzerland

Mader, André
University of Bern,
Switzerland

ANNEX IV

Expert reviewers of the IPBES Regional Assessment Report on Biodiversity and Ecosystem Services for Europe and Central Asia

Aapala, Kaisu
Finnish Environment Institute,
Finland

Aicher, Christoph
Helmholtz Centre for Environmental Research – UFZ,
Germany

Arends, Jeroen
Ecosystem Services Partnership (ESP),
Serbia

Arnauduc, Jean-Pierre
Fédération Nationale des Chasseurs,
France

Asikainen, Anna-Rosa
The Central Union of Agricultural Producers and Forest Owners (MTK),
Finland

Augustyn, Anna
Groupe de Bruges,
The Netherlands

Aumeeruddy-Thomas, Yildiz
Centre National de la Recherche Scientifique,
France

Barbieri, Marco
On behalf of the Convention on the Conservation of Migratory Species of Wild Animals (CMS),
Germany

Barrantes, Olivia
Universidad de Zaragoza,
Spain

Başak Dessane, Esra*
Project House Cooperative,
Turkey

* These experts, who were part of the assessment, offered comments on chapters other than their own, through the external review process.

Bashta, Andriy-Taras
Association “Fauna”/National Academy of Sciences of Ukraine,
Ukraine

Batisha, Ayman
International Sustainability Institute,
Egypt

Beichler, Simone
Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB),
Germany

Bernués, Alberto
CITA de Aragón,
Spain

Bjork, Lars
Uppsala University,
Sweden

Bonells, Marcela
On behalf of the Ramsar Convention Secretariat,
Switzerland

Borgström, Suvi
Ministry of the Environment,
IPBES National Focal Point,
Finland

Boucherand, Sylvain
B&L évolution,
France

Bouma, Jetske
PBL-Netherlands Environmental Assessment Agency,
The Netherlands

Bowler, Diana
Senckenberg Biodiversity and Climate Research Centre,
Germany

Braks, Marieta
The Dutch National Institute for Public Health and the Environment (RIVM),
The Netherlands

Breeze, Tom
University of Reading,
United Kingdom of Great Britain and Northern Ireland

ten Brink, Ben*
PBL-Netherlands Environmental Assessment Agency,
The Netherlands

Brochier, Violaine
Electricity of France, Research and Development,
France

Brooks, Thomas
International Union for Conservation of Nature (IUCN),
Switzerland

Brooks, Bryan W.
Baylor University,
United States of America

Bugter, Rob
Wageningen Environmental Research,
The Netherlands

Bukvareva, Elena*
Biodiversity Conservation Center, Moscow,
Russian Federation

Butchart, Stuart
BirdLife International,
United Kingdom of Great Britain and Northern Ireland

Buttigieg, Sandra C.
University of Malta,
Malta

Cabecinha, Edna
University of Trás-os-Montes and Alto Douro, CITAB,
Portugal

Charrier, Philippe
Cyprus Community Initiative for Forests,
IPBES Stakeholder Forum, BESNet LDR,
IUCN CEC,
Cyprus/France

Clarke, Gerard
Department of Psychiatry and Neurobehavioural Science/APC Microbiome Institute, University College Cork,
Ireland

Condé, Sophie
European Topic Centre on Biological Diversity,
France

Connolly, James J. T.
Universitat Autònoma de Barcelona,
Spain

Coolsaet, Brendan
University of East Anglia,
United Kingdom of Great Britain and Northern Ireland

Costa, Rosaria
University of Messina,
Italy

Damsgaard, Mette Gervin
Environmental Protection Agency,
IPBES National Focal Point,
Denmark

de Vries, Sjerp
Wageningen Environmental Research,
The Netherlands

Droste, Nils
Helmholtz Centre for Environmental Research – UFZ,
Germany

Eggermont, Hilde
Belgian Science Policy Office,
IPBES National Focal Point,
Belgium

Erbil, Nurcan
Ardahan University, Health Sciences College,
Turkey

Espindola, Anahi
University of Idaho,
United States of America

Evergetis, Epameinondas
Agricultural University of Athens,
Greece

Fady, Bruno
National Institute of Agronomic Research (INRA),
France

Faith, Dan
bioGENESIS,
Australia

Fischer, Markus*
University of Bern,
Switzerland

Garcia Rodrigues, João
University of Santiago de Compostela,
Spain

Garnier, Julie
Odyssey Conservation Trust,
France

Gerino, Magali*
Université P. Sabatier - Toulouse 3,
France

Gocheva, Kremena
Bulgarian Academy of Sciences (IBER-BAS),
Bulgaria

Goring, Emma
Proaction Alliance,
United Kingdom of Great Britain and Northern Ireland

Goris, Nadine
Uni Research AS & Bjerknes Centre for Climate Research,
Norway

Güzel, Yelda
Mustafa Kemal University,
Turkey

Hallosserie, Agnes
Foundation for Research on Biodiversity,
France

Hallosserie, Agnes
On behalf of the 4th Pan-European IPBES Stakeholder Consultation (PESC-4)

Haluza, Daniela
Medical University of Vienna, Center for Public Health, Department of Environmental Health,
Austria

Heard Snow, Michael
University of Edinburgh,
United Kingdom of Great Britain and Northern Ireland

Hendriks, Rob J. J.
Ministry of Economic Affairs,
The Netherlands

Hettelingh, Jean-Paul
National Institute for Public Health and the Environment,
The Netherlands

Hilding-Rydevik, Tuija
Swedish Biodiversity Center, Swedish University of Agricultural Sciences and Uppsala University,
Sweden

Hilgers, Astrid
Ministry of Economic Affairs,
IPBES National Focal Point,
The Netherlands

Hochkirch, Axel
Trier University, Department of Biogeography,
Germany

Hokkanen, Heikki
University of Helsinki, Department of Agricultural Sciences,
Finland

Huynen, Maud
University of Maastricht,
The Netherlands

Igrejas, Gilberto
University of Trás-os-Montes and Alto Douro,
Portugal

Insarov, Gregory
Institute of Geography of the Russian Academy of Sciences,
Russian Federation

Isbell, Forest
University of Minnesota,
United States of America

Jacobs, Sander*
Research Institute for Nature and Forest INBO,
Belgium

Jähnig, Sonja
Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB),
Germany

Jamiyansharav, Khishigbayar
Colorado State University,
United States of America

Jäppinen, Jukka-Pekka
Finnish Environment Institute, Biodiversity Centre,
Finland

Keller, Roger
University of Zurich,
Switzerland

Keune, Hans*
Research Institute for Nature and Forest INBO,
Belgium

Khapugin, Anatoliy
Joint Directorate of the Mordovia State Nature Reserve and National Park "Smolny",
Russian Federation

Kock, Richard
Royal Veterinary College London,
United Kingdom of Great Britain and Northern Ireland

Kumar Mishra, Santosh
Population Education Resource Centre (PERC), Department of Continuing and Adult Education and Extension Work,
S. N. D. T. Women's University, Mumbai,
India

Kusch, Sigrid
University of Padua, ScEnSers Independent Expertise,
Italy/Germany

Langemeyer, Johannes
Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona,
Spain

Leiner, Stefan
On behalf of the European Union

Lemaitre, Frédéric
On behalf of BiodivERsA,
France

Lerner, Henrik
Department of Health Sciences, Ersta Sköndal Bräcke University College,
Sweden

Liekens, Inge*
VITO,
Belgium

Lindblad, Cecilia
Swedish Environmental Protection Agency,
IPBES National Focal Point,
Sweden

Lindecke, Oliver
Leibniz Institute for Zoo and Wildlife Research,
Germany

Lovell, Rebecca
University of Exeter,
United Kingdom of Great Britain and Northern Ireland

Lozano, Jorge
Leuphana University of Lüneburg,
Germany

Lundemo, Sverre
On behalf of WWF-Norway,
Norway

Mader, André
On behalf of the ECA values liaison group

Marquard, Elisabeth
On behalf of the 3rd Pan-European IPBES Stakeholder Consultation (PESC-3)

Martel, An
Ghent University,
Belgium

Matras-Swynghedauw, Emmanuelle
Ministry of Europe and Foreign Affairs,
IPBES National Focal Point,
France

Mazziotta, Adriano
Stockholm Resilience Centre, Stockholm University,
Sweden

Meessen, Heino
Bern University,
Switzerland

Minchenko, Natalya
NGO "Bagna",
Belarus

Miski, Mahmut
Istanbul University,
Turkey

Moleón, Marcos
University of Granada,
Spain

Molnár, Zsolt*
Centre for Ecological Research, Hungarian Academy of Sciences,
Hungary

Morales Reyes, Zebensui
Miguel Hernández University,
Spain

Morris, Sarah
On behalf of UNEP-WCMC and the Biodiversity Indicators Partnership (BIP),
United Kingdom of Great Britain and Northern Ireland

Negri, Valeria
University of Perugia,
Italy

Niemelä, Jari
University of Helsinki,
Finland

Nozadze, Salome
Department of biodiversity and forestry policy,
Georgia

Osojnik Črnivec, Ilja Gasan
Public Service for Farm Animal Genetic Resurces Preservation, Biotechnical faculty, University of Ljubljana,
Slovenia

Ostermeyer-Schlöder, Almuth
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB),
IPBES National Focal Point,
Germany

Paduano, Stefania
University of Modena and Reggio Emilia,
Italy

Pandit, Ram
University of Western Australia,
Australia

Pauli, Harald
GLORIA-Coordination, Austrian Academy of Sciences, IGF & University of Natural Resources and Life Sciences Vienna, ZgWN,
Austria

Pe'er, Guy
Helmholtz Centre for Environmental Research – UFZ,
Germany

Penker, Marianne
University of Natural Resources and Life Sciences, Vienna,
Austria

Petřík, Petr*
The Czech Academy of Sciences, Institute of Botany,
Czech Republic

Petrovych, Olesya
Ministry of Ecology and Natural Resources of Ukraine,
Ukraine

Poeta, Patricia
University of Trás-os-Montes and Alto DOURO, Veterinary Science Department, Vila Real,
Portugal

Popovic, Zorica
University of Belgrade, Institute for Biological Research,
Serbia

Poutahidis, Theofilos
Aristotle University of Thessaloniki,
Greece

Proença, Vânia*
Instituto Superior Técnico, Universidade de Lisboa,
Portugal

Purvis, Andy
Department of Life Sciences, Natural History Museum,
United Kingdom of Great Britain and Northern Ireland

Raab, Kristina
Helmholtz Centre for Environmental Research – UFZ,
Germany

Remme, Roy
National Institute for Public Health and Environment (RIVM) and Wageningen University,
The Netherlands

Reyjol, Yorick
French Agency for Biodiversity (AFB),
France

Ribeiro, Ana R.
Faculty of Engineering, University of Porto,
Portugal

Rixen, Christian*
Swiss Federal Institute for Forest, Snow and Landscape Research WSL,
Switzerland

Roe, Jenny
University of Virginia,
United States of America

Rolf, Werner
Technical University Munich,
Germany

Romero, José
Swiss Federal Office for the Environment (FOEN),
IPBES National Focal Point,
Switzerland

Rounsevell, Mark*
University of Edinburgh,
United Kingdom of Great Britain and Northern Ireland

Runhaar, Hens
Wageningen University & Research and Utrecht University,
The Netherlands

Rusch, Graciela
Norwegian Institute for Nature Research,
Norway

Ruud, Audun
Norwegian Institute for Nature Research,
Norway

Saeed, Shafqat
Muhammad Nawaz Shareef University of Agriculture,
Pakistan

Sánchez Zapata, José Antonio
University Miguel Hernández,
Spain

Savo, Valentina
Simon Fraser University,
Canada

Schigel, Dmitry
Global Biodiversity Information Facility (GBIF),
Denmark

Schleyer, Christian
University of Kassel, Section of International Agricultural Policy and Environmental Governance,
Germany

Schulp, Nynke
Vrije Universiteit,
The Netherlands

Seebens, Hanno
Senckenberg Biodiversity and Climate Research Centre (BiK-F),
Germany

Simões, Margarida
National Institute for Agrarian and Veterinary Research (INIAV),
Portugal

Skern-Mauritzen, Mette
Institute of Marine Research Bergen,
Norway

Skevington, Suzanne
Project Diamond Chair in Health Psychology, Division of Psychological Science and Mental Health, University of Manchester,
United Kingdom of Great Britain and Northern Ireland

Skouteri, Asimina
Institute of Mediterranean Forest Ecosystems,
Greece

Skryhan, Hanna
NGO "EKAPRAEKT", Belarusian-Russian University,
Belarus

Snethlage, Mark
University of Bern,
Switzerland

Sousa, Lisa P.
University of Aveiro,
Portugal

Spehn, Eva
Swiss Biodiversity Forum (SCNAT),
Switzerland

Stott, Andrew
Department for Environment, Food and Rural Affairs (DEFRA),
IPBES National Focal Point,
United Kingdom of Great Britain and Northern Ireland

Todorov, Daniel
Sofia University "St. Kliment Ohridski",
Bulgaria

Tzoulas, Konstantinos
Manchester Metropolitan University,
United Kingdom of Great Britain and
Northern Ireland

Vik, Nina
Norwegian Environment Agency,
IPBES National Focal Point,
Norway

Wade, Andrew
University of Reading,
United Kingdom of Great Britain and
Northern Ireland

Ward, Malcolm
Public Health Wales,
United Kingdom of Great Britain and
Northern Ireland

Watt, Allan
Centre for Ecology & Hydrology (CEH)/
ALTER-Net,
United Kingdom of Great Britain and
Northern Ireland

Weigend, Maximilian
Rheinische Friedrich-Wilhelms-Universität,
Germany

West, Tom
ClientEarth,
United Kingdom of Great Britain and
Northern Ireland

Willemen, Louise
University of Twente,
The Netherlands

Wojcik, Adrian
Nicolaus Copernicus University in Torun,
Poland

Wugt Larsen, Frank
European Environment Agency,
Denmark

Wulf, Friedrich
Pro Natura - Friends of the Earth
Switzerland,
Switzerland

Zaunberger, Karin
On behalf of the European Union

van Zeijts, Henk
PBL-Netherlands Environmental
Assessment Agency,
The Netherlands

Zisenis, Marcus
ECNC-European Centre for Nature
Conservation (former employee),
The Netherlands

IPBES Multidisciplinary Expert Panel/Bureau

Avdibegovic, Mersudin
University of Sarajevo,
Bosnia and Herzegovina

Barudanovic, Senka
Faculty of Science, Zmaja od Bosne,
Bosnia and Herzegovina

Diaz, Sandra
Universidad Nacional de Córdoba,
Argentina

Erpul, Gunay
Ankara University,
Turkey

Leadley, Paul
University of Paris-Sud,
France

Novitsky, Ruslan
National Academy of Science of Belarus,
Belarus

Pascual, Unai
Basque Centre for Climate Change,
Spain

Pataridze, Tamar
Ministry of Environment and Natural
Resources Protection of Georgia,
Georgia

Roué, Marie
Muséum National d'Histoire Naturelle,
France

Stenseke, Marie
Gothenburg University,
Sweden

Watson, Robert T.
University of East Anglia,
United Kingdom of Great Britain and
Northern Ireland

IPBES Technical Support Unit members

Balvanera, Patricia
Ecosystems and Sustainability Research
Institute, National Autonomous University of
Mexico,
Mexico
As part of the Values TSU

González, David
Deutsche Gesellschaft für Internationale
Zusammenarbeit GmbH/Ecosystems and
Sustainability Research Institute, National
Autonomous University of Mexico,
Mexico
As part of the Values TSU

Kang, Sung Ryong
On behalf of the IPBES Knowledge and
Data Task Force/Task Group on Indicators

Lazarova, Tanya
Netherlands Environmental Assessment
Agency (PBL),
The Netherlands
As part of the Scenarios and Models TSU

Mader, André
University of Bern,
Switzerland
As part of the Regional Assessment for
Europe and Central Asia TSU

Nakashima, Douglas
United Nations Educational, Scientific and
Cultural Organization (UNESCO),
France
As part of the Indigenous and Local
Knowledge TSU

Torre-Marin Rando, Amor
University of Bern,
Switzerland
As part of the Regional Assessment for
Europe and Central Asia TSU

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is the intergovernmental body which assesses the state of biodiversity and ecosystem services, in response to requests from Governments, the private sector and civil society.

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INTERGOVERNMENTAL SCIENCE-POLICY PLATFORM ON BIODIVERSITY AND ECOSYSTEM SERVICES (IPBES)

IPBES Secretariat, UN Campus

Platz der Vereinten Nationen 1, D-53113 Bonn, Germany

Tel. +49 (0) 228 815 0570

secretariat@ipbes.net

www.ipbes.net

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United Nations Environment Programme

United Nations
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Organization of the
United Nations

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