NATURAL CAPITAL AND CLIMATE POLICY

SYNERGIES AND CONFLICTS

Summary for Decision Makers

NATURKAPITAL DEUTSCHLAND – TEEB DE

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Henry Wüstemann, Volkmar Hartje, Aletta Bonn, Bernd Hansjürgens

Christine Bertram, Alexandra Dehnhardt, Ralf Döring,
Ulrike Doyle, Peter Elsasser, Dietmar Mehl, Bernhard Osterburg,
Katrin Rehdanz, Irene Ring, Mathias Scholz, Katrin Vohland

NATURKAPITAL
DEUTSCHLAND – TEEB DE

PUBLICATION DATA

Recommended format for citation
Natural Capital Germany – TEEB DE (2015): Natural Capital and Climate Policy – Synergies and Conflicts. Summary for Decision Makers. Original German version 2014. Technische Universität Berlin, Helmholtz Centre for Environmental Research – UFZ, Leipzig.

Authors of this Summary
Henry Wüstemann, Volkmar Hartje, Aletta Bonn, Bernd Hansjürgens, Christine Bertram, Alexandra Dehnhardt, Ralf Döring, Ulrike Doyle, Peter Elsasser, Dietmar Mehl, Bernhard Osterburg, Katrin Rehdanz, Irene Ring, Mathias Scholz, Katrin Vohland

The following authors contributed to individual chapters of this Summary
Chapter 3: Katrin Vohland, Ulrike Doyle, Christian Albert, Christine Bertram, Lisa Biber-Freudenberger, Aletta Bonn, Miriam Brenck, Benjamin Burkhard, Johannes Förster, Elmar Fuchs, Carolin Galler, Christina von Haaren, Pierre L. Ibisch, Timo Kaphengst, Christian Klassert, Reinhard Klenke, Stefan Klotz, Stefan Kreft, Ingolf Kühn, Elisabeth Marquard, Dietmar Mehl, Insa Meinke, Karin Naumann, Marcus Reckermann, Katrin Rehdanz, Stefan Rüter, Wiebke Saathoff, Julia Sauermann, Mathias Scholz, Uwe Schröder, Ralf Seppelt, Daniela Thrän, Felix Witing
Chapter 4.1: Bernhard Osterburg, Jochen Kantelhardt, Horst Liebersbach, Bettina Matzdorf, Michaela Reutter, Norbert Röder, Lena Schaller
Chapter 4.2: Aletta Bonn, Augustin Berghöfer, John Couwenberg, Matthias Drösler, Rita Jensen, Jochen Kantelhardt, Vera Luthardt, Thorsten Permien, Norbert Röder, Lena Schaller, Burkhard Schweppe-Kraft, Franziska Tanneberger, Michael Trepel, Sabine Wichmann
Chapter 4.3: Peter Elsasser, Matthias Bösch, Georg Leefken, Bernhard Möhring, Till Pistorius, Joachim Rock, Sebastian Rüter, Bettina Schröppel
Chapter 4.4: Alexandra Dehnhardt, Mathias Scholz, Dietmar Mehl, Uwe Schröder, Elmar Fuchs
Chapter 4.5: Christine Bertram, Ralf Döring, Katrin Rehdanz, Jacobus Hofstede, Astrid Kowatsch

The authors of the unabridged version are listed on the final page of this Summary.

Natural Capital Germany – TEEB DE Coordination Group
Bernd Hansjürgens (Helmholtz Centre for Environmental Research – UFZ), Aletta Bonn (UFZ), Miriam Brenck (UFZ), Katharina Dietrich (Federal Agency for Nature Conservation – BfN), Urs Moesenfechtel (UFZ), Christa Ratte (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety – BMUB), Irene Ring (UFZ), Christoph Schröter-Schlaack (UFZ), Burkhard Schweppe-Kraft (BfN)

Acknowledgements: The authors and the TEEB DE Coordination Group wish to thank everyone who has actively contributed to making this brochure a success.

Funding and support: »Natural Capital Germany – TEEB DE« is a research and development project within the framework of the Environmental Research Plan. It is supported by the Federal Agency for Nature Conservation (BfN) with funding from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). Expert assistance: BfN, Department I 2.1 Legal Affairs, Economics and Ecologically Sound Regional Development.

Graphic Design | Layout: Metronom | Agentur für Kommunikation und Design GmbH, Leipzig

Cover photo: Marco Barnebeck, Pixelio.de

Production: Grafisches Centrum Cuno GmbH & Co. KG, Calbe

Published in 2015, copies printed: 1,000

Paper from sustainable forestry
ISBN: 978-3-944280-11-0

berlin

HELMHOLTZ
ZENTRUM FÜR
UMWELTFORSCHUNG
UFZ

Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit

BfN
Bundesamt
für Naturschutz

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NATURAL CAPITAL GERMANY – TEEB DE: THE PROJECT AND HOW THIS REPORT FITS IN

»Natural Capital Germany – TEEB DE« is the German follow-up project to the international TEEB study (The Economics of Ecosystems and Biodiversity), which analysed the interactions between nature's services, value added by economic activity, and human wellbeing. By adopting an economic perspective, »Natural Capital Germany – TEEB DE« aims to make nature's potential and services more transparent and visible. Through its economic assessment of natural capital, the project seeks to ensure that better account is taken of nature's services in public and private decision-making processes, in order to safeguard the natural bases of life and biological diversity for the long term. The project therefore draws on approaches and instruments existing in Germany and elsewhere in the world. It also supports the fulfilment of environmental, sustainable development and nature conservation goals and strategies, particularly the German National Strategy on Biological Diversity.

The project is funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the German Federal Agency for Nature Conservation (BfN). It is coordinated by study leader Prof. Dr. Bernd Hansjürgens and his team at the Helmholtz Centre for Environmental Research (UFZ).

The »Natural Capital Germany – TEEB DE« project is centred around four thematic reports, which are produced by teams of experts, both academics and practitioners. The four main reports are based on existing analyses, strategies and case studies that highlight the importance of natural services for human wellbeing in Germany, and cover the following topics:

1) Natural Capital and Climate Policy – Synergies and Conflicts;

2) Capturing the Value of Ecosystem Services in Rural Areas;

3) Ecosystem Services in the City – Protecting Health and Enhancing Quality of Life;

4) Natural Capital Germany: New Policy Options – A Synthesis.

An introductory brochure and a brochure for business have already been published and can be downloaded from the project website (www.naturkapital-teeb.de):

- The Value of Nature for Economy and Society – An introduction
- The Business Perspective – Being prepared for new challenges

»Natural Capital Germany – TEEB DE« is supported by a Project Advisory Board with high-level members from academia, the media and business, as well as an associated Stakeholder Committee of NGOs, business organisations, ministries, federal states (German *Länder*) and municipalities. This involvement ensures active stakeholder participation, information and networking in the project.

This publication presents some of the key findings from the first TEEB DE report, entitled *Natural Capital and Climate Policy*. The report was produced under the auspices of TU Berlin's Department of Landscape Economics. The report leader is Prof. Dr. Volkmar Hartje. The aim is to identify from an economic perspective synergies between climate change mitigation and adaptation, on the one hand, and the conservation of natural capital, its services, and biological diversity, on the other. It also highlights options for ecosystem-based solutions that can mitigate or avoid conflicts between these two policy fields.

PREFACE

Climate and energy policy are high on the agenda. The German Government has set itself the goal of reducing Germany's greenhouse gas emissions by 80–95 % by 2050, but this can only be achieved with great effort. Germany is also committed to phasing out nuclear energy and plans to shut down all its nuclear power plants by 2022. These measures form part of the *»Energiewende«* – the energy transition to renewables, which is a highly controversial and intensively debated topic both in Germany and abroad.

The second major environmental problem of our age alongside climate change – biodiversity loss – is often overlooked by comparison. Many people lack an awareness of this issue. And yet viewed in terms of its impacts on our wellbeing, it is perhaps just as important as climate change. In fact, climate change and biodiversity are linked in many diverse ways. It is not just that climate change puts biological diversity at risk, but that climate policy can also be supported by our use of nature. The key phrase is »ecosystem-based climate policy«. If this is carefully crafted, synergies can be created and made use of, benefiting both policy fields.

This report draws attention to these aspects. It identifies the potential synergies between nature and environmental conservation and climate change mitigation and adaptation, and shows how conflicts can be avoided or mitigated if necessary. It also makes it clear that this is worthwhile, not least economically. Our economy will not only make savings; we will also gain very substantial benefits if we focus to a greater extent on climate policies that take account of natural capital.

»Natural Capital and Climate Policy – Synergies and Conflicts« is the first report in »Natural Capital Germany – TEEB DE«, the German follow-up project to the international TEEB study. The special feature of this report is that it deliberately focuses on one selected ecosystem service, which we call »climate service«. Other ecosystem services play a secondary role in our analysis. This does not mean that they are less important; it is simply that the present report focuses specifically on how two key policy fields can be interlinked.

We hope that our readers will find this »Summary for Decision Makers« interesting and informative and that it will be a source of inspiration in their own work.

ACKNOWLEDGEMENTS

This publication, »Natural Capital and Climate Policy – Synergies and Conflicts. Summary for Decision Makers«, is based on the unabridged version which establishes the foundations and will be published in 2015. More than 70 authors were involved in compiling the unabridged version, along with a great many independent experts and reviewers. We would like to take this opportunity to thank them all.

We also wish to express our sincere thanks to the following groups and individuals:

- the »Natural Capital Germany – TEEB DE« Project Advisory Board: Stefanie Engel, University of Osnabrueck; Uta Eser, Environmental Ethics Bureau; Karin Holm-Müller, University of Bonn, member of the German Advisory Council on the Environment; Beate Jessel, President of the Federal Agency for Nature Conservation (BfN), Bonn; Marion Potschin, University of Nottingham; Christian Schwägerl, science, political and environmental journalist; Karsten Schwanke, television presenter and meteorologist; Antje von Dewitz, CEO of VAUDE; Angelika Zahrnt, long-time member of the German Council for Sustainable Development and Honorary President of Friends of the Earth Germany (BUND);

- the »Natural Capital Germany – TEEB DE« Stakeholder Committee: Rüdiger Becker, Association »Municipalities for Biological Diversity« / City of Heidelberg, Agency for Environmental Protection, Trade Supervision and Energy; Carolin Boßmeyer, Biodiversity in Good Company Initiative; representatives of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB); Ann Kathrin Buchs, German Working Group on Water Issues of the Federal States and the Federal Government (LAWA)/Lower Saxony Ministry for Environment, Energy and Climate Protection; Andreas Burger, Federal Environment Agency (UBA); Sarah Richter, German Association of Towns and Municipalities; Wiltrud Fischer, project management of the Federal Ministry of Education and Research (BMBF) at the German Aerospace Centre; Claudia Gilles, German Tourism Association (DTV); Alois Heißenhuber, Scientific Advisory Board of the BMEL »Biodiversity and Genetic Resources«/Technical University Munich; Udo Hemmerling, German Farmers' Association; Till Hopf, German Nature and Biodiversity Conservation Union (NABU); Edelgard von Houwald, Federal Ministry of Food and Agriculture (BMEL); Günter Mitlacher, World Wide Fund for Nature (WWF Germany); Michaela Pritzer, Federal Ministry of Transport and Digital Infrastructure

(BMVI); Catrin Schiffer, Federation of German Industries (BDI); Reinhard Schmidt-Moser, German Working Group on Nature Conservation, Landscape Management and Recreation of the Federal States and the Federal Government (LANA)/Schleswig-Holstein Ministry of Energy, Agriculture, the Environment and Rural Areas; Ulrich Stöcker, German Environmental Aid (DUH); Magnus Wessel, Friends of the Earth Germany (BUND); Markus Ziegeler, German Forestry Council (DFWR); Jochen Zimmermann, Federal Ministry for Economic Affairs and Energy (BMWi);

- and all the scientists and academics at the various federal research institutions, including staff at the Natural Capital Competence Centre of the German Federal Agency for Nature Conservation, who provided critical and constructive support during the genesis of this report, which is greatly appreciated.

The views expressed in this Summary are those of the authors and do not represent the official positions of the participating organisations.

Berlin and Leipzig, January 2014

Volkmar Hartje, Climate Report Leader	Bernd Hansjürgens, Study Leader, Natural Capital Germany – TEEB DE

CORE MESSAGES

- Nature and biodiversity build the foundation for human life and supply economy and society with a variety of **ecosystem services**. Many of these services are also of great importance for **climate change mitigation** and **adaptation**. This linkage is the main focus of this report. Moreover, nature and biodiversity are inherently valuable, and this is reflected in political goals and legal requirements.

- Some **climate change mitigation and energy policy instruments** can have negative impacts on nature and ecosystem services, e. g. by promoting the cultivation of energy crops or unfavourable choices of location for wind farms, hydropower plants, and power lines. The cultivation of energy crops reinforces the current trend towards more intensive agriculture, conversion of grassland into cropland, and drainage of peatlands. This increases greenhouse gas emissions, has adverse effects on biological diversity, and contributes to the loss of numerous ecosystem services.

- By **identifying, measuring and undertaking an economic valuation** of climate-relevant (and other) services of nature, synergies and potential conflicts between climate policy and nature conservation can be analysed more accurately. **Ecosystem-based approaches** make use of nature's services for climate change mitigation and adaptation. They offer opportunities for climate policies which reduce greenhouse gas emissions, build the adaptive capacities of land-use systems to climate change, and conserve and promote biological diversity and the ecosystem services provided by the various physiographic regions. They thus have the potential to significantly increase our ecosystems' resilience to climate change.

- In **agriculture**, there are various cost-effective options for climate change mitigation, such as increasing the efficiency of fertiliser use, conserving permanent grassland, and making use of opportunities for lower-impact biomass production. There is also scope to make greater use of waste from landscape management, such as grass residues and hedge cuttings, in renewable energy generation.

- In addition to **peatland conservation, rewetting of farmed peatlands** is a significant mitigation measure which can be implemented at fairly low cost compared with other CO_2 avoidance options.

- Degraded carbon-rich soils (primarily farmed peatlands) produce around 41 Mt CO_2e of emissions per year (4.3 % of Germany's gross total annual emissions), but account for just 8 % of land used for agricultural purposes. Researchers calculated that a programme of measures for the rewetting of 300,000 hectares of peatland in Germany would avoid economic damage amounting to € 217 million annually. Rewetted peatlands provide habitats for highly endangered natural communities, but can also continue to be utilised, in a nature-compatible manner, through the introduction of paludiculture.

- Sustainable **forest management** can combine wood production with nature and environmental conservation and climate change mitigation. German forests are currently a carbon sink and, according to the German Government's Forest Strategy 2020, must be maintained as such. The opportunities for further increasing the positive climate impacts of forests are limited, however, and should not be analysed separately from wood utilisation. There is scope to make greater use of wood as a substitute for energy-intensive materials (e.g. in the construction industry) and for other energy carriers and to temporarily increase CO_2 sequestration in long-lasting wood products (product sequestration), but this decreases the amount of carbon stored in forest biomass. Conversely, lower usage intensity would increase forest sequestration but would decrease substitution effects and sequestration in wood products. For this and other reasons, the political debate about forest management should not focus solely on climate change mitigation but should adopt a holistic view, taking account of the ecosystem as a whole, with its diverse ecosystem services, including the contributions made by forests to climate change adaptation.

- The **conservation and restoration of near-natural floodplains** are an example of potential synergies between biodiversity conservation and climate change mitigation, e.g. through the rewetting of carbon-rich alluvial soils. Furthermore, floodplains contribute to climate change adaptation by lowering flood peaks and reducing flood damage. Their other ecosystem services include reducing nutrient loads and improving habitat function for wildlife. Calculations for a programme for the renaturation of floodplains on the Elbe river show that taking these effects into account, economic benefits of € 1.2 billion and a benefit-cost ratio of 3:1 can be achieved.

- An economic analysis of the costs and benefits of **climate change adaptation in coastal regions** identifies a number of cost-effective and near-natural solutions for selected sites on the Baltic Sea. With managed realignment of dikes (depolderisation), it is possible, in some cases, to reduce spending on raising the height of dikes and dike maintenance and water management costs.

- The **economic value of nature's services** and the follow-up costs of ecosystem degradation and destruction have yet to be given adequate consideration in policy-making and business. Knowledge gaps and structures that impede more intensive use of multifunctional ecosystem-based solutions must be identified, with appropriate additions to the environmental policy toolbox. An important first step in this direction would be to set up a fund for the financing of ecosystem-based climate change mitigation and adaptation measures, with contributions coming inter alia from the private sector, e.g. through private trading of carbon allowances.

- **An international responsibility – a focus on Germany is not enough.** The globalisation of trade flows in energy resources, agricultural and wood products has impacts on climate regulation, environmental resources and biological diversity in the international context. German climate policy to some extent reinforces political and economic drivers that lead to substantial impairment of biodiversity and ecosystem services at the global level. Policy makers must continue to develop tools that identify and assess these impacts, so that they can be duly considered and mitigated via policy action.

1 HOW ARE BIODIVERSITY AND CLIMATE CHANGE LINKED?

Climate change and biodiversity loss, defined as species extinction, degradation of -> Ecosystems and loss of genetic diversity, are among the key problems of global change. Species extinction is progressing at a rate 100 to 1,000 times higher than the »natural« extinction rate without human interference [1]. It is feared that if this trend continues, around a third of all species on Earth may become extinct by the end of the 21st century. In Germany, 12 % are counted as high-risk species due to their climate sensitivity [2].

We do not yet know how this loss will affect our wellbeing and our economic development. There is concern, however, that this development – unique in the history of humankind – will have very significant negative repercussions on human wellbeing and living conditions. Braat and ten Brink [3] calculate that in 2050, the economic consequences of -> Biodiversity loss will correspond to a yearly GDP reduction of 7 %.

Anthropogenic climate change also has the potential to dramatically alter our living environment. In Germany, the mean annual temperature has risen by approximately 1°C in the last 100 years, and 2000–2009 was the warmest decade during this period. According to estimates presented in the IPCC Fifth Assessment Report (2013), the global temperature will rise by 0.3–4.8°C by the end of this century relative to the 1986–2055 reference period. Furthermore, according to the Report, global mean sea level rise of 26 to 82 cm, depending on the scenario, is likely by 2100. The consequences for human communities and wellbeing will be significant: according to estimates presented in the Stern Review [4], the costs of climate change will be 3–20% of global GDP each year by 2100.

Between these two global processes – climate change, on the one hand, and loss of biodiversity and ecosystem services, on the other – there are numerous linkages and interdependencies:

- **Climate change** is one of the main drivers of biodiversity loss [43]. It directly influences -> BIOLOGICAL DIVERSITY by changing the living conditions for animals and plants; moreover, it indirectly exerts influence through the design of climate policy (climate change mitigation or adaptation measures).

- The mitigation and adaptation measures taken within the **climate policy** framework are often associated with land-use changes (e.g. conversion of near-natural areas into land for energy production, construction of dikes), which also have an effect on biodiversity and the provision of ecosystem services. This can cause conflicts between climate policy and nature conservation/biodiversity policy goals.

- **Ecosystem-based climate policy**, by contrast, aims to make use of synergies between nature conservation and climate action and to prevent conflicts. The conservation and restoration of biodiversity and ecosystems can help to protect the climate by avoiding emissions and capturing carbon in plants and soil (mitigation) and support adaptation to climate change (see Box 1).

FIGURE 1
(photo: Pixelio.de)

BOX 1

Ecosystem-based climate policy – mitigation and adaptation

Measures for the avoidance of climate-damaging emissions, e.g. the conservation of carbon reservoirs and sinks, help to protect the climate; this is known as **mitigation** of climate change. However, even if the political goal of limiting global warming to a maximum of 2°C is met, major climatic changes will occur in many regions. For that reason, and in the interests of precaution, measures aimed at supporting **adaptation** to climate change are increasingly the focus of scientists' and policy makers' attention.

The concept of **ecosystem-based climate policy** is the further development of the ecosystem approach enshrined in the -> CONVENTION ON BIOLOGICAL DIVERSITY (CBD) adopted by the United Nations, which established guidelines for long-term sustainable ecosystem management. Ecosystem-based **climate policy** means avoiding or offsetting greenhouse gas emissions. This can be achieved by capturing carbon in biomass and soil (e.g. in forests or renewable raw materials) or by avoiding emissions through the conservation of natural carbon reservoirs (e.g. peatlands). Ecosystem-based adaptation aims to reduce ecosystems' and society's vulnerability to climate change and strengthen ecosystem resilience. This approach to **climate change adaptation** can complement or replace technical solutions (e.g. construction of dikes and floodwalls) with natural solutions such as the conservation or -> RENATURATION of natural floodplains.

FIGURE 2

Under water: the 2013 Elbe floods (photo: André Künzelmann, UFZ)

2 NATURAL CAPITAL, ECOSYSTEM SERVICES AND CLIMATE CHANGE: AN ECONOMIC PERSPECTIVE

Nature is inherently valuable, which should be reason enough to preserve it. In addition, the many and varied services that nature provides for human wellbeing (-> ECOSYSTEM SERVICES; see Box 2) have a significant economic value. These services, such as food production, regulation of the regional hydrological cycle and urban microclimate, and even the recreational benefits afforded to us by nature are economically significant. They enhance our quality of life and form the basis for numerous economic activities, and are therefore vital for our prosperity and wellbeing.

These reflections about the economic value of nature's ecosystem services are relevant in relation to climate change as well. Plants absorb greenhouse gas emissions from the air as they grow, and on carbon-rich soils such as peatlands, help to lock in emissions and form carbon reservoirs, reducing atmospheric CO_2. Forests help to regulate the temperature and protect against flooding during heavy rainfall. At high-montane sites, they help to prevent landslides. All these are ecosystem services of nature, protecting human communities and their assets and in some cases replacing or enhancing technical solutions such as dams and dikes.

BOX 2

Natural capital and ecosystem services

-> NATUR CAPITAL comprises nature with its diversity of species, communities and -> ECOSYSTEMS. Together with technical capital (machinery, production plants, etc.) and human capital (knowledge, labour), it forms the basis for wealth creation and prosperity. The various services provided by nature – known as ecosystem services – are prerequisites for the production of numerous goods and services; they also promote health and are therefore essential for our -> WELLBEING. Nature is a form of capital in an economic sense and its services can be regarded as a »dividend« for society. Maintaining the natural capital stock ensures that this dividend will be continuously available to future generations as well (see introductory brochure to »Natural Capital Germany – TEEB DE«).

Starting with the supporting services as the foundation for all subsequent services, and in line with the Millennium Ecosystem Assessment [43] referred to in the global TEEB study [5] and the Common International Classification of Ecosystem Services (CICES) now being developed [6], three distinct types of ecosystem services of direct or indirect benefit to human wellbeing can be identified:

- -> PROVISIONING SERVICES: These services involve the provision of material goods, such as food, fresh water, wood, fibre and biomass-based energy inputs;
- -> REGULATING SERVICES: Ecosystems provide services by regulating the climate and precipitation, protecting against floods and soil erosion, and capturing and breaking down pollutants.
- -> CULTURAL SERVICES: Natural landscapes, with their species richness and aesthetic appeal, form part of the national cultural heritage and identity. They have leisure and recreational value and are places for social interaction.

Whereas markets exist for many of the provisioning services, this is often not the case for regulating and cultural services. They are -> PUBLIC GOODS, which, without government regulation and economic incentives, are often not taken into proper account in decision-making, resulting in their overexploitation or impairment.

FIGURE 3 – 4 Mixed orchards: the 2008 harvest in the Bodensee-Oberschwaben region (photo: Ulfried Miller, BUND Ravensburg); beehive (photo: Jana Mänz, www.jana-maenz.de)

FIGURE 5 ▸ Fun in a field of dandelions
(photo: Paul Lehmann, UFZ)

In some cases, we only recognise the value of nature when the services concerned are impaired or cease entirely. For example, the costs of flood damage are often substantial because we have denied our rivers the space they need to move; the remaining floodplains lack adequate capacities to retain large amounts of water after heavy rainfall. This happens because decision makers are unaware of, or do not have to cover, the costs associated with the loss of nature and the services that it provides.

The aim of economic analysis is to uncover the hidden value of biological diversity and ecosystem services – the -> NATURAL CAPITAL – for human wellbeing and society and help to ensure that effective strategies and tools for the conservation of natural capital are implemented effectively and efficiently. The fact is that people only protect the assets that they value. By undertaking an -> ECONOMIC VALUATION, we can identify options for action to better integrate the value of nature into private and public sector decision-making.

For this report on »Natural Capital and Climate Policy«, three types of nature's services are of particular significance. They are illustrated in Box 3 with reference to forests:

- **Market-priced ecosystem services:** These are ecosystem services which are traded in the marketplace (e.g. food, wood) and are therefore already factored into consumers' and producers' cost-benefit decisions. The value attached to these services is generally based on their market price.

- **Climate-related ecosystem services:** These ecosystem services contribute to climate change mitigation and adaptation. The extent to which these services contribute to climate change adaptation depends on the type, condition and specific location of the ecosystem concerned. Their benefits include the avoidance of damage resulting from climate change. Various economic methods are available for their valuation (see below).

- **Other, non-climate-related ecosystem services:** These comprise further ecosystem services other than those relating to climate change mitigation and adaptation. Again, various methods are available for their economic valuation. These are described in the relevant sections of this report.

BOX 3

Forest ecosystem services

- **Market-priced ecosystem services:** Users of wood derive a benefit from its use, e. g. for furniture or fuel, and are willing to pay for it. The sale of the wood generates revenue for forest owners.

- **Climate-related ecosystem services:** The contribution made to climate change mitigation depends on the quantity of greenhouse gas emissions that the forest captures and withdraws from the atmosphere. Forests also contribute to climate change adaptation, e. g. by preventing flooding or protecting against landslides.

- **Other, non-climate-related ecosystem services:** Forests provide many other services as well: non-wood forest products (honey, mushrooms, natural medicinal substances), stabilisation of the hydrological balance, a pleasant environment for walkers, recreation for holidaymakers, habitats for flora and fauna, inspiration for creativity, a starting point for environmental and forest education, etc.

Against this background, an economic perspective on climate and energy policy and natural capital aims to create more transparency by looking beyond purely private economic factors and identifying the **social costs (e. g. the costs of flood and storm damage) and, above all, the social benefits** of ecosystem services. This report focuses particularly on ecosystem services of relevance to climate change mitigation and adaptation and pursues three objectives:

- Firstly, the analysis will identify nature's services for the **avoidance of greenhouse gas emissions** (conservation of carbon reservoirs and, if possible, enhancement of sink performance) and for **adaptation of ecosystems** to climate change.

- Secondly, by comparing the economic values of climate-related ecosystem services and other non-climate-related ecosystem services, the aim is to uncover **synergies** and **conflicts** between climate policy and nature conservation/biodiversity policy.

- Thirdly, recommendations for **ecosystem-based climate change mitigation** and **ecosystem-based adaptation strategies** will be presented.

In order to illustrate the social costs and benefits of these services, it is necessary to apply sound environmental valuation methods whose development in the recent past has made the economic valuation of non-market services possible. Ecosystem services for climate change mitigation are of particular interest for the purpose of this report. Depending on the specific issue to be addressed, the following methods can be applied to put a value on these services: an orientation towards the price of carbon allowances in the EU Emissions Trading System (EU ETS), avoidance costs, the public's -> Willingness To Pay, or avoided costs of climate-related damage (see detailed analysis in Chapter 2 of the unabridged version of this report). As damage caused by climate change is long-lasting and affects the entire globe, discounting and weighting of international damage play a key role in determining avoided damage costs; however, a consensus has yet to be reached on these particular issues.

FIGURE 6
Hainich National Park, 2013
(photo: Paul Lehmann, UFZ)

3 IMPACTS OF CLIMATE CHANGE AND CLIMATE POLICY ON ECOSYSTEM SERVICES AND BIODIVERSITY IN GERMANY

Climate change has direct and indirect impacts on -> BIOLOGICAL DIVERSITY. Direct impacts mean the effects of climatic parameters, such as changing temperatures and rainfall patterns, on -> BIODIVERSITY, whereas indirect impacts result from mitigation and adaptation measures adopted within climate and energy policy.

Impacts of climate change on biological diversity

The geographical distribution of flora and fauna is constrained not only by the availability of suitable habitats but also by climatic parameters. Small- or large-scale changes in climatic conditions affect the composition of flora and fauna in an -> ECOSYSTEM, and this in turn has repercussions for the interaction between species and the processes and products – i.e. the ecosystem services – that benefit human wellbeing.

Box 4 provides an overview of the various causal linkages in Germany. It should be noted that previous damage to ecosystems (e.g. drainage of wetlands, fragmentation of habitats, eutrophication) can amplify the impacts of climate change on biodiversity.

Although ecosystems are changing due to the effects of global warming, they can continue to provide important ecosystem services as long as they maintain a certain level of resilience and adaptability.

BOX 4

Impacts of climate change on ecosystems and species diversity in Germany

In Germany, climate change is likely to lead to higher mean annual temperatures, less rainfall in summer, and more precipitation in winter, albeit with regional variations. The frequency and intensity of extreme weather events are also expected to increase, although the scale of this has yet to be determined [7]. Climate change is causing sea levels to rise and increases the likelihood of higher storm surges. All this will have various effects on species diversity and biological interactions, and on ecosystems and their use (see, for example, [8, 9]):

- **Ecosystems and soils used for agriculture:** The reduction in water availability adversely affects agriculture in Germany's central uplands (Mittelgebirge) and Alpine regions and in eastern Germany. Higher temperatures result in a longer growing season, with a shift in sowing and harvesting times, which may create more favourable conditions for agricultural production. In addition, higher atmospheric carbon dioxide (CO_2) concentrations have a fertilisation effect on plants. However, shifts in the ranges of certain species may cause problems by encouraging the occurrence of (new) pests and diseases. Heat stress and water shortages could have a particularly adverse effect on carbon-rich peatlands whose hydrological balance is disrupted, resulting in higher greenhouse gas emissions. Heavy rainfall events on exposed vegetation-free soils can cause substantial erosion damage.

- **Forest ecosystems:** Higher temperatures can increase forest biomass, but stands may also be increasingly at risk from heat, drought, forest fires, breakage and (new) pests. Higher atmospheric carbon dioxide (CO_2) concentrations and longer growing seasons may have a positive effect on growth, but might also change physiological properties. The net effect on raw timber production and other forest ecosystem services is largely unclear.

- **Rivers and floodplains:** Floodplains are likely to be affected by decreased water availability in summer and more frequent flooding in winter. Changes in rainfall patterns, i.e. the intensity, duration and timing of rainfall, may worsen the flood risk in some river basins in Germany. Reduced water levels in streams and rivers during the summer months, on the other hand, may lead to changes in the composition of species communities, e.g. losses of filter feeders, and thus to a decrease in water quality. Other adverse impacts could include a decline in the cooling function of rivers and their navigability.

FIGURE 7 More frequent droughts may occur in some regions as a result of climate change, leading to changes in ecosystem services (photo: Pavel Klimenko, Fotolia.com).

- **Seas and coasts:** Water temperatures in maritime areas and tidal flats will generally increase, which is likely to cause changes in the plankton, benthic, fish and bird populations. Sea level rise could reduce the size of tidal flats and the bird populations which depend on them. Marshes and low-lying areas behind the dikes, some of which are well below sea level, will have to be drained at increasing costs in order to protect settlements. The formation of peatlands and shallow lakes will result in changes in agriculture, settlement structures and landscape appearance. Climate change could also shift the ranges and composition of species. The fishing industry may well have to adapt, therefore, to changes in commercially viable fish stocks in future.

- **Biological diversity:** Climate change will affect biological diversity at the level of habitats, species and genetic diversity. Typical adaptations to climatic changes already observed in the life cycles of fauna and flora are earlier flowering of plants, longer growing periods, and the earlier arrival of migratory birds. As every species reacts differently to climate change, ecological interactions may be disrupted. Shifts in species distribution areas can also be observed, with the spread of species from the south and the incursion of new and in some cases invasive species.

Impacts of climate and energy policy on biological diversity

In Germany, energy consumption by power plants, industry, transport and private households is the main source of climate-damaging greenhouse gases (see Figure 8). Policy measures such as subsidies on certain fuels and transport in some cases make matters worse. Agriculture accounts for just 8 % (or 11 %, including emissions from carbon-rich farmed (peat)lands and the conversion of grassland into cropland) of Germany's gross emissions. However, as an ecosystem-based approach to climate change mitigation starts with land use-based emissions, this report also focuses on agriculture.

Climate policy and the phase-out of nuclear power will be key factors determining Germany's future land use. Germany aims to phase out fossil fuels in nearly all of its electricity production by 2050 and increase energy efficiency. The use of renewable energies, such as biomass, wind power and photovoltaics, and the expansion of electricity grids will play an important role in replacing fossil fuels. In 2012, renewables already accounted for a one-eight share of total final energy consumption in Germany (12.6 % in February 2013), which was more than twice the 2004 figure [10]. This avoided more than 130 million tonnes of greenhouse gas emissions (CO_2 equivalents = CO_2e) in 2011 alone (see Chapters 3 and 4 of the unabridged version).

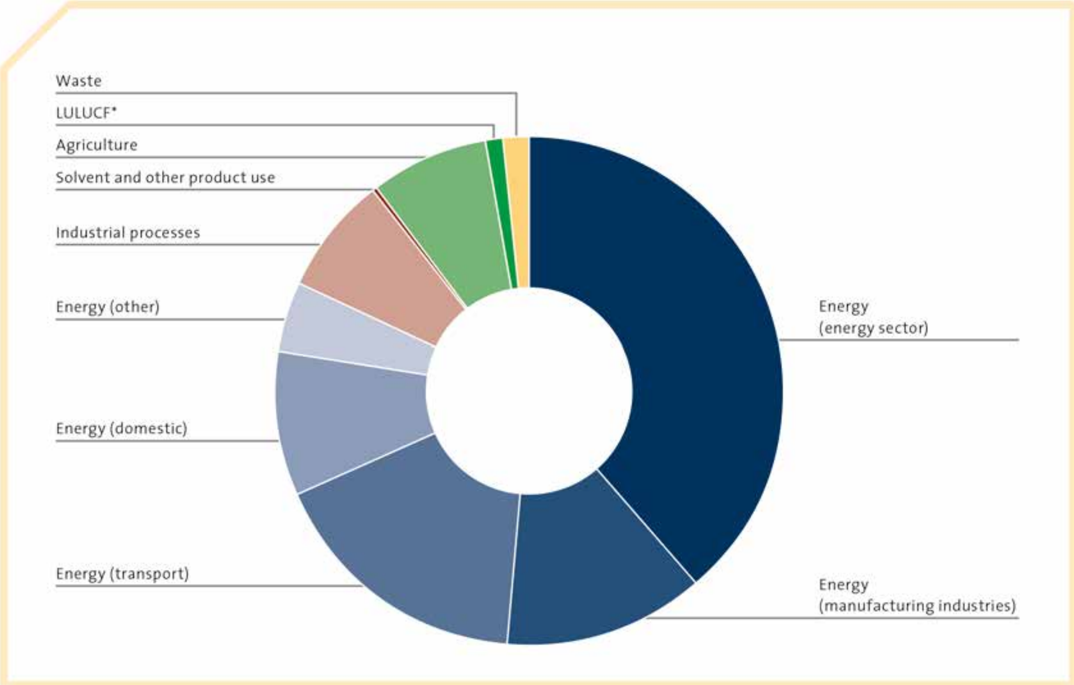
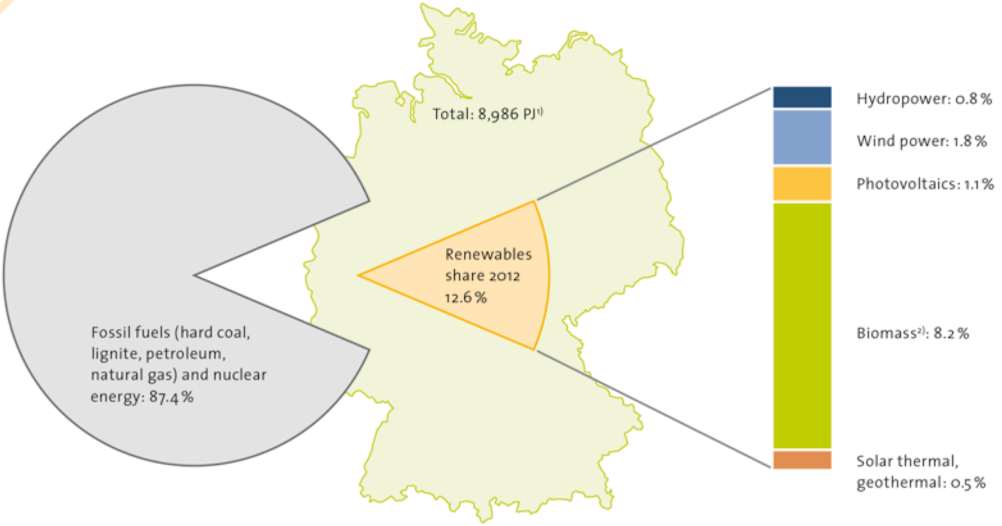


FIGURE 8 German greenhouse gas (GHG) emissions by sector (data for 2011, Federal Environment Agency (UBA) 2013); * LULUCF = Land Use, Land Use Change and Forestry, includes CO_2, N_2O and CH_4. In the LULUCF sector, emissions from agricultural soils, mentioned in the text, are offset against forest sequestration, for example.

Biomass currently plays an important role, accounting for 65.5% of final energy consumption from renewables, followed by wind power (16.7%). These two energy sources – biomass and wind – thus account for around 80% of renewable energy in Germany. Hydroelectric power, photovoltaics, geothermal and solar thermal energy each account for a relatively small share (see Figure 9). It is also significant that more than 50% of renewable energies in Germany are based on biogenic solid fuels (mainly wood). Primarily a source of heat energy, wood yields 120 TWh (terawatt-hours = 1,000,000,000 kilowatt hours) annually, making it the most significant renewable energy, well ahead of wind power, which is utilised in the electricity sector and provides 46 TWh.

The expansion of electricity generation from renewables does more to avoid greenhouse gas emissions than renewables expansion in the heat sector. In Germany, the contribution made by wind power to emissions avoidance is therefore roughly equivalent to that achieved through the use of wood as an energy source.



1) Source: Working Group on Energy Balances (AGEB); **2)** Solid and liquid biomass, biogas, landfill and sewage gas, biogenic share of waste, biofuels; source: BMU – E I 1 based on Working Group on Renewable Energy Statistics (AGEE-Stat) and ZSW, using data from AGEB; 1 PJ = 10^{15} joules. NB: Any discrepancies in totals are due to rounding. Version: February 2013; provisional data.

FIGURE 9 ▸ Share of renewables in final energy consumption in Germany, 2012 [10]

Germany aims to achieve a further substantial increase in the renewables share of final energy consumption, with a target of 18 % by 2020 [11, 12] (see Table 1); at the time of writing, however (December 2013), it seems set to achieve 19.8 %. Over the coming years, the electricity sector will be the main priority for renewables expansion. There are limits, however, to the potential growth that can be achieved in biomass, largely due to land-use competition in the agricultural sector and the limited availability of forest biomass. The supply of energy according to need is gaining in importance, which requires not only bioenergy carriers but also various storage technologies and grid connections, which may also have an impact on land use.

Conflicts between energy transition *(Energiewende)* and other social objectives, but also with some climate change mitigation and adaptation goals, arise inter alia from the requirement for land for the provision of renewable energy carriers and related infrastructure. At present, energy crops are grown on more than 2.1 million hectares of arable land [13], with a further 200,000 hectares of land occupied by wind farms and 2,500 hectares by free-standing solar energy installations [14]. However, the potential energy yields and qualities of the sites currently in use vary considerably (see unabridged version, Chapter 3).

Negative effects on biological diversity can arise as a direct result of land-use changes, e.g. the conversion of grassland into farmland for the cultivation of energy crops, but can also be caused indirectly through the intensification of use as a consequence of increased demand for products and production areas (see Chapter 4.1). Other conflicts with ecosystem services can result from the increased use of fertilisers in agriculture (water and air pollution, greenhouse gas emissions), soil sealing, and impairment of landscape appearance.

TABLE 1
Climate and energy policy targets in Germany to 2050 [11]

YEAR	CLIMATE	RENEWABLE ENERGIES	
	Greenhouse gas emissions compared with 1990	Share of electricity	Share overall
2020	-40 %	35 %	18 %
2030	-55 %	50 %	30 %
2040	-70 %	65 %	45 %
2050	-80 bis -95 %	80%	60%

Key factors determining the potential side effects of increased renewable energy use are the specific site and the environmental, social and economic conditions in the locality. As bioenergy villages and energy cooperatives show, there is considerable potential for nature-compatible development in rural regions [15]. However, conflicts can arise with local residents and nature conservation objectives. The current system of support for renewable energies, which is partly based on flat rates, often fails to take site-specific factors into account and should therefore be underpinned by regional strategies, developed in consultation with local communities and respecting nature conservation goals. In this context, the opportunities for ecosystem-based climate mitigation programmes should be utilised, with greater use being made of green cuttings and waste from landscape management, for example.

4 CLIMATE POLICY THROUGH INVESTMENT IN NATURAL CAPITAL

4.1 AGRICULTURE: REDUCING EMISSIONS, AVOIDING PLOUGHING UP GRASSLAND, USING BIOENERGY SUSTAINABLY

Background

As the largest land user, covering more than 50 % of Germany's total area, **agriculture** has considerable influence on land use and related climate functions. Agriculture produces greenhouse gas (GHG) emissions and thus contributes to global warming, but it is also one of the sectors most impacted by climate change. With approximately 105 million tonnes of carbon dioxide equivalents (Mt CO_2e), agriculture directly causes 7.7 % (11 % if agricultural soils are included) of Germany's total GHG emissions (i.e. methane and nitrous oxide emissions and CO_2 from agricultural land use/land-use change). In addition, agriculture is responsible for other, mainly indirect emissions resulting from the production of inputs such as mineral fertilisers and imported animal feed. Although current farming practices in Germany offer potential to reduce GHG emissions, agriculture and the provisioning of economically relevant services (e.g. food growing, landscape appearance) always produce some unavoidable emissions.

To date, agriculture has not played a prominent role in German **climate policy**. A mitigation strategy for the agricultural sector, with quantitative targets, does not yet exist. By contrast, considerable progress has been made on strategies to promote bioenergy. They aim to reduce GHG emissions in the energy sector, but may lead to higher production-related emissions from agriculture and land use. In the medium term, it is likely that policy makers will expect more intensive climate change mitigation efforts from agriculture as well.

As regards **land-use change**, the amount of land used for human settlement and transport purposes in Germany is increasing, largely at the expense of farmland. From 2000 to 2010, Germany lost more than 35,000 hectares of farmland every year. Since the mid 1990s, however, the loss of arable land to new settlements and transport infrastructure has been compensated for by the conversion of grassland into cropland (see unabridged version, Chapter 4).

The issue

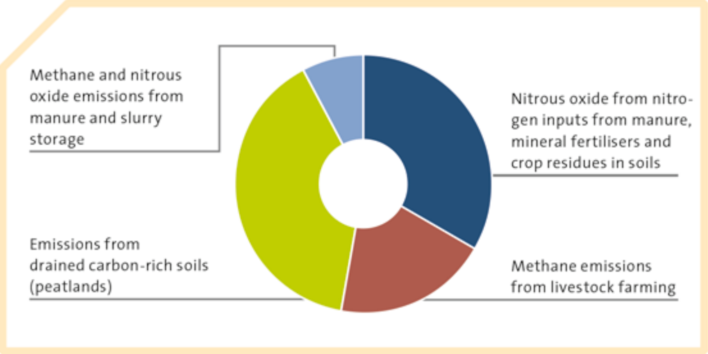
On balance, then, the loss of farmland mainly consists of a **decrease in the amount of permanent grassland** [16]. In terms of climate goals, this is a worrying development. Grassland soils are significant carbon reservoirs. When grassland is converted into cropland, part of the carbon is released and emitted as CO_2. The loss of land for food production as a result of the expansion of the area covered by settlements and the transport infrastructure can lead to further land-use changes and intensification of production on the remaining arable land, with adverse effects on the climate and other -> ECOSYSTEM SERVICES elsewhere.

In 2010, **emissions from agriculture** amounted to around 105 million tonnes of carbon dioxide equivalents (Mt CO_2e) – approximately 11 % of Germany's gross emissions. Four sources of emissions are particularly significant [17]:

- Nitrous oxide from nitrogen inputs caused by manure, mineral fertilisers and crop residues in soils (34.6 Mt CO_2e),
- Methane emissions from digestion processes in livestock farming (20.3 Mt CO_2e),
- Methane and nitrous oxide emissions from manure and slurry storage (7.8 Mt CO_2e), and
- Emissions from drained carbon-rich soils (peatlands; see Chapter 4.2). These produced 41 Mt CO_2e of emissions (mainly carbon dioxide, but also nitrous oxide) in 2010 and thus accounted for 4.3 % of Germany's total GHG emissions.

The use of peatlands for arable farming or as grassland is therefore a particularly potent source of emissions (see Figure 10). Other GHG emissions come from the liming of farmland and the conversion of grassland into cropland.

FIGURE 10 ▸ GHG emissions from German agriculture, based on emissions reporting, in Mt CO_2e, for 2010 [17].



Agricultural biomass can be used in energy production, replacing other energy carriers. The resulting GHG reductions are not attributed to the agricultural sector but are indirectly visible in the energy sector. The release of carbon dioxide (CO_2) from the burning of agricultural biomass is not included in national GHG reporting as it comes from carbon that was previously captured in biological materials.

Encouraging the intensive cultivation of annual crops, such as maize and rapeseed, as energy crops has a number of disadvantages. Firstly, the expansion or intensification of agricultural production is likely to cause additional adverse environmental impacts, e.g. as a result of nutrient loads, reduction in crop rotation, and increased application of pesticides. Secondly, sources of biomass produced in this way are far less favourable, from a climate perspective, than wood biomass or multiannual energy crops, as the additional emissions from inputs and fertiliser use have a negative effect on the balance sheet. Furthermore, with biofuels and biogas based on maize, the CO_2 avoidance costs amount to well in excess of € 100/t CO_2e [18].

Emissions from livestock farming account for a major share of agricultural GHG emissions in Germany [19]. Direct emissions from livestock production mainly consist of methane from the digestion process in ruminant animals, nitrous oxide emissions from nitrogen excretion in livestock husbandry, and methane and nitrous oxide emissions from storage of manure. A substantial proportion of these emissions is directly related to grassland use, which in Germany mainly consists of grazing by ruminants (cattle, sheep, goats, etc.). The potential for climate-optimised ruminant nutrition is subject to physiological constraints. Emissions from the storage of manure and slurry,

FIGURE 11 ▸ Maize: an energy crop for biogas and E10 (photo: hjschneider, Fotolia.com)

by contrast, can be avoided by fermentation in a biogas plant and subsequent storage in a gas-tight tank. Research studies have not yet determined conclusively whether outdoor grazing of ruminants is more beneficial, from a climate perspective, than year-round indoor housing [19; 22].

Options for action

Opportunities for reducing greenhouse gas emissions from agriculture (besides the rewetting of farmed peatlands; see Chapter 4.2) arise primarily in relation to grassland conservation, but reductions can also be achieved through more efficient agricultural production and by optimising biomass production in order to achieve climate and nature conservation gains.

Conservation of grasslands: The conservation of much of the grassland found in Central Europe depends on its use by human communities, primarily for livestock farming. The main areas of grassland use are found in coastal marshland, fluvial plains, former peatlands, and central upland and Alpine areas which are unsuitable for arable farming. In view of the diverse ecosystem services provided by extensively used grassland in particular [20], the conservation of grasslands is now a priority in the protection of the environment and water resources within EU agricultural policy and regional contractual nature conservation programmes.

From a climate perspective, the conservation of grasslands is extremely important, as it avoids the CO_2 emissions that would otherwise be produced from land-use change, e.g. the conversion of grassland to cropland (see Figure 12). A study by Reutter and Matzdorf [21] shows that the use of species-rich grassland, classed by the EU as high nature value (HNV) farmland, for arable farming would emit 88–187 t CO_2/ha in Germany. Conversion of 5 % of the existing HNV stocks (52,532 ha) would cause climate damage costing € 435.8 million annually [20].

FIGURE 12 ▸ Cropland and grassland (photo: Gerd Ostermann, NABU)

Extensification or »sustainable intensification«? Extensification of production undoubtedly reduces land use-related greenhouse gas emissions. Whether it also improves product-related burdens is a contentious issue in the research community [22]. Extensification of agricultural production, as practised in organic farming, for example, results in reduced use of pesticides and mineral fertilisers and lower stocking densities than conventional farming. This is desirable from a nature conservation and environmental perspective, but also decreases agricultural productivity and increases land requirements compared with conventional farms [19].

Organic farming offers other climate benefits: in particular, it reduces energy use and promotes carbon sequestration in soils [23]. Cereal yields of organic farms in Germany are around 50 % lower on average than the output of conventional farms, but organic farms often achieve higher profits per worker [24] – excluding external costs but including agri-environmental premiums for organic farming. The use of nitrogen-based mineral fertilisers is banned in organic farming. To meet the soil's nitrogen needs, therefore, it is necessary to plant nitrogen-fixing legumes, e. g. clover grass, on arable land. Together with lower yields, this additionally increases the land requirement in organic farming. Nonetheless, organic farming offers many other environmental benefits, notably for the attainment of nature conservation and water resource protection goals. For that reason, promoting this system of agriculture is a sensible approach, especially in protected and environmentally sensitive areas.

As there is not an infinite supply of farmland available worldwide, -> OPPORTUNITY COSTS of land-use decisions arise in relation to climate change mitigation. For example, if high productivity is achieved, this in theory frees up a certain amount of land which can be utilised in a manner that delivers substantial climate and nature conservation benefits. Certainly, the pressure to use the land decreases. So in terms of reducing agriculture's climate footprint and net impacts, taking account of probable global »carbon leakage«, it is clear that extensification per se does not automatically qualify as an appropriate measure for protecting the climate.

In Germany, around 6 % of the total utilised agricultural area is currently farmed organically. Conventional agriculture therefore has an important role to play in reducing greenhouse gas emissions from farming. An important entry point is improving nitrogen fertiliser use in order to reduce nitrogen surpluses [19]. Due to the substantial contribution of nitrogen to greenhouse gas emissions – around 34.6 Mt CO_2e – this aspect is extremely important. Nitrous oxide emissions from nitrogen turnover in the soil during crop production can only be partially reduced, however, and can never be avoided completely. Reducing nitrogen other than by reducing surpluses could lead to »carbon leakage«, e.g. intensification of production elsewhere, or indirect land-use changes.

Optimising biomass production with respect to climate change mitigation and nature conservation: By optimising production of biomass for energy generation with respect to climate protection and nature conservation, an effective contribution can be made to climate change mitigation. As the prerequisite, however, the GHG balance of biomass cultivation must be smaller, even applying a broader definition of system boundaries, than that of the fossil energy carriers being replaced. With a combination of food and bioenergy production, significant bioenergy potential can be tapped [23]. The impacts of biomass cultivation-related land-use change on -> BIODIVERSITY and ecosystem services (e.g. soil fertility, soil carbon storage) must also be factored into biomass accounting.

Energy biomass production can be aligned more strongly to the needs of the environment if other crops are also used and if it is combined with climate targets and conservation of other ecosystem services. Examples are paludiculture (farming on wet peatlands; see Chapter 4.2), cultivation of wild plant mixtures, fermentation of waste from landscape management and grassland residues (Box 5), and nature-compatible planting of short-rotation coppices (Box 6).

FIGURE 13 ▸ Feeding a dry fermentation biogas plant with waste from landscape management (photo: Wulf Carius, BUND)

BOX 5

Energy production using waste from nature conservation and landscape management (meadows)

Species-rich meadows, which were mown twice a year, were once a common source of fodder in livestock farming. Species-rich meadows and pastures are the basis for a very large percentage of Germany's biological diversity and are classed as high nature value (HNV) grassland. However, today's high-producing cattle are so strongly adapted to high-energy feed that vegetation from meadows that are mown twice a year does not provide adequate nutrition for them, other than in the growth phase, when it may under certain circumstances be suitable. To achieve maximum productivity, these cows require energy-rich residues from meadows that are mown several times a year and tend to be species-poor, or feed concentrate, which is often imported.

Species-rich meadows that are mown twice a year are therefore in steady decline and are now classed as endangered biotopes. Various agri-environmental programmes pay compensation to farmers who conserve these sites by adopting appropriate management regimes. A growing problem, however, is what to do with the residues that must be removed from the meadows in order to maintain their species diversity.

One solution is to use the residues from the twice yearly mowing of species-rich meadows as a feedstock for biogas plants. The German Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz* – EEG) provides bonuses for the utilisation of »waste from landscape management«. Although this waste is not a particularly suitable or competitive biogas fermentation substrate, initial experience shows that utilising residues from species-rich meadows as a biogas feedstock cuts management costs and in some cases is economically viable even without additional premiums (www.mulle.lpv.de). Furthermore, no land-use competition arises between this form of nature conservation-oriented bioenergy production and food growing (»food versus fuel«). The German Association for Landcare (*Deutscher Verband für Landschaftspflege* – DLV) estimates the potential area for this type of energy production at 900,000 ha; [25]; currently, only a fraction of this is being used.

BOX 6

Short-rotation coppices (SRC) in alley cropping systems

Short-rotation coppices (SRC) are stands of fast-growing trees, such as varieties of poplar and willow, planted on farmland, with a harvesting cycle (i. e. the period from the establishment of new stands to harvesting) of three or more years. After harvesting and drying, the growth can be utilised as solid fuel (wood chips). Short-rotation coppices offer climate benefits, for depending on site conditions and management regime, they can increase soil carbon content and replace fossil fuels; with a relatively extensive management regime, the coppices themselves require little energy input. As the establishment of short-rotation coppices can in some cases have negative impacts on biological diversity and on landscape appearance and the -> NATURAL BALANCE, cultivation regimes that create as many positive synergies as possible should be selected.

One of these regimes involves the planting of short-rotation coppices in alley cropping systems on arable land. Fast-growing trees are planted in rows spaced at specific intervals, and annual arable crops are grown between them [26]. The system offers various benefits compared with pure arable farming, notably erosion control. Wind erosion can cause substantial soil losses. In Mecklenburg-Western Pomerania, for example, as much as 3 % of topsoil is being lost to erosion every year. This is irreversible and causes economic losses of € 4–6 per tonne of soil [27], which can amount to more than € 700/ha per year. In addition, erosion causes direct damage by injuring, uprooting and destroying crops. This drives up the costs for farmers, who may have to retill or replant the fields. Short-rotation coppices in alley cropping act as windbreaks, avoiding or minimising these costs. Other potential benefits in cleared and farmed landscapes include increased recreational value, as woodland provides additional structure in the landscape, making it more diverse, interesting and pleasing to the eye. Short-rotation coppices should not generally be planted on grassland as they can cause sustained and negative changes and can destroy these ecosystems' functions as habitats for certain species.

FIGURE 14 A short-rotation coppice (Japanese poplar): field trial (photo: Helge May, NABU)

4.2 PEATLANDS AND CARBON-RICH SOILS: REWETTING AS A CLIMATE INVESTMENT

Background

Peatlands and other carbon-rich soils are vitally important in protecting the climate, the hydrological balance and biodiversity. Undisturbed peatlands are the only terrestrial ecosystems that accumulate carbon continuously and store it over long timescales; this is because water-saturated soils slow the decay of dead plant material, resulting in a build-up of organic matter. Peatlands are Germany's largest terrestrial carbon reservoir, sequestering 1,200–2,400 million tonnes of carbon (approx. 4,300–8,600 t CO_2e). Conserving this carbon reservoir makes an effective and sustainable contribution to climate change mitigation.

Carbon-rich soils include all peatlands as well as several other soil types, irrespective of their current land use. Depending on the definition applied, they cover 1.4–1.8 million hectares, i.e. approximately 4–5 % of Germany's land-surface area, and account for 8 % of land used for agricultural purposes.

The issue

Drained peatlands are significant sources of climate-damaging greenhouse gases. Draining peatlands for agriculture and forestry lower the water table and expose soils to the air. The carbon that has accumulated over centuries or millennia then binds with oxygen (oxidation) to form carbon dioxide. This is then continuously released into the atmosphere. More than 95 % of Germany's former peatlands have been drained for agriculture and forestry and, to a lesser extent, for peat extraction.

FIGURE 15 ▸ Beestland – a peatland in the Peene river valley (photo: Dominik Zak, Leibniz-Institute of Freshwater Ecology and Inland Fisheries)

Drained peatlands that are no longer in a natural state therefore have considerable climate relevance. They are a continuous source of emissions, releasing around 41 Mt CO_2e per year and accounting for approximately 39 % of emissions from German agriculture and 4.3 % of Germany's gross total annual GHG emissions [17]. Germany thus has Europe's highest total emissions from farming on peatlands [28]. However, relatively cost-effective options are available for rewetting these soils, with a high long-term savings potential of around 35 Mt CO_2e per year [29].

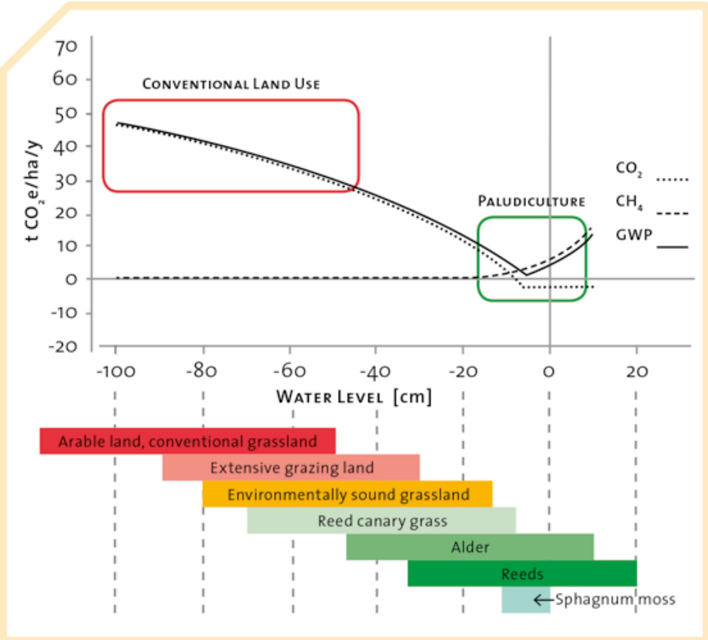


FIGURE 16 ▸ Greenhouse gas emissions (excluding N_2O) and options for the agricultural use of peatlands, depending on mean water level. Raising the water level to just below the soil surface substantially reduces GHG emissions but requires the use of new crops (paludiculture, e. g. reeds and alder on wet land; see Box 8); GWP = global warming potential, or sum of CO_2e; dotted curved line: CO_2 emissions; dashed curved line: methane emissions (CH_4) in CO_2e/ha/y; unbroken curved line: sum of CO_2 and CH_4 emissions in CO_2e/ha/y. (Source: Sabine Wichmann, own graphics, adapted from [30, 31], options for agricultural use based on [32])

The position of the water table is the most important factor influencing the greenhouse gas emission rates from peatlands (Figure 16). The following correlations are relevant here: CO_2 and nitrous oxide (N_2O) emissions increase as the water level falls, depending on land use, vegetation, and use of fertilisers. The smallest climate impact occurs at a water level of up to 10 cm below the surface. During long-term submergence (10 cm above the surface) in summer, the climate impact increases due to the release of methane (CH_4). This dependence of gas fluxes on water level and vegetation is used to calculate greenhouse gas emissions and estimate the ecosystem services for climate change mitigation that can be achieved by raising the water level. If this GHG quantification is possible, economic instruments, e.g. carbon allowances under schemes such as MoorFutures (see Box 9), can be applied. The potential reductions from the application of these methods are, on principle, estimated very conservatively.

The various land-use options for peatlands create diverse synergies and conflicts between ecosystem services. Conventional agriculture is not suitable for peatlands. In particular, maintaining peatlands in a drained state in order to grow maize for biogas production produces more greenhouse gas emissions than fossil fuel use (see Box 7).

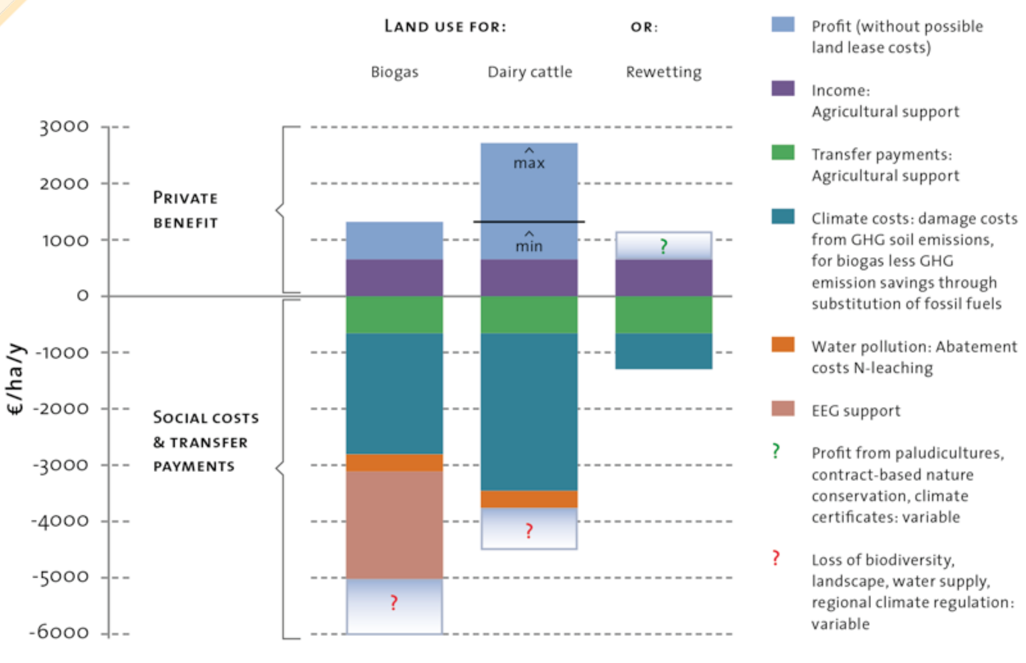
BOX 7

Costs and benefits of arable farming on peatlands
by Augustin Berghöfer and Norbert Röder

A perspective on ecosystem services reveals the various costs and benefits of land use. Figure 17 presents the findings of a commercial gain vs. social cost analysis, with reference to North-West German peatlands. Three variants are compared: a drained peatland used to grow biogas feedstocks; a drained peatland used to grow maize as feed for dairy cattle; and a rewetted peatland.

Electricity from energy crops generates commercial revenue, but the social costs and subsidies are around four times higher. Electricity

FIGURE 17 Private benefits, social costs and subsidies for land use on drained peatlands in Lower Saxony. Estimates in €/ha/y for biogas electricity from energy crops, maize cultivation for dairy cattle fodder, and rewetting for nature conservation/climate change mitigation, with paludiculture if appropriate. For the commercial perspective (private gains), economic efficiency



EEG = Renewable Energy Sources Act *(Erneuerbare-Energien-Gesetz)*
Source: Berghöfer and Röder (2014), authors' own analysis.

production from energy crops grown on peatlands clearly damages the climate, as draining the peatlands for energy crop cultivation produces far more emissions than are avoided through the substitution of fossil fuels. Here, government incentives have a counterproductive effect. As the example of dairy farming shows, arable farming on peatlands, even without EEG subsidies, generates significant private gains due to the currently high world market price of milk and high productivity.

Intensive farming of peatlands is also associated with high social costs. Greenhouse gas emissions from drained peatland soils are the main problem. The same applies to intensive grassland use, which is widespread on peatlands.

So from a commercial perspective, rewetting, possibly combined with site-appropriate farming (paludiculture, see Box 8), is not an attractive option compared with arable farming under present conditions. From a societal perspective, however, it is by far the best use of peatlands, as it has a less harmful effect on the climate and water resources and enhances, not harms, other ecosystem services in many cases. The use of peatlands will only meet the needs of society, however, if there is more coherence between regulatory frameworks and funding policy, and site-specific ecosystem services and negative impacts are taken into account.

calculations for model enterprises were used. Agricultural support is provided for rewetted sites only if they continue to be eligible for aid. (Source: Augustin Berghöfer and Norbert Röder, authors' own analysis; for details and references, see Chapter 5, unabridged version)

Options for action

To reduce emissions from peatlands, action is required in three areas:

- **Protection of near-natural peatlands** in order to safeguard the soil carbon reservoir and avoid future emissions;

- **Extensification and environmentally compatible use:** Conversion of agriculture on peatlands from arable farming and intensive grassland to wet »managed grassland« or paludiculture (Box 8) with higher water levels, to be achieved by reducing the effective depth of drainage channels;

- -> RENATURATION through complete rewetting, possibly accompanied by vegetation management measures.

Long-term restoration of drained peatlands to a near-natural state, through rewetting, renaturation and, if appropriate, environmentally compatible use, makes a significant contribution to climate change mitigation. Drained and farmed peatlands produce such high land use-related emissions that the net effects of the expected carbon leakage (intensification of production elsewhere, etc.) from the

BOX 8

Paludiculture –
Alternative farming methods on wet and rewetted peatlands
by Sabine Wichmann

Paludiculture on wet and rewetted sites can safeguard the comprehensive ecosystem services provided by peatlands. -> REGULATING SERVICES, such as nutrient filtering and long-term carbon sequestration in peat, are similar to those provided by natural peatlands. -> PROVISIONING SERVICES are supplied at the same time. Wet cultivation techniques are applied to grow crops such as peat moss, a high-quality raw material for culture substrates in commercial horticulture, reeds and sedges as building materials and energy crops, and alder, a source of high-quality timber. Paludiculture (www.paludikultur.de) is a beneficial alternative form of use which creates synergies for the climate and environment and, if utilised on degraded peatlands, offers nature conservation gains as well. Calculations of energy recovery from fen biomass show that rewetting peatlands makes sense from an environmental and an economic perspective [32].

FIGURE 18 ▸ Paludiculture (photo: Wendelin Wichtmann, Western Pomerania Paludiculture Initiative – VIP)

cessation of farming at these sites are negligible. Rewetting can create synergies with nature conservation and the protection of soils and water resources. Wüstemann et al. [33] calculated that a programme of measures to implement the National Strategy on Biological Diversity in Germany on more than 300,000 hectares of peatland would avoid climate damage amounting to € 217 million annually (based on the authors' assumed damage costs of € 70/t CO_2). New instruments that contribute to the rewetting of peatlands, such as MoorFutures, are therefore to be welcomed (see Box 9).

BOX 9

Innovative financing for peatland rewetting: MoorFutures
by Thorsten Permien

Drained peatlands are the single most important source of GHG emissions in Mecklenburg-Western Pomerania, currently accounting for 6.2 Mt CO_2e per year [34] – more than the emissions from transport. The Ministry of Agriculture, Environment and Consumer Protection of Mecklenburg-Western Pomerania (LUMV), in consultation with landowners and land users, therefore aims to rewet peatlands. A particular focus is set on the potential of alternative sustainable forms of land use that are viable when water levels are raised. Whereas a drained, intensively farmed peatland emits around 18–40 t CO_2e per hectare per year on average [17], rewetting can reduce these emissions by 10–20 t [35].

Targeted conservation measures on around 30,000 hectares of peatland in 2000–2008 substantially reduced greenhouse gas emissions. The social benefits lie primarily in avoided climate-related damage, the costs of which run to tens of millions of euros every year, according to a study by the University of Greifswald [35].

So that companies have a chance to invest in a better future through climate change mitigation, the »MoorFutures« scheme, launched in 2011, offers carbon credits from peatland rewetting via the voluntary carbon market (www.moor-futures.de). One MoorFuture corresponds to one tonne CO_2e saved. The MoorFutures standard is based on the principles of the Verified Carbon Standard (VCS). As many of the legal bases for the scheme are already established in German law, implementing the MoorFutures standard is much more cost-effective and pragmatic than comparable international standards.

FIGURE 19 ▸ Peatland path
(photo: thomasp24, Fotolia.com)

4.3 FORESTS: CLIMATE CHANGE MITIGATION AND ADAPTATION

Background

Around one third of Germany's land mass is covered by forest. Over the past four decades, the forest area has steadily increased by around 1 million hectares to the current figure of 11.1 million hectares [17]. German forestry makes use of synergies between wood production, ecosystem services and the conservation of biological diversity; the more near-natural the forest management regime, the stronger these synergies become in most cases (specific forest-related aims are defined in the German National Strategy on Biological Diversity). In fulfilling the legal requirement for sustainable management, all stakeholders must consider the multifunctionality of forests.

In **climate change mitigation**, the world's forests have an extremely important function as carbon reservoirs. In Germany, too, the forests' climate services are significant. Germany's 11.1 million hectares of forest are net carbon sinks, absorbing around 25 Mt CO_2e per year (see Table 2). This is the net amount of carbon dioxide that is removed from the atmosphere annually as a result of tree growth. Due to the age structure of the forests, however, this sink effect will decrease in the next few years.

Forests also play a key role in **climate change adaptation**. Due to their rainfall retention capacities, for example, they contribute to flood protection and are especially important for avalanche and erosion control. They also have a cooling effect on the microclimate in urban areas. Climate-related changes in local conditions, however, may well put the productivity and general condition of forests at risk, along with some of the services that they provide.

The German Government's Forest Strategy 2020 [36] states that forests are to be maintained as a CO_2 sink. The Federal Government's climate and energy goals are to be backed by measures to adapt German forests to climate change and to tap the CO_2 reduction potential in forests and timber. The Strategy also states that »appropriate steps are to be taken to promote the use of timber from sustainable forestry as a substitute for energy-intensive materials with an unfavourable environmental impact assessment and carbon footprint«. To some extent, these are conflicting goals, so the Forest Strategy 2020 is only of limited use as a basis for defining targets and tools. It does, however, have a number of synergies with the National Strategy on Biological Diversity.

The issue

In terms of area, German forests are protected, but they are under economic pressure due to the growing demand for wood as an energy carrier. The various items of legislation associated with the German Government's Integrated Energy and Climate Programme (IECP) (»Merseburg decisions«), notably the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz* – EEG) and the Renewable Energies Heat Act (*Erneuerbare-Energien-Wärmegesetz* – EEWG), have created fresh momentum here. In 2012, wood was already Germany's most important renewable energy source, providing 38 % of total renewable energy and 75 % of renewable heat energy [10]. Today, more than 50 % of wood production (including waste wood, by-products and residues) are utilised for energy recovery, either directly or at the end of the product lifetime, and this is increasing compared with the use of wood as a material input. There is growing demand for wood for both these purposes [37, 38].

These trends are likely to be reinforced by the National Biomass Action Plan for Germany [39]. This aims to increase the share of bioenergy in overall end energy use from 6.2 % (2007) to 10.9 % in 2020, inter alia by mobilising timber reserves.

Market trends and policy frameworks which indirectly affect the management of forests and hence their ecosystem services are of great relevance in considering the role of forests in climate change mitigation. In particular, renewable energy expansion targets, which are motivated by climate policy, and the related legislation are driving up demand for energy wood.

FIGURE 20
(photo: Inga Nielsen, Fotolia.com)

In Germany, the potential for forest bioenergy use is reaching its limits, however (see Forest Strategy 2020 [36]), so it is uncertain, overall, how the targets are to be achieved. The impact of forest development and forest utilisation on the greenhouse gas balance can be generally described in terms of the following three factors:

FIGURE 21 ▸ Carbon sequestration in house-building (wood panels) (photo: BG, Fotolia.com)

- **Carbon sequestration in forests themselves (»forest sequestration«):** This refers to the amount of CO_2 stored directly in forest and its components (trees and vegetation associated with them, deadwood, litter and soil; see Table 2). The quantity of CO_2 stored in forest increases with annual incremental growth of the individual components and decreases with extraction of timber and natural processes of decomposition and decay. Forest utilisation strategies, such as the choice of planned production periods, target tree diameters and tree species, influence these changes, whose net effects can to some extent be estimated by modelling.

- **Carbon sequestration in wood products (»product sequestration«):** Carbon is stored in wood products until they decompose or are used for energy purposes. However, international emissions reporting under the Kyoto Protocol (second commitment period) only takes account of wood products from domestic sources, as sustainable production cannot be guaranteed for imports. The carbon footprint of imported wood is therefore excluded from accounting.

- **Substitution effects:** Using wood as a material often creates positive substitution effects, as greenhouse gas emissions are lower than in the manufacture and use of equivalent products made from alternative materials (e.g. aluminium, steel, concrete, oil, gas). The substitution effect can be increased by means of cascade use, but is greatly reduced if wood is used solely for energy purposes (e.g. heat), and also depends on which specific fuel is replaced by wood.

TABLE 2 ▸ Greenhouse gas balance of German forests, 2010 (excluding product sequestration and substitution effects). Living biomass and deadwood made a substantial contribution to German forests' carbon sink capacity. By contrast, drainage and loss of mineral soils produce greenhouse gas emissions (based on [17], p. 473, Chapter 7.2 – »forest land«). (GHG emissions are shown as positive values; carbon sequestration from the atmosphere is denoted by a minus sign.)

CO_2 emissions or sequestration by forest components or forest utilisation	Annual emissions or sequestration in thousand tonnes CO_2e
CO_2 sequestration in living biomass (above and below ground)	-21.772
CO_2 sequestration through increase in deadwood (above and below ground)	-3.638
CO_2 sequestration in litter	-593
Emissions from drainage of organic soils	675
Emissions from mineral soils after conversion	333
Emissions from liming	58
Emissions from forest fires	4
Total	-24.933

There are interactions between forest sequestration and product sequestration. If the forest area remains unchanged, an increase in forest sequestration will reduce sequestration in wood products, and vice versa. Synergies with forest-related nature conservation goals tend to arise if carbon sequestration is concentrated on forest carbon sinks and, for example, old stands with a high proportion of deadwood are maintained. Conversely, some measures which aim to increase product sequestration or focus on substitution potential rely on more intensive use of wood, and while this is of commercial interest to forestry enterprises, it can lead to conflicts with nature conservation goals in forests.

With regard to the forest carbon sink, the above scenario of carbon stock development is likely to change in future. In recent years and decades, very substantial carbon stocks have built up in Germany's forest carbon sinks, primarily due to reforestation after the Second World War and the resulting age structure of forest stands. However, over the coming decades, the carbon sink capacity of German forests may well decrease because a disproportionately large number of forests will soon be ready for felling (albeit with part of the harvest being converted into wood products, which will continue to store CO_2). According to estimates, carbon stored above ground could decrease by around 19.1 Mt carbon over the next 40 years, corresponding to annual emissions of 1.75 Mt CO_2 [40]. However, if forest carbon sinks and product sequestration are both included in the balance, the carbon sink capacity of Germany's current forest management regime is expected to remain in the region of 22 Mt CO_2e per year for the near future [42]. This figure does not take account of substitution potential and the sequestration capacities of deadwood, soil and litter; in that respect, it is not comparable with the figure given in Table 2 above and underestimates actual sink capacity.

As well as contributing to climate change mitigation, forests provide **many other ecosystem services** (for a detailed description, please refer to the second TEEB DE report, Capturing the Value of Ecosystem Services in Rural Areas), some of which are relevant to **climate change adaptation**. For example, forest cover reduces surface runoff by capturing and storing rainfall and can stabilise the landscape water balance. In this context, evaporation and infiltration rates depend inter alia on the forest management regime.

FIGURE 22
(photo: Fontanis, Fotolia.com)

Options for action

To maintain and improve mitigation services from forestry in Germany, three strategies can be considered:

- **Forest conservation to prevent loss of sequestration capacities:** Unlike many tropical forests, this strategy is already being implemented in Germany as various legal provisions pertaining to the forest sector preserve the overall forest area and protect it from losses.

- **New planting:** Afforestation and natural reforestation of hitherto unforested sites create additional carbon sinks. The German Greenhouse Gas Inventory refers to a current afforestation figure of around 3,100 ha per year [17]. This is a very effective option, as new forest on former cropland or pasture absorbs, on average, 10.3 t CO_2/ha/y for the first 20 years, rising to a full 16.8 t CO_2/ha/y in the two decades thereafter. Fast-growing pioneer species initially sequester much more carbon than species such as oak and beech, which are ecologically adapted to later succession. In the interests of nature conservation, however, new forest should not be planted on ecologically valuable sites such as nutrient-poor grassland or meadow valleys.

- **Possible changes to the management regime** (see Box 10):
  - From a climate policy perspective, **reducing production periods** can in some cases make an effective contribution to the attainment of climate goals. From a forestry perspective, there are arguments in favour of this approach, for reducing production periods decreases the risk of (climate-related) outbreaks of disease and infestation and in some circumstances increases incremental growth, thus enhancing sink capacity. It can also safeguard long-term profitability at a time of increasing risks. However, this strategy can adversely affect forest carbon sinks, as well as nature conservation goals that aim to increase the proportion of old stands in forests.

  - Silvicultural strategies aimed at **extending the production periods** increase the timber stock and the carbon stocks that it contains. This is potentially compatible with many forest-related nature conservation goals, such as the preservation of old stands. However, it reduces the inflow of domestically felled timber into the product carbon sink. This is particularly problematical if domestic demand is then met from timber imports, possibly from non-sustainable sources [41]. Under certain circumstances, it also increases risks (e.g. storm-felling) and generates opportunity costs for forest owners.

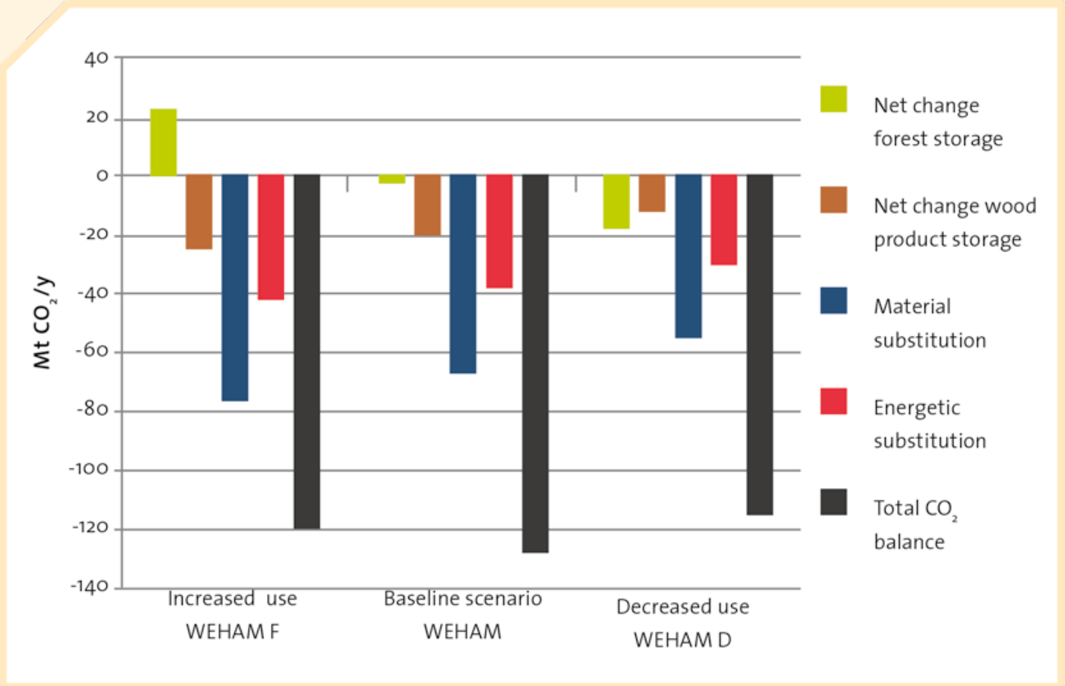
- The **conservation and rewetting of forest mires and peaty forest soils** are important climate goals as their carbon stocks per hectare of soil are almost four times higher than in mineral soils (see Chapter 4.2).

BOX 10

Forest-use change scenarios

In a study on the climate impacts of changes in forest utilisation, three separate forest management options for 2013–2020 were compared, based on data from the 2008 German National Forest Inventory (Note: »increased use« means a reduced cutting interval; »baseline scenario« means maintaining the current intensity of utilisation; »decreased use« means a longer cutting interval; see Figure 23 [41, which provides background on the various scenarios]). It was shown that more intensive use reduces forest carbon sequestration, whereas less use decreases the sequestration effect of wood products. Overall, the study found that the best carbon footprint is achieved for the baseline scenario, i.e. an unchanged utilisation strategy, as any change in usage would produce more emissions. More detailed analyses which include alternative parameters (e.g. longer observation periods) would be useful but are not available at present.

FIGURE 23 Carbon footprint for forest management scenarios of varying intensities, 2013–2020; negative figures: sinks; positive figures: emissions (based on [41])



In view of society's current demand for wood as both a material input and an energy source, both options – to extend or to reduce production periods – perform less favourably, from a climate perspective, than the current management regime. It is difficult, therefore, to amplify the climate benefits afforded by German forests. Furthermore, increasing the size of the forest carbon sink would reduce the supply of local timber, which would drive up imports if demand for wood as a material and energy source remains unchanged. These additional imports could potentially increase the pressure to utilise forest areas which are not currently being managed sustainably or are not being managed at all, thereby causing climate-damaging deforestation in other parts of the world. For that reason, the political debate about forest management should not focus solely on climate aspects but should adopt a holistic view, taking account of society's demand for energy and raw materials, the potential contribution made by wood as a renewable resource, and the ecosystem as a whole, with its diverse ecosystem services, including the contributions made by forests to climate change adaptation.

In order to assess the relevance of German forests' climate contribution compared with their other ecosystem services, it is helpful to cast a glance at recent studies which estimate the economic value of these ecosystem services (see discussion in unabridged version). The available valuation studies show that in addition to wood production, forests offer substantial benefits to society through their provisioning of other services, without this being reflected in prices. These services particularly include recreation and biodiversity conservation, whose estimated benefits for society are entirely comparable with the value placed on forests' production services. The economic value of forests' climate services depends on the specific scenario of forest and timber utilisation being considered, the associated changes in the GHG balance, and the economic valuation method applied. If these changes are valued using emission trading prices or short-term avoidance costs, the difference in the contribution made by climate services, switching between the various scenarios, is relatively small. However, if valuation is based on damage costs and a low -> Discount Rate is applied, the value of the climate services increases substantially, but due to the only marginal changes in the carbon footprint relative to other ecosystem services, it nonetheless remains low.

In the provisioning of public goods and services, it is also important to consider how individual interests and societal interests can be aligned. If it is in society's interest to strengthen certain climate change mitigation and adaptation options, such as forests' sink capacity and water retention functions, thereby generating additional costs for enterprises, it is important to clarify how forest owners, for example, can be persuaded to support these options and whether appropriate incentives could be useful here (financed, for example, by the Forest Climate Fund; see Box 11).

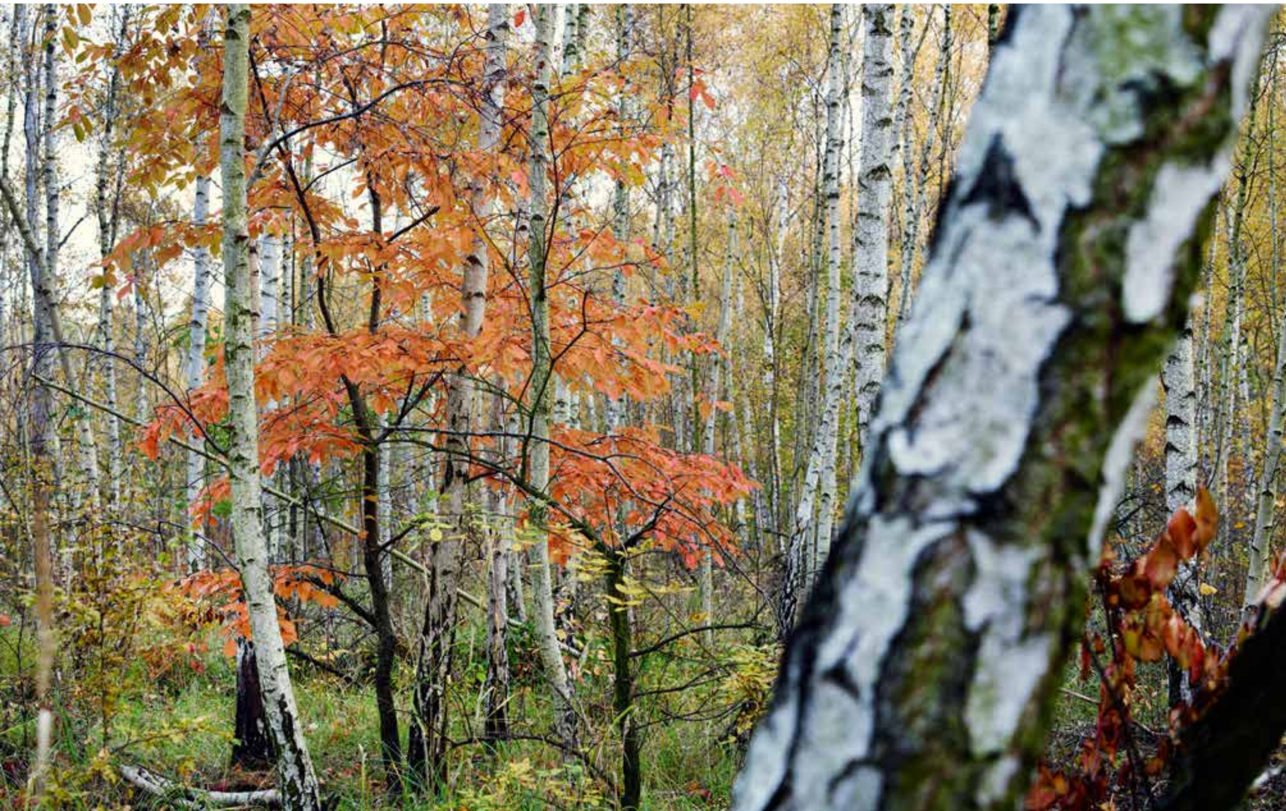
BOX 11

Forest Climate Fund

The Forest Climate Fund (http:// www.waldklimafonds.de) was established by the German Government on 1 July 2013, with joint responsibility for this funding mechanism lying with the Federal Ministry of Agriculture (BMEL) and the Federal Environment Ministry (BMUB). It is part of the programme associated with the Energy and Climate Fund, which has initially committed € 34 million to the Forest Climate Fund for the period to 2019. The Forest Climate Fund supports measures to promote adaptation of forests to climate change and safeguard and increase forest carbon sequestration and carbon storage in wood products. It also aims to increase knowledge and expertise in these areas.

Voluntary solutions are another option, and various approaches are applied in Germany. One example is the Forest Share scheme developed in Mecklenburg-Western Pomerania (see Box 12). Other organisations run similar voluntary schemes: *PrimaKlima e.V.*, for example, also offers private individuals and companies an opportunity to offset their GHG emissions by planting trees.

FIGURE 24 ▸ A birch forest at Neue Harth near Zwenkau in autumn: part of the renaturation of a former mining area (photo: André Künzelmann, UFZ)



BOX 12

The Forest Share scheme in Mecklenburg-Western Pomerania
by Thorsten Permien

Tourism produces greenhouse gas emissions. A family of four from Germany spending a holiday in Mecklenburg-Western Pomerania releases, on average, an estimated 850 kg of CO_2 into the air as a result of their vacation activities. This is approximately the amount of carbon that can be stored in 10 m^2 of forest. Planting and cultivating such a forest area to capture these emissions costs around € 10.

The basic idea of the Forest Share scheme (www.waldaktie.de) is to capture CO_2 and store it for the long term in trees growing in »climate forests« in Mecklenburg-Western Pomerania, where woodland is sparse. The scheme gives holiday-makers a real-life experience of climate action. As well as contributing to climate change mitigation, the scheme improves the quality of high value cultural ecosystem services (recreation, experience of nature, a more diverse and therefore enhanced landscape appearance). With this in mind, Mecklenburg-Western Pomerania's Environment Ministry, tourism association and forest administration launched the Forest Share scheme: the purchase of one symbolic € 10 share pays for the planting of trees which, during their lifetime, can store a good 800 kg CO_2 in trunks, foliage and soil.

Currently, a total of 13 »climate forests« are successively being planted, funded by the sale of Forest Shares. More and more companies are also joining the scheme and are integrating Forest Shares into their corporate social responsibility strategies. The project has received various awards, notably from the »Germany – Land of Ideas« initiative and the UN Decade of Education for Sustainable Development.

FIGURE 25 ▸ Tree-planting in Bützow's climate forest under the Forest Share scheme www.waldaktie.de, 2010 (photo: Mecklenburg-Western Pomerania *Landesforst* Administration)

4.4 FLOODPLAINS: MAKING ROOM FOR RIVERS

Background

Across Germany, the loss of characteristic floodplain habitats has assumed dramatic proportions. With the Status Report on German Floodplains [42], Germany now has its first nationwide inventory of floodplain loss for 79 rivers, as well as an overview of land use on the remaining active floodplains and the status of former floodplains which are no longer connected to rivers. According to the Report, German floodplains have lost, on average, two-thirds of their former area due to dike construction and other flood protection measures, and in many sections of Germany's major rivers, now amount to only 10–20% of their original extent [42]. This has deprived the rivers of the space they need to retain water and reduce water levels during floods.

Freshwater ecosystems will be directly impacted by climate change due to the expected changes in rainfall and discharge patterns. They also play a two-fold role in climate policy (see, for example, [43]). Firstly, they provide mitigation services by reducing greenhouse gas emissions, and secondly, they make a significant contribution to climate change adaptation by providing flood protection areas. Their mitigation services are conditional on two factors:

- Firstly, aquatic ecosystems and near-natural floodplains, due to their function as major carbon reservoirs, contribute to climate regulation. This applies particularly to carbon-rich mineral and peaty soils of floodplain landscapes. The calculated carbon stocks of soils in the active floodplains amount to 549 Mt CO_2e [44]. These carbon stocks can only be maintained and increased if floodplains have a near-natural hydrological balance with adapted land use, or are developed in a near-natural manner.

- Secondly, GHG calculations have shown that land use, mainly agriculture, on peatlands in morphological floodplains is producing annual emissions of around 2.5 Mt CO_2e [44]. This corresponds to the annual CO_2 emissions of more than 1.3 million cars (based on assumed annual consumption of 2 t CO_2e per capita from private vehicles). Assuming damage costs of € 80–120 / t CO_2 (for information about damage costs, see unabridged version), this amounts to around € 200–300 million per year. There is considerable mitigation potential here, demonstrating the extremely important role of floodplains' carbon-rich soils in climate change mitigation.

The issue

In August 2002, catastrophic floods in the Elbe and Danube river basins caused damage totalling around € 11 billion. The floods affected more than 370,000 people and claimed 21 lives. The damage caused by the 2013 floods, according to provisional estimates, cost around € 7–8 billion. Traditional flood protection measures are therefore increasingly being called into question and new solutions are being demanded.

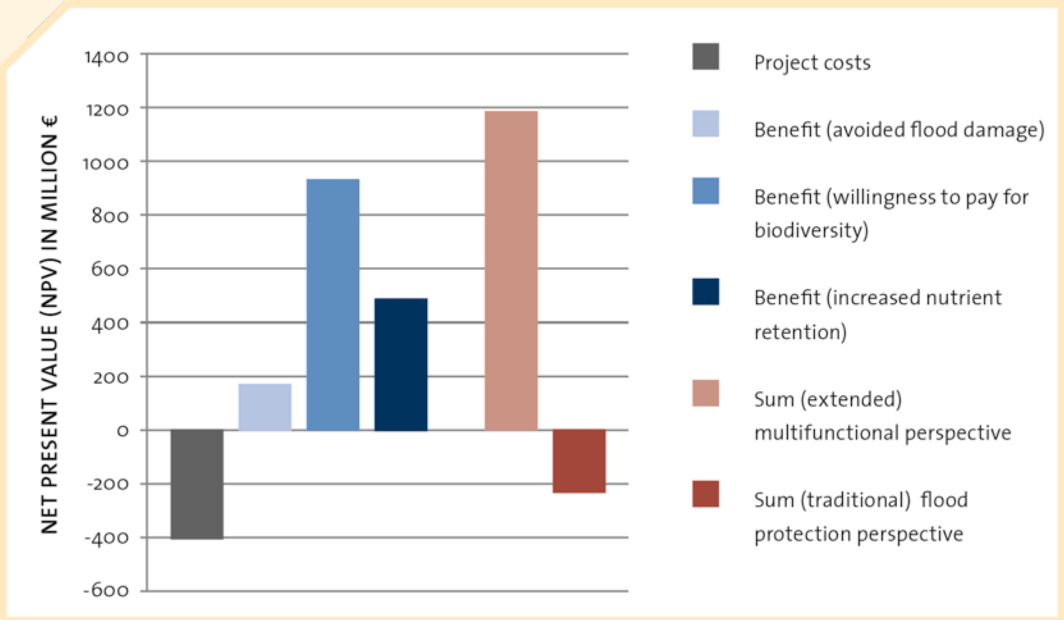
Options for action

In order to make use of and develop the potential of freshwater ecosystems for climate change mitigation and adaptation, coordination and coherence between hitherto separate policy areas (e.g. flood protection, nature conservation, climate change mitigation, agriculture and shipping) are essential. However, justifying floodplain

BOX 13

Economic costs and benefits of various dike relocation measures
A case study on the Central Elbe *(Mittlere Elbe)* from Dresden to Lauenburg showed that the economic benefits of nature-compatible flood protection measures via various dike relocation schemes, creating up to 35,000 ha of additional floodplain, are three times greater than their costs (Figure 26, [45] see unabridged version, Chapter 8).

FIGURE 26 ▸ Costs and benefits of dike relocation measures for climate change adaptation ([45]; see also for valuation of alternative scenarios, including creation of managed polders)



Adopting a traditional perspective, which only takes account of the flood reduction effect but does not consider additional ecosystem services, these measures would not be worthwhile: investment costs of around € 407 million (factoring in the reduced costs of dike maintenance) would be uneconomical compared with avoided flood damage totalling € 177 million. However, when the research team conducted a wider cost-benefit analysis which included direct project costs, annual avoided flood damage and other ecological and social benefits, it was found that if all the positive effects of the options are factored in, dike relocation yields a substantially larger total net benefit, amounting to around € 1.2 billion, than technical flood protection measures. From an economic perspective, based on the assumptions made in the case study, the creation of floodplains by means of dike relocation is therefore an appropriate preventive flood protection solution. The cost savings from avoided flood damage, better nutrient retention in the riverine ecosystem and the increased value attached by the general public to biodiversity enhancement in the reactivated floodplain landscape outweigh the costs of the measures.

reactivation purely in terms of climate policy often does not go far enough. Floodplain renaturation can contribute to the attainment of goals set forth in the EU Water Framework Directive (WFD), Floods Directive, and Habitats and Birds Directives and also has positive climate impacts.

The 2005 Act to Improve Preventive Flood Control *(Gesetz zur Verbesserung des vorbeugenden Hochwasserschutzes)* aims inter alia to create more space for rivers and to claim and recover former floodplains as natural retention areas. There should be no building on floodplains, and areas used for intensive farming should be converted to grassland. These goals have not yet been achieved. In Germany, dike relocations have increased the total floodplain area by just 1 % in the last 15 years. The floods in May/June 2013 increased the pressure to give greater priority to near-natural flood protection. The Conference of Environment Ministers on 2 September 2013 therefore agreed the development of a national flood protection programme, centred on the creation of new retention areas for rivers by means of dike relocations and managed flood polders. In suitable sections of floodplains, areas for renaturation should be identified and safeguarded through long-term site management.

FIGURE 27 ▸ Lödderitz Forest (Saxony-Anhalt) during the Elbe floods, 6 June 2013 (photo: André Künzelmann, UFZ)

BOX 14

Dike relocation in Lödderitz Forest
by Mathias Scholz, Astrid Eichhorn and Georg Rast

The alluvial forests in the Central Elbe *(Mittlere Elbe)* comprise one of the largest remaining near-natural deciduous floodplain forest complexes in Germany, and have a rich species inventory of typical fauna and flora. Under the auspices of WWF Germany, a large-scale nature conservation project, currently the largest dike relocation project in Germany, will provide an additional floodplain of 600 hectares when it is completed in 2018. The project will build 7.3 km of new dike, modify the drainage system, and build a new pumping station in order to mitigate the impacts of seepage and drainage water on local communities. The projected costs of the dike relocation scheme are € 23.2 million, excluding land purchases, compensation and cuttings in the old dike.

The dike relocation will greatly improve flood protection. According to model calculations, it will lower the floodwater level in the Elbe between Aken and Lödderitz by as much as 28 cm. At the Elbe river floodplain near Lenzen, the positive impacts of a (completed) dike relocation, which has provided an additional 420 hectares of floodplain, are already being observed. During the floods of 2011 and 2013, the dike relocation had beneficial effects by reducing peak levels at the upstream Schnackenburg gauge by more than 20 cm compared with levels before the dike was opened.

In the Elbe river floodplain near Lödderitz, even conservative estimates show that dike relocation will greatly improve nutrient retention as well. If this water purification service is evaluated in terms of the avoided costs of agricultural strategies, the floodplains in the dike relocation area provide a purification service valued at around € 700,000 annually (cash value with a 3 % discount rate and a 30- or 90-year calculation period: € 13 million or € 22 million respectively, which is equivalent to the costs of dike relocation even without factoring in the flood protection effect). As there are extensive old alluvial forest stands in the dike relocation area which already sequester around 400,000 t CO_2e in their above-ground biomass, the additional carbon sequestration gained from new forest planting will be relatively low [44]. However, for other areas where large-scale forest development is envisaged, it offers considerable potential in future.

4.5 COASTAL AREAS: DIKE RELOCATION AVOIDS MAINTENANCE COSTS

Background

Coastal and marine ecosystems provide a variety of ecosystem services. Globally, the vegetation of coastal ecosystems is an important carbon sink. Furthermore, gas and climate regulation is a significant ecosystem service provided by the world's oceans [46]. Coastal ecosystems also offer protection against storms and coastal erosion. However, coastal areas are particularly at risk from sea level rise, which is an expected consequence of climate change.

The issue

Higher water levels during storm surges can damage dikes, port and transport infrastructure and buildings along the coasts. If dikes are breached, this can have catastrophic impacts on human life, infrastructure and settlements [47].

Agriculture is also at risk, not only from flooding but also due to the ever-increasing costs of drainage in diked-in polders as sea levels rise.

Options for action

In contrast to the situation with flooding inland, where additional floodplains can mitigate the impacts, such measures are not appropriate in densely populated coastal regions as the areas concerned will not be large enough to retain (continuously flowing) masses of water. Nonetheless, in individual cases, ecosystem-based adaptation measures are viable and beneficial, such as dike relocation at selected sites, especially on the Baltic Sea. Dike relocation can in some cases cut spending on raising the height of dikes and reduce dike maintenance and water management costs. Instead of farmed polders, salt meadows are created, which sequester large amounts of carbon and provide habitats for a variety of species, such as wading birds and vegetation adapted to flooding and salinity. These areas can in some cases continue to be farmed extensively. By conducting an analysis of all costs and benefits, as far as possible, the feasibility of this option can be determined on a case-by-case basis (Box 15).

BOX 15

Dike relocation at Darss on the Baltic Sea coast in Mecklenburg-Western Pomerania

The *Sundische Wiese* in the eastern part of Zingst peninsula forms part of the core area of the Western Pomerania Lagoon Area National Park *(Nationalpark Vorpommersche Boddenlandschaft)*. A flood protection scenario was developed for this site, which envisaged the depolderisation of diked-in and drained grasslands *(Sundische Wiese)*, the removal of the old dike and the construction of a shorter new dike to protect settlements, and the (re)planting of typical »salt meadows« on depolderised areas, providing a habitat adapted to periodic flooding. The new dike will protect the settlements from the higher water levels predicted during flood events in future. The salt meadows will sequester carbon during their further growth. Farming will continue to take place on a reduced area, but more extensive methods will be used.

In a cost-benefit analysis, the following two land-use scenarios were compared:

- Option I »Depolderisation and development of salt meadows«: construction of a shorter new dike, removal of the old dike, closure of pumping stations, development of extensively managed salt meadows instead of farming on polders, reduced overall length of dike.

- Option II »Safeguarding the status quo«: maintenance and reinforcement of existing dikes, continued farming on polders with reliance on drainage channels and pumping stations, continued current grassland use [48].

The main costs of dike construction, reinforcement and maintenance and of water management and the revenue and costs from the two agricultural scenarios were compared. The sink function of the new salt meadows was not included. It was found that the salt meadow option

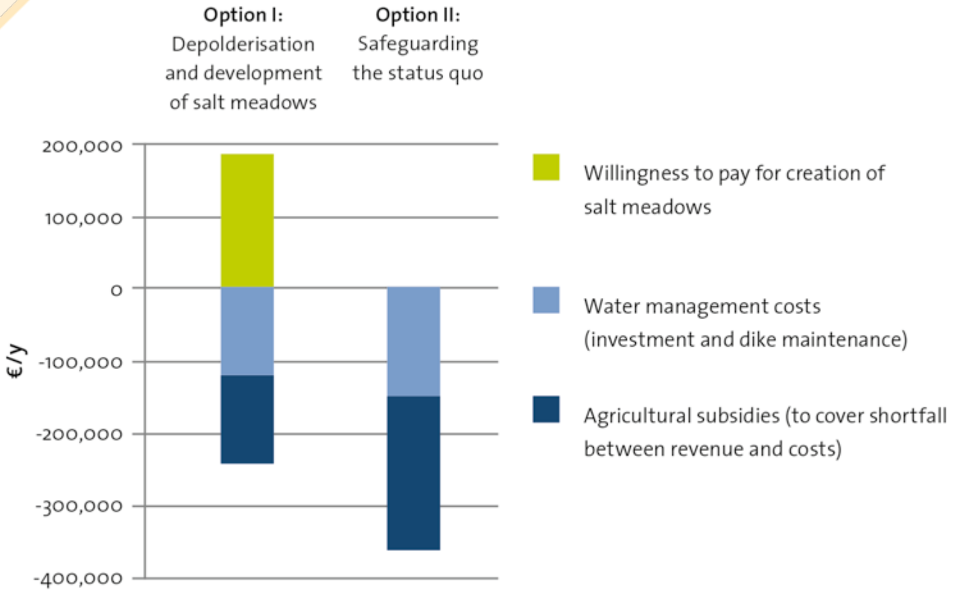
FIGURE 28 ▸ View of part of the *Sundische Wiese*, the Baltic Sea and the *Grosser Werder* peninsula, 2004. (photo: Sabine Viertel, www.darss4you.de)

was more favourable, both in terms of the annualised costs of dike construction, maintenance and water management (»salt meadow option«: € 115,827 per year; »safeguarding the status quo«: € 148,300 per year) and in terms of agriculture. Both agriculture options are only commercially viable due to current agricultural subsidies. In net terms, they are economically unprofitable; in other words, they generate more costs than income and therefore rely on government subsidies. However, the required support is lower in the case of salt meadows (€ 121,893 per year instead of € 209,922 per year) (see Figure 29).

In order to identify additional public benefits from depolderisation, a -> Willingness To Pay Analysis was conducted to determine the value attached by the general public/tourists to the creation or restoration of now rare salt meadows. This produced a value of around € 185,000 per year for this specific 806-hectare site.

The example shows that here, dike relocation as an ecosystem-based »softer« coastal protection measure greatly reduces costs and offers additional benefits for recreation and nature conservation, and that there is a substantial -> Willingness To Pay for these services on the part of the general public.

FIGURE 29 Balance sheet for a dike relocation project at *Sundische Wiese* (Darss) (based on [48]). Option I: Construction of a shorter new dike, removal of the old dike, closure of pumping stations, development of extensively managed salt meadows instead of farming on polders, reduced overall length of dike. Option II: Maintenance/reinforcement of existing dikes, continued farming on polders with reliance on drainage channels and pumping stations, continued current grassland use.



5 TARGETS AND OPTIONS FOR IMPLEMENTING ECOSYSTEM-BASED CLIMATE POLICY

An economic analysis and inventory of the services provided by nature can do much to support the development and implementation of successful climate policies. Mainstreaming of ecosystems and their services creates numerous synergies in climate change mitigation and adaptation. At present, however, the potential afforded by ecosystem-based climate policy is not being utilised sufficiently, due to inconsistencies, contradictions, and fragmentation of responsibilities, affecting decision-making on targets, tools, and organisation of relevant measures. Ecosystem-based climate policy is therefore still in its infancy in Germany. Building on what little impetus exists in order to develop this type of policy will only be successful if there is more coordination and coherence between sectors and their respective policies (particularly agriculture and forestry, water resource protection, climate and energy policy, transport and the utility sector, and nature conservation). This applies, firstly, to the setting of targets in the various sectors and, secondly, to the ways and means of achieving them. Economic arguments can be helpful here.

FIGURE 30 ▸ Demarcating a nature conservation area in peatlands in the Peene river valley (photo: Kerstin Marten, Schwerin)

5.1 SETTING TARGETS FOR ECOSYSTEM-BASED CLIMATE POLICY

The significance attached to ecosystems, -> BIODIVERSITY and climate change mitigation varies across the relevant policy areas. Whereas the state of our ecosystems is of crucial importance to agricultural policy and to forest, marine and nature conservation policy, it plays little or no role in national climate and energy policy. Here, there is a much stronger focus on reducing emissions from energy production and energy consumption in industry, transport and households.

From an economic perspective, three recommendations are made here for making use of synergies between climate and biodiversity policy:

- **Conservation of ecosystems with major carbon reservoirs and high sink potential (establishment of the »no net loss principle« in relation to carbon reservoirs):** In ecosystems with particularly high sink potential (peatlands, forests, floodplains, grassland), conserving their current sequestration function is the most important objective. In this way, even allowing for lost profits, climate action can be undertaken cost-effectively while creating synergies with biodiversity targets. With the exception of forests, however, many German states lack appropriate and effective legal targets, mechanisms and rules on the conservation of these sites.

- **Restoration of degraded ecosystems:** The goal of -> RENATURATION of degraded ecosystems is set forth in Target 2 of the EU Biodiversity Strategy and in the global biodiversity targets to 2020 with specific climate relevance (»Aichi Biodiversity Targets« 14 and 15 in the Strategic Plan for Biodiversity 2011–2020 adopted within the framework of the Convention on Biological Diversity). From an economic perspective, it would make sense to focus efforts particularly on sites with high potential for synergies between climate action and biodiversity conservation (peatlands, floodplains, etc.), as this will yield substantial overall benefits. The renaturation of ecosystems requires investment and creates -> OPPORTUNITY COSTS. There is considerable regional variation in sites' potential for renaturation. For these reasons, priorities must be set, taking account of the cost-effectiveness of measures, based on their contribution to climate change mitigation and biodiversity conservation, and their effects on other ecosystem services. There is potential, in this context, to build on the renaturation programmes that already exist in some German federal states.

- **Climate-oriented land use:** A third level of action for ecosystem-based climate policy is the development of climate-oriented production and utilisation strategies for agriculture and forestry, supported by appropriate targets and measures. The question of which tools should be deployed to implement these strategies (regulatory instruments, funding criteria, positive and negative financial incentives, etc.) is ultimately a matter for policy makers, taking account of efficiency and significance for stakeholders.

Agriculture currently lacks a comprehensive climate policy target for emissions reduction, backed by appropriate measures. In order to make use of synergies between climate policy and biodiversity conservation, two goals should be considered and reviewed: firstly, with regard to grassland conservation, a quantitative target for high nature value grassland should be introduced, as this offers significant potential to create synergies (see Chapter 4.1). Secondly, funding practices for bioenergy should be reviewed. The targets for biomass use were defined by the German Government in its National Renewable Energy Action Plan [11]. However, the targets set by the EU for increasing the biomass share by 2020 have already been modified by halving the previously envisaged rate of increase and ruling out the use of sites of high nature value [11]. Furthermore, the amended Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz* – EEG) adopted in January 2012 caps the share of maize that can be used as a biogas feedstock. The authors of the present report welcome these amended targets because they help to improve coordination and coherence between the various policy areas. In the further development of support schemes for renewable energies, additional assistance should be given to cultivation regimes that allow low-impact use, are economically sound, and can potentially have positive effects on biodiversity. Examples are the use of residues from extensively managed species-rich meadows, paludiculture on rewetted peatlands, and short-rotation coppices in alley cropping systems that have positive effects on landscape structure.

The **forestry** sector also currently lacks a coherent strategy to safeguard and strengthen the positive climate effects of forests with due regard for long-term sustainability and the conservation of other ecosystem services provided by forests. Besides the services that they provide for recreation and biodiversity conservation, forests perform various other functions which are important for society's adaptation to climate change, such as protection against the increased risk of avalanches and rockfalls, erosion control, water retention and filtering, and cooling of the microclimate in urban areas. Due to the interactions between forest carbon sinks, sequestration in wood products, and substitution of climate-damaging products (see Chapter 4.3), there would appear to be little scope to make more intensive use of the existing synergies between biodiversity conservation and climate change mitigation in the forestry sector. There is still a considerable need for research here. The conservation and rewetting of forest mires offer some limited opportunities which should be utilised. So it is even more important to ensure that forests, in accordance with policy objectives, can continue to perform their sink function and fulfil their important role in the conservation of biological diversity in future (when more significant amounts of forest than at present will reach the age when they are ready for felling) with no adverse impacts on the attainment of climate goals. In the wood products sector, increasing cascade use and prioritisation of the use of wood as a material input can create positive substitution effects.

Due to the growing significance of **biomass** as a renewable energy source in Europe, it is important to ensure that bioenergy is generated solely from sustainably produced and managed biomass so that, firstly, clear reductions in greenhouse gas emissions are achieved compared with fossil fuels, and secondly, the natural environment and high nature value sites are protected from utilisation and degradation. Relevant criteria for biofuels and bioliquids are already defined in EU Directive 2009/28/EC, and must now be extended to solid and gaseous biofuels as well.

FIGURE 31
(photo: Franz Mairinger, Pixelio.de)

5.2 OPTIONS AND INSTRUMENTS FOR IMPLEMENTATION

As a basis for implementing present and future targets for ecosystem-based climate action, an analysis of existing and new instruments is required, and this must include a review of policy coherence and financing options. As a comprehensive review of policy options is presented in the fourth TEEB DE report, the following comments relate solely to aspects of direct relevance to the creation of synergies between climate change mitigation and adaptation and -> NATURAL CAPITAL:

- In Germany, a range of instruments (policy mix) is in place, which must be developed further and adapted in order to achieve policy coherence. This requires better coordination and alignment of planning laws and regulatory frameworks and a refocusing of funding policy, especially for agriculture, supplemented by market-based instruments.

- A key instrument for creating synergies is to develop a **fund for ecosystem-based climate policy** as a means of financing action in pursuit of climate- and biodiversity-related priorities, such as those identified in Chapter 5.1. With the establishment of the »Forest Climate Fund«, a possible model has already been developed (see Chapter 4.3). From an economic perspective, the bundling of measures and the targeted opportunities afforded by prioritisation are

FIGURE 32
(photo: Metronom GmbH)

arguments in favour of this type of fund-based solution. It is also important to ensure that the federal states provide practical funding opportunities for measures relating to particularly climate-relevant ecosystems, such as the renaturation of peatlands and floodplains, under schemes co-financed by the European Regional Development Fund (ERDF) and European Agricultural Fund for Rural Development (EAFRD). There is also scope to make greater use of innovative concepts based on the voluntary carbon market, e.g. for the rewetting of peatlands, and private financing mechanisms for afforestation (»Forest Shares«).

- The previous chapters of this report also make it clear that protecting healthy bogs and peatlands in Germany is crucially important from a climate and biodiversity perspective. **Climate- and biodiversity-related peatland conservation and rewetting** could potentially be deployed as solutions under existing nature conservation and agri-environmental programmes. To that end, however, the climate dimension of these programmes would need to be expanded and developed. Innovative programmes based on some form of contractual climate action (akin to contractual nature conservation) should also be considered, focusing on climate-friendly peatland management. -> SITE POOLS and eco-accounts for the implementation of -> COMPENSATION MEASURES under the -> IMPACT REGULATION provisions of nature conservation legislation should also be utilised for this purpose, provided that this is functionally derivable and justified, enabling climate and nature conservation goals to be achieved simultaneously.

- **A realignment of agricultural support** towards climate change mitigation and nature conservation should primarily aim to create incentive schemes that are coherent with the objectives of ecosystem-based climate policy, outlined above. The EU's Common Agricultural Policy (CAP) reform package, which will take effect in 2015, has made at least a verbal commitment to focus more strongly on climate and environmental issues. For example, »greening« of direct payments under Pillar 1 will be introduced. Compliance will be mandatory for all farmers applying for support under the Basic Payment Scheme and will amount to 30% of these payments. The »greening« rules cover three areas: crop diversification, measures to maintain permanent grassland, and Ecological Focus Areas. The ban on the conversion of grassland is a particularly effective way of protecting the climate and is significant for nature conservation. A ploughing and conversion ban applies to designated permanent grassland sites within and optionally also outside -> NATURA 2000 areas, including those with carbon-rich soils. However, in the new funding period, 5% of grassland can again be ploughed up for use as arable land, and the basis for the calculation of payments is once again the area of arable land, which will change as a result of this conversion. Whether effective protection is achieved will very much depend on how these aspects are implemented at national level. Under Pillar 2, which funds rural development, the EU Member States must spend at least 30 % of funding on agri-environmental measures, including climate change measures. In terms of conserving natural capital and ecosystem services, the provisions on »greening« (particularly grassland conservation) are to be welcomed in principle. However, the targets must be mandatory and must therefore be enshrined in national law; otherwise, farmers who do not receive direct payments will still be able to plough up grassland. Enforcement must also be more robust. Overall, the incentives to make use of synergies between climate- and biodiversity-related management regimes must be reinforced in order to counterbalance market forces that encourage development in a very different direction.

- For the conservation and renaturation of natural and near-natural **freshwater ecosystems and floodplains**, various instruments are available; in addition to the provisions relating to protected areas set forth in nature conservation legislation, they include water resource protection mechanisms, primarily the programmes based on the EU Water Framework Directive. In the authors' view, the opportunities for dike relocation and restoration of floodplains, as economically viable measures for climate change adaptation, are not given due consideration at present. It is hoped that this will change following the decision by the German states' environment ministers to set up a national flood protection programme as a consequence of the floods in June 2013, so that floodplain renaturation, as a form of preventive flood protection, will be implemented more consistently in future.

Policies and instruments that take greater account of ecosystems in climate change mitigation and adaptation already exist, therefore, in Germany. In terms of their implementation, however, it is essential that the great importance of natural capital for effective – and cost-effective – climate action be identified, recognised and translated into strategies for action. Coordination and coherence between the various sectors and policy fields, which have hitherto operated in isolation from each other, have a particularly important role to play in this context

FIGURE 33
A near-natural alluvial meadow (photo: Vera Kuttelvaserova, Fotolia.com)

GLOSSARY

BENEFITS (OF ECOSYSTEM SERVICES)
-> Benefits arise directly or indirectly from the utilisation and/or positive significance of ecosystem services (-> direct/indirect utility, cultural ecosystem services).

BIODIVERSITY
-> Biological diversity

BIOLOGICAL DIVERSITY
The diversity of life on Earth (biodiversity) means the variability among living organisms and the ecological complexes of which they are a part. It comprises 1) diversity of ecosystems, communities, habitats and landscapes; 2) diversity between species; and 3) genetic diversity within species.

CONVENTION ON BIOLOGICAL DIVERSITY (CBD)
A global agreement to protect biodiversity, which opened for signature at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. It has three main objectives:

- the conservation of biological diversity,
- the sustainable use of its components,
- the fair and equitable sharing of the benefits arising out of the utilisation of genetic sources (access and benefit-sharing – ABS)

CULTURAL SERVICES
Ecosystem services of benefit and significance for recreation, aesthetic experience, spiritual enrichment, ethical requirements, cultural identity, heritage, knowledge and cognition.

DISCOUNT RATE
An interest rate used to determine the present value of future benefits and costs. The term »social rate of time preference« is often used in relation to public investment projects. In general, discounting future benefits and costs is considered to be justified only if social welfare is at least maintained in future.

ECO-ACCOUNT
Eco-accounts are used to hold eco-points for registered and completed mitigation projects which qualify as compensation or substitution measures to offset future interventions in nature and landscape. A landowner can acquire eco-points by implementing appropriate measures in order to secure the long-term conservation of a site. A project developer can purchase the relevant number of eco-points to fulfil his mitigation obligations, depending on the type and severity of the planned intervention. In this way, the developer does not have to implement the compensation and substitution measures himself and can, in some cases, save on transaction costs.

ECONOMIC VALUATION

The process of estimating a value for a particular good or service in a certain context, often in monetary terms. Economic valuation is based on the preferences of the persons concerned. Economic valuations are often summarised in the form of cost-benefit analyses. If not all services or impacts are, or can be, valued in monetary terms, other techniques are applied, such as a cost-effectiveness analysis.

ECOSYSTEM

The components of a distinct physiographic region (e. g Lower Saxony Wadden Sea) or a specific type of physiographic region (e. g nutrient-poor watercourse) and their interactions. The term can apply to various spatial levels (local, regional) and covers (semi-)natural ecosystems (e. g undisturbed raised bogs), near-natural ecosystems (e. g calcareous oligotrophic grasslands), as well as those strongly shaped by human intervention (e. g. agroecosystems).

ECOSYSTEM SERVICES

Ecosystem services are the direct and indirect contributions of ecosystems to human wellbeing. They comprise goods and services that directly or indirectly provide economic, material, health or psychological benefits. Distinct from the term »ecosystem function«, »ecosystem service« is an anthropocentric concept, focusing on the benefits that ecosystems provide for people. The concept of »ecosystem goods and services« is synonymous with ecosystem services, and the two terms are used interchangeably.

HABITATS DIRECTIVE

European Union directive (Council Directive 92/43/EEC of 21 May 1992), whose aim is the conservation of natural habitats and of wild fauna and flora and the establishment of a coherent European ecological network of special areas of conservation (Natura 2000).

HUMAN WELLBEING

Concept prominently used in the Millennium Ecosystem Assessment [43]. It describes elements which constitute a »good life«, including basic material goods, health and bodily wellbeing, good social relations, security, peace of mind and spiritual experience, and freedom of choice and action.

IMPACT REGULATION

Impact mitigation is governed by the provisions of Article 14 ff. of the Federal Nature Conservation Act (*Bundesnaturschutzgesetz* – BNatSchG). Significant adverse effects on nature and landscape are to be avoided and minimised. Unavoidable significant adverse effects are to be offset via compensation measures or substitution measures.

INTERVENTION

Interventions in nature and landscape, as defined in Article 14 of the Federal Nature Conservation Act (*Bundesnaturschutzgesetz* – BNatSchG), are changes affecting the shape or use of areas, which may significantly or lastingly impair the performance and functioning of the natural balance or landscape appearance.

MITIGATION MEASURES

Mitigation measures, defined as compensation measures or substitution measures in the impact mitigation provisions of Article 14 of the Federal Nature Conservation Act (*Bundesnaturschutzgesetz* – BNatSchG), are nature conservation measures that are implemented to offset significant adverse effects that cannot be minimised or avoided. In some German states, eco-points from planned or implemented public or private nature conservation projects can be purchased by project developers to fulfil their legal compensation or substitution obligations. Eco-points are similar to carbon allowances. They are an expression of the value of compensation measures and are in some cases held in an -> eco-account.

NATURA 2000

Europe-wide network of protected areas designated under the EU Habitats Directive and the Birds Directive. Its aim is to safeguard all of Europe's major natural habitat types and endangered species. Natura 2000 currently covers 18 % of EU land area.

NATURAL BALANCE

Comprises abiotic components (soil, water, air/climate) and biotic components (organisms, habitats and communities) of nature and the interactions between such components.

NATURAL CAPITAL

An economic metaphor for the limited stocks of physical and biological resources found on Earth, and of the limited capacity of ecosystems to provide goods and services.

OPPORTUNITY COSTS

Foregone benefits of not using land or ecosystems in a different (alternative) way, such as the potential income from agriculture that is foregone due to the renaturation of a floodplain.

PROVISIONING SERVICES

Ecosystems' contribution to the provision of material goods and services, such as food, fresh water, and wood for building and fuel. They are often traded in the marketplace.

PUBLIC GOODS

A good or service in which the benefit received by any one party does not diminish the availability of the benefits to others, and where other persons cannot or should not be excluded from using it. Examples are the public road network, domestic security, clean air, and recreation in a freely accessible landscape.

REGULATING SERVICES

The services that ecosystems provide by acting as regulators of (other) ecosystem elements and processes, the latter (directly) benefiting human wellbeing; examples are soil filtering for groundwater quality, and hedges as protection against soil erosion.

RENATURATION

Restoration of an anthropogenically modified habitat to a near-natural state.

SITE POOL

A pool of potential compensation areas for measures to offset the impacts of future interventions. Sites are selected for the pool, registered and shown on relevant land-use plans. They thus form part of the supply side for mitigation and compensation measures.

TEEB

The Economics of Ecosystems and Biodiversity. The international TEEB study was initiated in 2007 by Germany in the course of its G8 presidency together with the European Commission. Supported by a variety of other institutions, it was implemented under the auspices of the United Nations Environment Programme (UNEP). The aim of the international TEEB study was to assess the economic value of nature's services, to determine the economic impacts of ecosystem degradation and to demonstrate the cost of policy inaction.

WILLINGNESS TO PAY

Estimate of the amount people are prepared to pay in exchange for a certain public good, such as the protection of endangered species, for which there is normally no market price.

WILLINGNESS TO PAY (WTP) ANALYSIS

A survey-based economic method to assess willingness to pay. The term »contingent valuation« is also used, as the method seeks to determine willingness to pay under certain (contingent) conditions. Willingness to pay can be assessed by different methods. The WTP analysis is just one of several methods available to assess willingness to pay.

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INFORMATION ABOUT THE UNABRIDGED VERSION

This »Summary for Decision Makers« is based on the study **Natural Capital Germany – TEEB DE (2015): Natural Capital and Climate Policy – Synergies and Conflicts,** to be published in 2015 in German language, to which the following authors and reviewers contributed (for the convenience of the reader, title and chapter titles have been translated into English):

Editors:
Volkmar Hartje, Henry Wüstemann, Aletta Bonn

Authors:
Chapter 1: Natural Capital and Climate Policy: Introduction
Irene Ring, Henry Wüstemann (coordinating lead authors); Lisa Biber-Freudenberger, Aletta Bonn, Nils Droste, Bernd Hansjürgens

Chapter 2: Methodological Foundations of Ecosystem Services and Economic Valuation
Irene Ring, Henry Wüstemann (coordinating lead authors); Aletta Bonn, Karsten Grunewald, Ulrich Hampicke, Volkmar Hartje, Kurt Jax, Stefan Marzelli, Jürgen Meyerhoff, Burkhard Schweppe-Kraft

Chapter 3: Ecosystem Services, Biodiversity and Climate Change: The Foundations
Katrin Vohland, Ulrike Doyle (coordinating lead authors); Christian Albert, Christine Bertram, Lisa Biber-Freudenberger, Aletta Bonn, Miriam Brenck, Benjamin Burkhard, Johannes Förster, Elmar Fuchs, Carolin Galler, Christina von Haaren, Pierre L. Ibisch, Timo Kaphengst, Christian Klassert, Reinhard Klenke, Stefan Klotz, Stefan Kreft, Ingolf Kühn, Elisabeth Marquard, Dietmar Mehl, Insa Meinke, Karin Naumann, Marcus Reckermann, Katrin Rehdanz, Stefan Rüter, Wiebke Saathoff, Julia Sauermann, Mathias Scholz, Uwe Schröder, Ralf Seppelt, Daniela Thrän, Felix Witing

Chapter 4: Agriculture: Reducing Emissions, Avoiding Ploughing up Grassland, and Using Bioenergy Sustainably
Bernhard Osterburg (coordinating lead author); Jochen Kantelhardt, Horst Liebersbach, Bettina Matzdorf, Michaela Reutter, Norbert Röder, Lena Schaller

Chapter 5: Climate Change Mitigation through Rewetting of Carbon-Rich Soils
Aletta Bonn (coordinating lead author); Augustin Berghöfer, John Couwenberg, Matthias Drösler, Rita Jensen, Jochen Kantelhardt, Vera Luthardt, Thorsten Permien, Norbert Röder, Lena Schaller, Burkhard Schweppe-Kraft, Franziska Tanneberger, Michael Trepel, Sabine Wichmann

Chapter 6: Climate Change Mitigation as a Forest Ecosystem Service in Germany: How do German Forests Help to Protect the Atmosphere?
Peter Elsasser (coordinating lead author); Matthias Bösch, Georg Leefken, Bernhard Möhring, Till Pistorius, Joachim Rock, Sebastian Rüter, Bettina Schröppel

Chapter 7: The Role of Floodplains in Climate Change Mitigation and Adaptation
Alexandra Dehnhardt, Mathias Scholz, Dietmar Mehl (coordinating lead authors); Uwe Schröder, Elmar Fuchs

Chapter 8: The Role of Coasts and Oceans in Climate Change Mitigation and Adaptation
Christine Bertram, Ralf Döring, Katrin Rehdanz (coordinating lead authors); Jacobus Hofstede, Astrid Kowatsch

Chapter 9: Synergies and Conflicts between Climate Policy and Nature Conservation: Summary and Options for Action
Bernd Hansjürgens, Henry Wüstemann (coordinating lead authors); Christine Bertram, Aletta Bonn, Alexandra Dehnhardt, Ralf Döring, Ulrike Doyle, Peter Elsasser, Volkmar Hartje, Rita Jensen, Bernhard Osterburg, Katrin Rehdanz, Norbert Röder, Mathias Scholz, Daniela Thrän, Katrin Vohland

Reviewers:
Olaf Christen, Matthias Dieter, Thomas Ehlert, Klaus Glenk, Felix Grützmacher, Ulrich Hampicke, Stefan Heiland, Eckhard Heuer, Thomas Hickler, Karin Holm-Müller, Eduard Interwies, Rainer Kant, Stephan von Keitz, Stefan Mann, Günter Mitlacher, Klaus Müller, Georg Rast, Achim Schäfer, Christian Schleyer, Ernst-Detlef Schulze, Karsten Schwanke, Reimund Schwarze, Klement Tockner, Christine Wenzel

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