WBGU

German Advisory Council on Global Change

Flagship Report

Rethinking Land in the Anthropocene: from Separation to Integration

German Advisory Council on Global Change

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from Separation to Integration

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- identifies gaps in research and initiates new research,
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- elaborates recommendations for action,
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The WBGU received valuable suggestions from hearings with the following experts conducted during its special intensive conferences and regular meetings:

- On 19 September 2019, the WBGU had the opportunity to exchange views with Dr Alexander Popp (Potsdam Institute for Climate Impact Research), who provided information on the main findings of the latest IPCC Special Report on Climate Change and Land, to which he contributed as lead author.
- On 17 October 2019, the WBGU held a hearing with Dr Margret Engelhard (Federal Agency for Nature Conservation) to learn about the current state of modern genetic engineering and its regulation.
- On 15 November 2019, Dr Harald Ginzky (Federal Environment Agency) reported on his reflections on land/soil governance in the light of his experience at the UNCCD negotiations.
- On 18 December 2019, Dr Christiane Paulus and Inka Gnittke (BMU) reported on the current status of the Convention on Biological Diversity (CBD).
- On 23 January 2020, expert hearings were held with Jun.-Prof Dr Cathrin Zengerling (Albert Ludwig University Freiburg) and Prof Dr Joachim von Braun (Center for Development Research – ZEF, University of Bonn and Bioeconomy Council). Dr Zengerling gave an overview of approaches to (and possibilities for) taking aspects of environmental protection and climate-change mitigation into account at the WTO, in investment-protection agreements and in regional free-trade agreements. Prof Dr von Braun presented the work and views of the Bioeconomy Council (Bioökonomierat).

There were lively discussions on the WBGU's new flagship report at joint meetings with the Interministerial Committee for Monitoring the WBGU (IMA) held on 14 November 2019 and 11 May 2020; these were chaired by Dr Karsten Sach (BMU) and Volker Rieke (BMBF).

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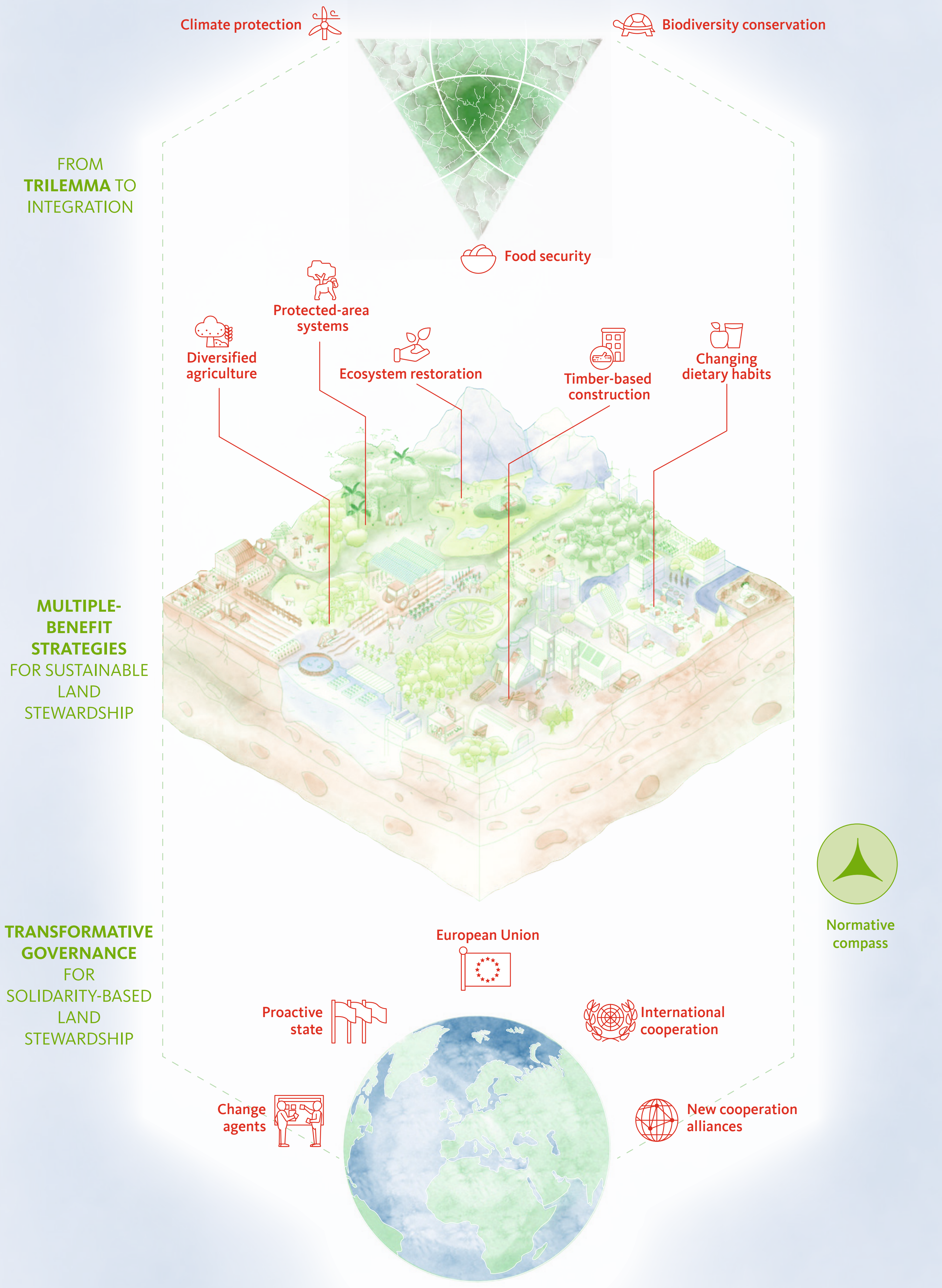
Acronyms and Abbreviations

AbL	Arbeitsgemeinschaft bäuerliche Landwirtschaft *Working Group on Rural Agriculture*
ABS	Access and Benefit Sharing (CBD)
ACCTS	Agreement on Climate Change, Trade and Sustainability
BauGB	Baugesetzbuch *(German) Building Code*
BECCS	Bioenergy with Carbon Capture and Storage
BMBF	Bundesministerium für Bildung und Forschung *German Federal Ministry of Education and Research*
BMEL	Bundesministerium für Ernährung und Landwirtschaft *German Federal Ministry of Food and Agriculture*
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit *German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety*
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung *German Federal Ministry for Economic Cooperation and Development*
BNatSchG	Bundesnaturschutzgesetz *German Federal Nature Conservation Act*
BZfE	Bundeszentrum für Ernährung *German Federal Office for Agriculture and Food*
C40	Cities Climate Leadership Group
CAP	Common Agricultural Policy (EU)
CBD	Convention on Biological Diversity (UN)
CBOs	Community-Based Organizations
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CGIAR	Consultative Group on International Agricultural Research
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora (UN)
CO_2	Carbon dioxide
COP	Conference of the Parties
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CS	Citizen Science
CSA	Climate Smart Agriculture (FAO)
CWR	Crop Wild Relatives
DAC	Direct Air Capture
DACCS	Direct Air Capture with Carbon Storage
DC	Development Cooperation
DGE	Deutsche Gesellschaft für Ernährung *German Nutrition Society*
ECOSOC	Economic and Social Council (UN)
EEA	European Environment Agency (EU)
EID	Emerging Infectious Diseases
EPAs	Economic Partnership Agreements

EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FBDG	Food Based Dietary Guideline
FDI	Foreign Direct Investment
FSC	Forest Stewardship Council
G7	Group of Seven (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States)
G20	Group of Twenty (19 individual countries plus the European Union)
GEF	Global Environmental Facility (UN)
GHG	Greenhouse Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit *German Society for International Cooperation*
GLII	Global Land Indicators Initiative
GLADA	Global Assessment of Land Degradation and Improvement (ISRIC)
GLASOD	Global Assessment of Soil Degradation (FAO)
GLF	Global Landscapes Forum
GLO	Global Land Outlook (UNCCD)
GLTN	Global Land Tool Network
GPFLR	Global Partnership on Forest and Landscape Restoration
Gt	Gigatons
IAMs	Integrated Assessment Models
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
ICCAs	Indigenous Peoples' and Communitiy Conserved Territories and Areas
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (UNEP, UNESCO, FAO and UNDP)
IPCC	Intergovernmental Panel on Climate Change (WMO, UNEP)
IPLCs	Indigenous Peoples and Local Communities
ISP	Input Subsidy Program
ISRIC	International Soil Reference and Information Centre
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture (FAO)
ITPS	Intergovernmental Technical Panel on Soils
IUCN	International Union for Conservation of Nature
JLG	Joint Liaison Group (Rio-Conventions)
KfW	Kreditanstalt für Wiederaufbau *Development Bank*
LDCs	Least Developed Countries
LDN	Land Degradation Neutrality (SDGs)
LULUCF	Land Use, Land Use Change and Forestry (UNFCCC)
MAB	Man and the Biosphere Programme (UNESCO)
NCDs	Non Communicable Diseases
NGO	Non-governmental Organization
NCP	Nature's Contributions to People
N4C	Natural Pathways to Climate Mitigation
O-5	Outreach States (Brazil, China, India, Mexico and South Africa)
OECD	Organisation for Economic Co-operation and Development
PADDD	Protected Area Downgrading, Downsizing, and Degazettement
PES	Payments for Ecosystem Services
PHD	Planetary Health Diet
PIC Convention	Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (UN); also "Rotterdam Convention"
POP Convention	Convention on Persistent Organic Pollutants (UN); also "Stockholm Convention"
PV	Photovoltaics

Ramsar Convention	Convention on Wetlands of International Importance Especially as Waterfowl Habitat (UNESCO)
R&D	Research and Development
REDD+	Reducing Emissions from Deforestation and Forest Degradation (UNFCCC)
ROG	Raumordnungsgesetz *(German) Spatial Planning Act*
SADC	Southern African Development Community
SDGs	Sustainable Development Goals (UN)
SMEs	Small and Medium-sized Enterprises
SRU	Sachverständigenrat für Umweltfragen *German Advisory Council on the Environment*
SSA	Sub-Saharan Africa
SUP	Strategische Umweltprüfung *Strategic Environmental Assessment*
TFEU	Treaty on the Functioning of the European Union
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	General Assembly of the United Nations
UN Habitat	United Nations Human Settlements Programme
UVP	Umweltverträglichkeitsprüfung *Environmental Impact Assessment*
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen *German Advisory Council on Global Change*
WBCSD	World Business Council for Sustainable Development
WCMC	World Conservation Monitoring Centre (UNEP)
WDPA	World Database of Protected Areas (UNEP-WCMC)
WHC	World Heritage Convention (UNESCO)
WHO	World Health Organization (UN)
WOCAT	World Overview of Conservation Approaches and Technologies
WRI	World Resources Institute
WTO	World Trade Organization
WWF	World Wide Fund For Nature



Climate protection
Biodiversity conservation
FROM TRILEMMA TO INTEGRATION
Food security
Protected-area systems
Diversified agriculture
Ecosystem restoration
Timber-based construction
Changing dietary habits
MULTIPLE-BENEFIT STRATEGIES FOR SUSTAINABLE LAND STEWARDSHIP
Normative compass
TRANSFORMATIVE GOVERNANCE FOR SOLIDARITY-BASED LAND STEWARDSHIP
European Union
Proactive state
International cooperation
Change agents
New cooperation alliances

Summary

Only if there is a fundamental change in the way we manage land can we reach the targets of climate-change mitigation, avert the dramatic loss of biodiversity and make the global food system sustainable. The WBGU proposes five multiple-benefit strategies illustrating ways of overcoming competition between rival claims to the use of land. These should be promoted by five governance strategies, especially by setting suitable framework conditions, reorienting EU policy and establishing alliances of like-minded states.

Where does international sustainability policy stand at the beginning of the 2020s? The answer is sobering. This report appraises the situation and reveals an urgent need for action by many government ministries (e.g. Environment, Education and Research, Agriculture, Development Cooperation) to develop a new approach to land stewardship:

- It looks like the climate-protection goals of the Paris Agreement can only be reached if, in addition to the decarbonization of the global economy, more areas of land are used to extract carbon dioxide (CO_2) from the atmosphere. However, this not only offers opportunities, it also involves considerable risks.
- The global food system is in crisis. The food security of a quarter of humanity is under threat, and another quarter suffers from unhealthy overconsumption. At the same time, the environmental damage and other external effects caused by industrial agriculture threaten our natural life-support systems, despite all past efforts – from the 'Green Revolution' of the 1960s and 70s to the European Union's Common Agricultural Policy.
- Biodiversity is experiencing a dramatic, human-induced mass extinction worldwide, the scale of which has been compared with the great geological extinction events of the past. This also greatly reduces the capacity of ecosystems to contribute to climate regulation and food security.

All this is happening in a situation where multilateralism is in deep crisis and the COVID-19 pandemic is making things even more difficult. The President of the European Commission, Dr Ursula von der Leyen, put it in a nutshell in her State of the Union Address to the European Parliament on 16 September 2020: "There is no more urgent need for acceleration than when it comes to the future of our fragile planet."

The diverse demands made on land for the purposes of climate-change mitigation, food security and the conservation of biological diversity are already in competition with each other, and land degradation will have a negative impact on all three aspects in the short or long term. The WBGU calls this the 'trilemma of land use' because, at first glance, it appears that any one of these challenges can only be met at the expense of the other two. This report uses examples to show how combinations of conservation and different uses in the landscape can generate multiple benefits so that competition can be overcome. In this respect, the Conferences of the Parties to the Framework Convention on Climate Change (UNFCCC), the Paris Agreement and the Convention on Biological Diversity (CBD) planned for 2021, as well as the forthcoming UN Decade on Ecosystem Restoration, are key forums for making decisive international progress towards sustainable land stewardship. The necessary land-use transformation will, however, not succeed just by changing existing international legal instruments and forums. The initiative of private actors, companies and societal groups, as well as measures at the state and supranational level, are also needed. Furthermore, coalitions of like-minded countries should join together in cooperation alliances to promote the global land-use transformation.

A global land-use transformation towards sustainability is urgently needed

Land is the "the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system" (definition from the Convention to Combat Desertification, UNCCD, Art. 1e). In the present report, the WBGU presents political design options for sustainable land stewardship. It develops examples of multiple-benefit strategies for the protection and restoration of ecosystems, for agriculture, dietary habits and the bioeconomy; strategies that are transformative because they are scalable and suitable as 'game changers'. In addition, the report proposes effective instruments for governance incorporating both change agents and the proactive state, the EU, international institutions (including the UNFCCC, CBD and UNCCD) and new, international cooperation alliances.

Land is a global commons: humankind must accept and assume its responsibility for land in order to mitigate climate change, conserve biodiversity and safeguard food security; it must discharge this responsibility nationally and enforce it internationally. The focus should be on halting the destruction of terrestrial ecosystems and on investing massively in their conservation and restoration. Globally sustainable land stewardship is a prerequisite for compliance with planetary guard rails and for meeting the UN Sustainable Development Goals (SDGs). The key strategies and governance requirements set out by the WBGU in this report can be characterized by the terms *systemic*, *synergistic* and *solidarity-based*.

Systemic interrelations as a key to global sustainability

A wide variety of interactions characterize the interplay between, on the one hand, land use and land degradation and, on the other, climate change, greenhouse-gas emissions and sinks, the loss and degradation of ecosystems and biodiversity, the exploitation of biogenic resources, and the increasingly critical state of the food systems. Fragmented and unsustainable land management leads to multiple conflicts concerning its protection and use, and to competition for land. The WBGU therefore urges a systemically substantiated, sustainable approach to land stewardship, which is an important key to the Great Transformation towards Sustainability. Ecosystems and their diverse services are essential bases for human life and economic activity and deserve to be at the centre of attention, whereby remote effects (telecouplings) – e.g. of material cycles or the world trade in agricultural goods – on land-use changes and land degradation must also be taken into account.

Synergistic interaction: from separation to integration

In selected thematic areas (ecosystem restoration, ecosystem conservation, agriculture, dietary habits, bioeconomy), the WBGU has developed five examples of *multiple-benefit strategies* for protecting and using areas of land, which contribute to a wide range of synergies and, overall, to sustainable land stewardship. In many cases, focusing on monofunctional land uses leads to competition between protection and different uses. A sustainable land stewardship that simultaneously enables climate-change mitigation, biodiversity conservation and food security, requires multifunctionality and synergies on areas of land and in the landscape. This is the only way to achieve multiple benefits overall and to overcome the trilemma of climate-change mitigation, biodiversity conservation and food security. The WBGU therefore recommends multiple-benefit strategies for sustainable land stewardship that combine several objectives and their implementation in one and the same landscape. For example, consideration should be given simultaneously to expanding and upgrading systems of protected areas (to cover 30% of the Earth's surface), accelerating land restoration, diversifying agriculture in various parts of the world, and changing people's dietary habits. Using timber in construction can combine climate protection, sustainable biomass production and a responsibly limited use of biogenic resources.

Solidarity-based assumption of responsibility

Multilateral policy approaches are indispensable for implementing overarching strategies for a transformation of land use at all levels of governance – from local, national and European to international. Land as a global commons requires actors at all levels to assume responsibility. International institutions, for example the three Rio Conventions UNFCCC, CBD and UNCCD, whose activities relating to land are currently not sufficiently coordinated, need more solidarity-based cooperation, scientific support across topics, and better stakeholder involvement. Furthermore, new multilateral alliances should be forged in order to promote the Great Transformation towards Sustainability before it is too late. They should above all bring together countries that are responsible for a particularly large proportion of global resource consumption.

Concept of the integrated landscape approach

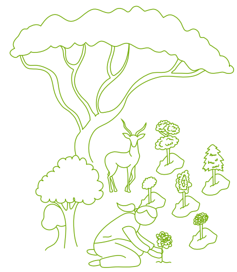
The strategic approaches for sustainable land stewardship – as summarized by the 'triad' systemic, synergistic, solidarity-based – must be implemented in practice on the land. The concept of the integrated landscape approach can provide some orientation here. The landscape provides a suitable frame of reference for governance: it is small enough to keep decision-making processes manageable, but large enough to accommodate the different interests of civil society, private and public stakeholders. In this context, a landscape is defined as an area characterized by specific geographical, natural, ecological and historical similarities and interacting structures which distinguish it from other areas. The integrated landscape approach underlying this report has the following characteristics:

- *Multifunctionality and multiple benefits:* The WBGU's normative compass and the identification of land-use synergies that can overcome the trilemma offer a basis for identifying a target system that can be shared by the different actors, as well as for strengthening multifunctionality in the landscape and developing solutions that are viable in the long term. The aim is to generate multiple benefits by the multifunctional use of suitable land and the combination of different pieces of land (e.g. agricultural fields that are also home to a wide range of agrobiodiversity, or pastures that are also a carbon sink).
- *Participation and reciprocity of stakeholders:* The private, public and civil-society stakeholders representing different interests should not only be identified and consulted; above all they should be encouraged to participate in the decision-making processes on how land should be managed. A suitable form of institutionalization would be the establishment of long-term multi-stakeholder forums that meet regularly and are also oriented towards the SDGs and other internationally agreed goals.
- *Shared framework for monitoring and evaluation:* This is an essential prerequisite for putting the negotiation processes on a common evidence base. In the sense of transdisciplinary approaches, local stakeholders should be encouraged and trained to each contribute their respective knowledge to facilitate joint learning.
- *Adaptive management:* Processes that take place in – or impact on – landscapes are dynamic and frequently non-linear. Adaptive management has proved its worth in coping with these potentially unpredictable and disruptive dynamics (e.g. economic or climate crises).

Five multiple-benefit strategies for sustainable land stewardship

In order to show how the trilemma of land use can be overcome, the WBGU presents five examples of multiple-benefit strategies. These relate to the thematic fields of ecosystem restoration, ecosystem conservation, agriculture, dietary habits and the bioeconomy.

1. Ecosystem restoration: make land-based CO_2 removal synergistic

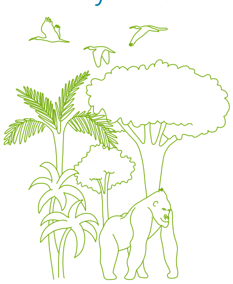


Measures for removing CO_2 from the atmosphere are no substitute for a massive reduction of CO_2 emissions with the aim of cutting emissions to zero. However, in order to reach the climate-protection goals of the Paris Agreement, additional measures to remove CO_2 from the atmosphere can hardly be avoided, although they involve considerable uncertainties and risks depending on the method, scope and effectiveness of implementation and can potentially increase the pressure on the land. When setting targets for climate policy and designing timetables and accounting structures, a clear distinction should therefore be made between reductions in CO_2 emissions and CO_2 removal from the atmosphere. Net emission targets or climate-neutrality targets should, if at all, only be formulated if the assumed contributions of CO_2 emissions reductions and CO_2 removal respectively are explicitly stated; otherwise, the chances of achieving the climate protection goals might be jeopardized. The sustainably achievable potential of the individual approaches to removing CO_2 from the atmosphere should be explored locally, nationally and internationally and firmly integrated accordingly into climate-policy strategies as well as accounting and incentive structures.

If an ambitious reduction of global CO_2 emissions is achieved at an early stage, this will make it possible to avoid risky, large-scale methods of CO_2 removal and to focus on approaches which, while offering only limited potential for CO_2 removal, promise significant additional benefits for biodiversity and food security. One especially promising approach to CO_2 removal from the atmosphere is the restoration of degraded land ecosystems, a multiple-benefit strategy which has particularly high political appeal in view of the forthcoming UN Decade on Ecosystem Restoration. Rewetting and restoring peatlands has great potential for conserving very specialized ecosystems and for storing CO_2 sustainably. The site-specific reforestation of deforested areas offers sustainable potential for CO_2 removal and, moreover, opens up the possibility of contributing to sustainable livelihood systems or directly to human food supplies by establishing or creating agroforestry systems. Projects for afforesting hitherto unforested areas should be critically and individually appraised. The WBGU recommends that the target set by the Bonn Challenge of restoring 350 million hectares of terrestrial ecosystems worldwide by 2030 (which is equivalent to about 2% of the Earth's terrestrial surface) should be not only achieved, but significantly expanded; the focus should be on restoring biodiverse forests that are adapted to local conditions. In addition, not only reforestation but also the restoration of wetlands (rewetting) and grasslands (reducing grazing pressure) should be addressed.

The WBGU recommends that the multiple potential benefits of restoring degraded land should be exploited at an early stage over large areas. In addition, national and international research should be intensified on the costs, feasibility and permanence of ecosystem restoration and on how much land area is potentially available worldwide for this purpose. Furthermore, in order to finance restoration measures, payment systems for the creation and conservation of ecosystem services should be developed; these should be implemented much more consistently and systematically than hitherto, not only with regard to possible CO_2 removal, but also in general with regard to ecosystem services that can be characterized as commons.

2. Expand and upgrade protected-area systems



Effective and well connected systems of protected areas form the backbone of ecosystem conservation and are a decisive prerequisite for defusing the global biodiversity crisis and maintaining basic ecosystem services. Preventing the further degradation and destruction of ecosystems also benefits climate-change mitigation by avoiding CO_2 emissions and preserving natural carbon reservoirs. The value and conservation of the land inhabited by Indigenous Peoples and Local Communities (IPLCs) is of key importance here since most of its ecosystems are as yet untouched by intensive forms of cultivation.

Protected-area systems are characterized by the fact that their priority goal is the effective conservation of ecosystems and biodiversity. Protected areas that use zoning – i.e. division into areas with different combinations of conservation and sustainable use – allow the coexistence of valuable nature with human activities that are compatible with biodiversity conservation. Multiple benefits for food security can be realized in these protected areas, e.g. by allowing sustainable forms of use in certain zones which can even be a prerequisite for biodiversity conservation.

The WBGU recommends expanding terrestrial systems of protected areas to cover 30% of the Earth's land area while consistently applying internationally agreed quality criteria, and proposes this goal for the CBD's post-2020 framework. However, international negotiations must not be reduced to area targets; rather, existing Aichi quality criteria for protected areas should be maintained and compliance regulations tightened. As part of an integrated landscape approach, there should be improved networking, both between the protected areas and with restored areas and the surrounding land. In addition to the top-priority conservation goals, the other dimensions of the trilemma should also be borne in mind, checked for possible synergies and, in the landscape context, integrated more closely into the management plans of protected areas. Industrialized countries should make greater use of their financial capacity, where possible in combination with private financing, to expand and upgrade protected-area systems both at home and in developing countries. In order to secure the valuable conservation effect of regions inhabited by IPLCs, their traditional rights and traditional knowledge should be formally recognized not only at the UN level but also in national contexts.

3. Diversify farming systems

Agriculture shapes the landscape and land management in many parts of the world. It is the foundation of food security. However, both industrial agriculture and subsistence farming jeopardize climate-change mitigation and biodiversity and degrade the soils. The WBGU therefore recommends transforming the hitherto largely monofunctional, production-oriented agricultural systems towards ecologically intensive, multifunctional systems, e.g. agro-forestry, focusing on people, agro-ecological practices and the provision of ecosystem services. One of the German Federal Government's priorities should be the necessary transformation of the EU's agricultural policies.

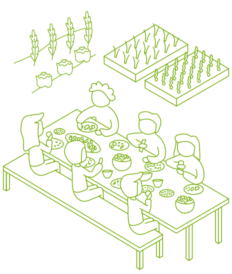
The WBGU recommends that EU agricultural policy should move away from industrial farming methods through a comprehensive ecological transformation. Agricultural subsidies should always be linked to environmental improvements, relying wherever possible on multifunctional production systems. Area-based direct payments should be transformed into payments for ecosystem services. Agri-environmental and climate-change-mitigation measures with especially positive effects on conserving biodiversity ('dark-green measures') should be further developed despite the additional administrative effort involved. The implementation of the envisaged national strategic plans from 2021 onwards should be monitored by the EU. In line with the concept of a circular economy, crop cultivation should be linked with animal husbandry, nutrient cycles should be closed and efforts made to increase nutrient efficiency and improve the recycling of nutrients (especially phosphorus, but also nitrogen and other nutrients). At the same time, greater efforts should be made to create carbon sinks and protect natural carbon reservoirs.

In order to shift land use towards sustainability, it is essential to involve and consult a wide range of stakeholders. Education and training programmes should provide information on diversified agricultural production systems and agri-ecological practices, explain the aims and requirements of agri-environmental programmes better and encourage participation. This transformation of agriculture will not be possible without the further development and implementation of digitalization in agriculture. The development and implementation of technical innovations for sustainability, e.g. precision agriculture, should be carefully considered and promoted – as long as they are not exclusively oriented towards large-scale systems and large-area agriculture but contribute towards the aims of ecological transformation and multifunctionality. In the medium term, the EU's Common Agricultural Policy (CAP) should be integrated into a more comprehensive system that also promotes ecosystem and biodiversity conservation and the provision of ecosystem services outside of agricultural land.

The productivity of subsistence agriculture in sub-Saharan Africa needs be sustainably improved to maintain soil quality over the long term. To achieve this, temporary financial support should be provided not only for materials, but also to cover the additional labour input required to ensure that farmers and herders are prepared to take on the additional work during the several years of adjustment that will be needed to restore the soils before yields increase. For a co-management of land use in semi-arid regions, farmers and herders should be familiarized with an integrated landscape approach by experts, and supported in its implementation.

The WBGU is convinced that a global transformation of agriculture can only succeed if it is backed by a stronger orientation of international trade towards sustainability criteria. The design and implementation of certification schemes (e.g. Fairtrade, the 'Bio-Siegel' organic seal, FSC) and protected labels of origin should be improved and, where appropriate, new schemes developed (e.g. climate labels for agricultural products) to promote sustainability. In regional trade agreements, the development of guidelines for voluntary eco-labelling should be proactively adopted from the planned Agreement on Climate Change, Trade and Sustainability (ACCTS). Furthermore, sustainability in trade should be promoted by supply-chain management, if necessary by passing supply-chain legislation at the European level. Finally, resilience to shocks and food crises should be strengthened: a small number of net exporting countries supply a large number of net importing countries, and most developing countries, specifically in sub-Saharan Africa, are dependent on food imports. Resilience – i.e. the capacity to robustly withstand shocks, climate-change effects and food crises – should be increased through diversified farming systems (especially 'climate-smart' measures), a new fund under the Economic Partnership Agreement (e.g. to promote agricultural productivity in sub-Saharan Africa), and through Aid for Trade measures for sustainable products.

4. Transform dietary habits: enable and encourage the assumption of responsibility on the demand side



The dysfunctionality of the global food system is one of the main drivers of the trilemma of land use. Above all, diets heavy in animal products in industrialized countries and the growing middle classes in emerging economies and developing countries are exacerbating land-related problems for climate and biodiversity protection and making sustainable food security more difficult. Promising potential for alleviating this problem lies in changing dietary habits. In Europe, a corresponding shift in values towards lower levels of meat consumption is already evident.

In the WBGU's view, there is an urgent need for a transformation of the global food system and of worldwide dietary habits. Both must be geared equally to human health and the conservation of ecosystem services. In particular, it is essential to encourage changes in consumer behaviour towards a reduced consumption of animal products. The necessary transformation of dietary habits can be decisively promoted by making consistent changes to framework conditions, establishing sustainability-oriented norms and creating corresponding incentives for business and consumers. In addition to the already mentioned EU CAP reform and corresponding changes in development cooperation, the components of such a transformation include an information and education offensive and resolute implementation of nutritional guidelines in line with the Planetary Health Diet (PHD). The PHD's guiding principle is that part of daily meals should be based on reduced amounts of animal products, especially red and processed meat. This should be laid down by the relevant institutions (e.g. in Germany by the Federal Centre for Nutrition – BZfE) as a principle for new nutritional guidelines, and also recommended by the German Federal Government. To create a role model, meals based on the PHD nutritional guideline should be offered in public communal catering or break-time catering, e.g. at the conferences of public institutions. Furthermore, a 'Sustainable Food Supply' certificate could be introduced for the retail sector, guaranteeing that what is on offer complies with the basic principles of the PHD and that food products are offered with sound information on environmental externalities.

The WBGU is also convinced of the urgent need to establish framework conditions to ensure that ecosystem services and the costs of their degradation are reflected as fully as possible in food prices. For example, hitherto neglected external costs of climate change and environmental degradation should be systematically documented by research and internalized by appropriate measures (certification, taxation, financial support). Social hardships related to price increases should be monitored and, where appropriate, cushioned.

Finally, the Federal Government should use trade as an engine for achieving sustainable and healthy nutrition. International trade and investment agreements should take into account impacts on the nutrition of populations. The Principles for Responsible Investment in Agriculture and Food System developed by the Committee on World Food Security strengthen food security and the right to adequate nutrition and should be consistently implemented. This applies in particular to regional and bilateral trade agreements, which offer investors particularly strong protection.

5. Shape the bioeconomy responsibly and promote timber-based construction

The use of materials or energy from biomass in the bioeconomy offers a wide range of options for replacing emissions-intensive processes and fossil resources. However, the growing demand for land for biomass production is increasingly competing with the land requirements for food security and biodiversity conservation. In order to shape a bioeconomy based on sustainable land use, it is therefore necessary to create a framework limiting the use of biomass and setting priorities according to types of use. Taking the conservation of biodiversity and natural carbon reservoirs into account, a hierarchy in the use of biomass should give first priority to food and only then to materials and specific energy-related uses. Preference should be given to uses in which carbon is stored, or for which there are no other non-fossil energy alternatives. To achieve this, reduction targets for material consumption should be defined and, as material uses of biomass are stepped up, the sustainability demands on its production should be tightened and expanded in parallel; non-bio-based climate-protection strategies should be pursued. The use of by-products from agriculture and forestry for materials or energy can also contribute to economically sustainable development and food security, especially in developing countries and emerging economies.

The WBGU recommends boosting the use of timber in construction. Timber from locally adapted, sustainable forestry offers effective possibilities for long-term carbon storage. Specifically for the promotion of timber-based construction, the WBGU recommends proclaiming a global 'Mission for Sustainable Construction' together with international partners. This mission would strategically link the development and large-scale implementation of sustainable (timber-based) construction methods to a sustainable supply of raw materials, involve state actors as well as business, science and civil society, and develop global strategies on sustainable raw materials and building-material use. It is particularly important in this context to factor-in environmental costs (e.g. CO_2 prices in the cement and steel sectors, environmental requirements for sand), which would also make sustainable construction more attractive relative to conventional construction and create incentives for material efficiency and reuse. In order to establish all stages in the value chain of sustainable construction worldwide and also in rural areas, the necessary knowledge must be disseminated (e.g. information on materials, construction methods, standards and certification, as well as recycling options). A greater number of practice-oriented, inexpensive engineering and dual-training courses and advanced training in sustainable construction should be offered, and not only by industry/trade associations.

Industrialized countries should adjust their legal frameworks (e.g. building codes), remove relevant obstacles and promote a circular economy and sustainable public construction. Accordingly, the WBGU supports the approach taken by the President of the European Commission, Dr von der Leyen, in striving for this goal within the European Green Deal and creating a

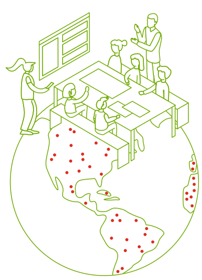
'New European Bauhaus' to support this ambitious project.

In developing countries and emerging economies, the establishment of regional, sustainable building-materials and construction industries should be promoted. Especially countries with high construction needs or sustainable resource potential should be supported in the production of sustainable building materials and in the planning, construction, maintenance and reuse of regionally adapted sustainable buildings. One example is the collaboration between local farmers and foresters, construction companies and R&D institutions, linked to local programmes of investment and international trade.

Five governance strategies for a solidarity-based land stewardship

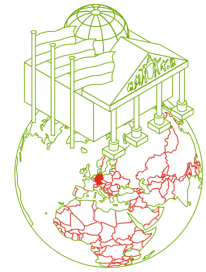
As part of the global commons, terrestrial ecosystems and their services depend on all stakeholders assuming broad and solidarity-based responsibility. The multiple-benefit strategies offer starting points for important changes, but a global land-use transformation is a challenge that goes far beyond individual multiple-benefit strategies. It is important that suitable framework conditions and incentive systems are created by governance at all levels – local, national, European, international and transnational.

1. Support change agents



Solidarity-based consumption habits that are sensitive to the scarcity related to productive land are becoming increasingly widespread. Now there are numerous examples of change agents trying out new land-related protection and use practices. Some landowners are making their land available for ecosystem conservation or uses that are more sustainable, or are themselves trying out restoration and alternative cultivation methods; consumers are falling back on a wide range of options for growing food themselves and seeking sustainable alternatives when buying products made of wood. In order to broadly promote such pioneering activities and solidarity-based consumption, networking and visibility should be supported and financial resources provided.

2. Set political framework conditions for solidarity-based land stewardship

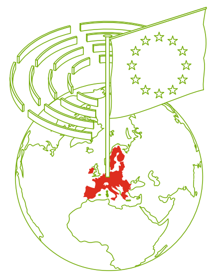


The challenge for governments lies in developing a consistent system of different instruments (e.g. price incentives, voluntary and mandatory sustainability standards, spatial planning, subsidies) to support a land-use transformation not only for change agents but also for society as a whole and to break down barriers. States should ensure that both those who use land and those who consume products produced on the land take into account the negative impacts their actions have on ecosystems – and that their positive contributions to the conservation or restoration of ecosystems and ecosystem services are rewarded by society. Building on a large number of partial, sectoral regulations, a system of coordinated instruments is therefore needed that is as comprehensive as possible in terms of areas, (sectoral) biomass uses and actors, especially when demand for new uses of land and biomass is greatly increasing, e.g. as a result of higher CO_2 prices. This can be achieved, for example, by linking sustainable resource strategies with standards and certification systems, promoting circular and cascading uses, offering financial incentives, and gearing research and development towards sustainability.

Furthermore, particular challenges for the proactive state lie in enforcing domestic requirements on land stewardship also at the international level (e.g. through free trade agreements or border tax adjustments), in order to prevent displacements of unsustainable modes of behaviour and thus indirect land-use changes. These challenges also involve identifying and cushioning distributional effects of government action and the transformation of land use in general. In particular, indicators for, and monitoring of, the sustainable use of land and biomass should be further developed. Selected, existing instruments for production and trade – ranging from voluntary certification and financial incentives to restrictions, the establishment of protected areas (e.g. for nature conservation or groundwater protection) and outright bans (e.g. on pesticides) – should be improved and enforced in the interest of sustainable land stewardship. Finally, it is necessary to develop a consistent system from the partial, sectoral governance approaches.

The legal implementation and planning of the integrated landscape approach in Germany should primarily use existing planning instruments – e.g. spatial planning, which seems particularly suitable due to its interdisciplinary and broad approach. In particular, the possibility of using planning law to plan and designate multifunctional land uses should be integrated as a guiding concept into national planning law and planning activities.

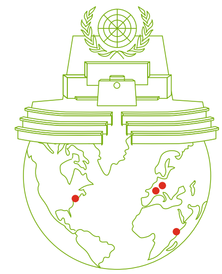
3. Tackle land-use transformation in the European Union



As a community of shared laws and values whose territory is largely interconnected, the EU is particularly well suited for testing a land-use transformation over a large area. In this sense, the European Green Deal can be used to advance not only climate neutrality by 2050 but also a transformation in land use towards sustainability. It also bears particular international responsibility because of the high demand for land outside the EU, which it can take into account primarily through its trade policy. The key policy for a European land-use transformation is the EU's Common Agricultural Policy (CAP). Within the EU, funds are needed not only for the ecological transformation of agriculture, but also for sustainable forestry, establishing and expanding protected-area systems, restoring ecosystems and, where appropriate, developing more land-based approaches to CO_2 removal – as well as for other objectives that impact on the quality, protection and use of land. In order to establish uniform framework conditions and funding conditions for all these concepts of land use and protection, the CAP should in future be further developed into a Common Ecosystem Policy (CEP). Furthermore, the EU should set quantified targets for reducing the consumption of resources – analogous to its climate-mitigation targets – and gear the circular economy to them. A sub-target should limit the use of biomass. Sustainability standards like those that already apply to the promotion of bioenergy and biofuels should be extended to other uses of biomass.

The WBGU believes it is essential that the EU use its foreign-trade policy to promote a global land-use transformation. The EU should make the sustainable stewardship of land a key issue in the negotiations on future – and the reform of existing – trade agreements. It should furthermore use its weight in trade policy to integrate the protection of global commons more fully into the regulations of the World Trade Organization and promote the development and production of sustainable goods and services by reducing relevant trade barriers. Unilateral actions at its external borders should be further pursued and explored in line with the objectives of EU environmental policy.

4. Strengthen international cooperation and coordination with a focus on land

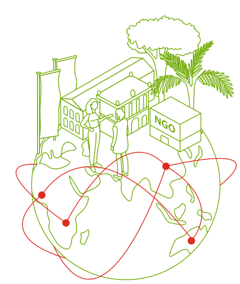


Numerous international organizations, institutions and conventions under international law are working on the global land-use transformation. The WBGU focuses here on cooperation under the Rio Conventions, scientific assessments of land use, and the potential for increasingly 'glocal' interlinkage.

The WBGU recommends convening a 'Global Land Summit' in 2025 – a joint conference of the parties to all three Rio Conventions. In this way, for the first time, a lot of attention can be generated for the global land-use transformation, and many resources can be made available to develop a common vision for sustainable land stewardship. This cooperation should be supported by upgrading the Joint Liaison Group, the link between the three conventions. Not least, the CBD's post-2020 framework should be resolutely developed and implemented.

The synthesis potential of global scientific assessments should be used across the board. Local solutions and process knowledge for implementation at the landscape level should also be scientifically assessed and processed. Regional research and competence centres should be expanded to research and test regional approaches to sustainable land stewardship in practice. In order to effectively address global environmental change, indigenous and local positions should not only be given a higher profile in international forums; rather, the role of IPLCs as knowledge carriers, transformation actors and locally affected people should also be consistently strengthened and better integrated.

5. Establish new cooperation alliances for the global land-use transformation



Existing forums for a global transformation of land use are indispensable. To enable rapid progress, they need to be strengthened and, in addition, new forms of cooperation set up. The WBGU therefore recommends the establishment of new cooperation alliances by like-minded states and subnational regions.

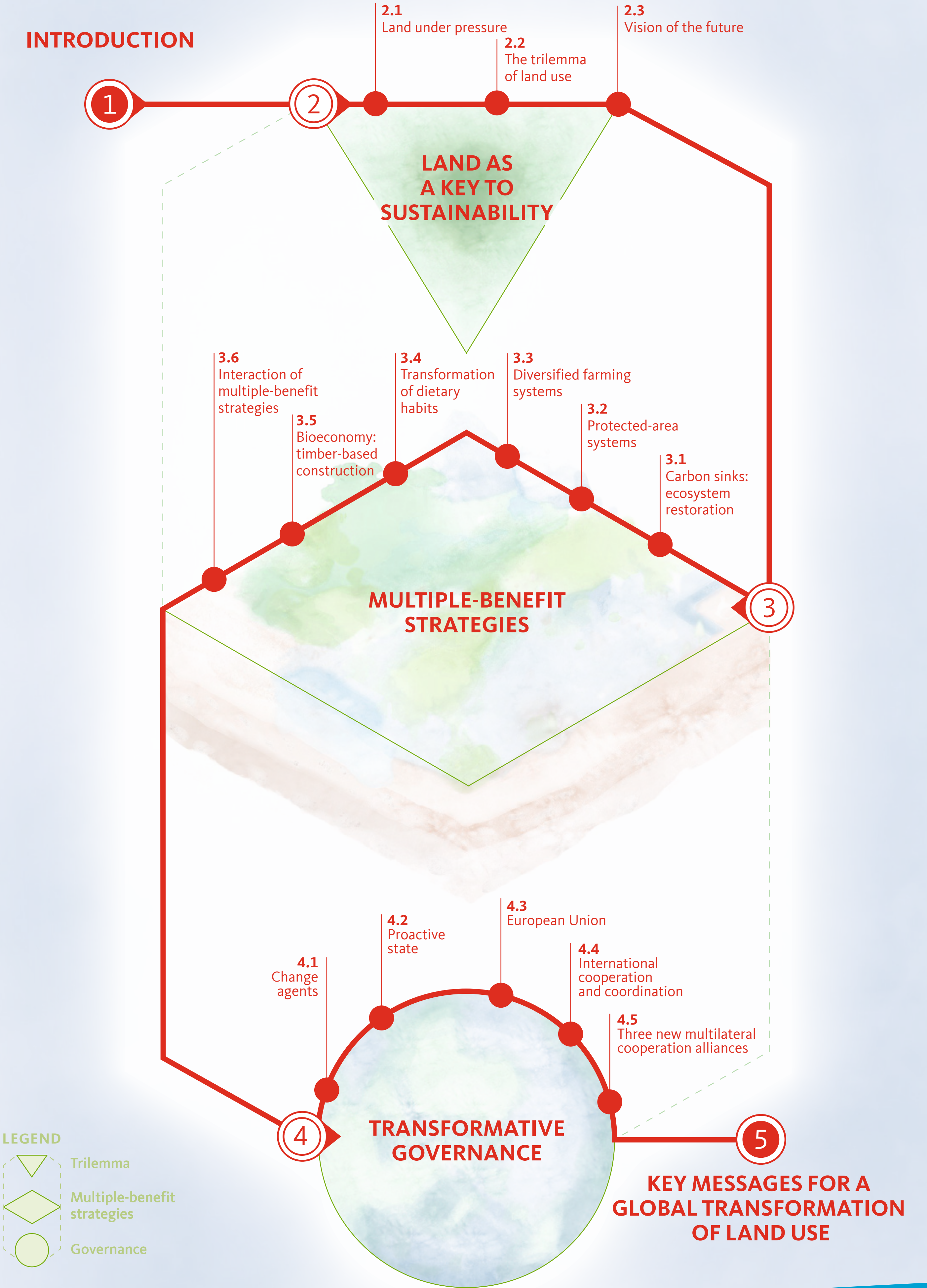
The first model that the WBGU is developing and proposing is that of *regional alliances* which aim for the cross-border implementation of integrated landscape approaches. Regions should cooperate institutionally more closely as neighbours to make cross-border land uses possible, e.g. in the form of the proposed multiple-benefit strategies. Regional alliances of sub-national regions can, for example, establish regional circular economies and value chains, further develop existing biosphere reserves into forerunners of integrative landscape areas, or set up regional innovation hubs for sustainable farming methods.

The aim of the WBGU's second model is for states around the world to assume responsibility by joining forces to form a *supranational alliance for a global land-use transformation*. The purpose of these alliances is to unite countries that want to jointly pursue sustainable land stewardship and agree on common values and regulations to achieve this aim, e.g. common production standards. Member states of these alliances can be spread over different regions of the world. They become effective by transferring specific sovereign powers to the alliance, following the EU model. These powers can be enforced vis-à-vis the member states by alliance institutions. Such supranational alliances can form pioneering alliances for sustainable world agricultural trade, jointly implement transparent and sustainable supply chains, and effectively advance a Green Deal globally.

The WBGU's third model consists of *global conservation alliances* for valuable ecosystems. In these conservation alliances, states and other – also private – actors join forces with the aim of conserving and restoring valuable ecosystems in third countries, which should also be members of the conservation alliance. Conservation alliances can, for example, jointly lease such areas and, in this way, move beyond the often passive role of being mere 'donor countries' and inclusively assume joint responsibility together with local stakeholders.

Committing to initiating the global land-use transformation

In order to overcome the trilemma of land use, this report offers options for overcoming land-use competition between climate-change mitigation, biodiversity conservation and food security. This requires a fundamental change in our approach to land stewardship. The aim is to show the way forward with a combination of the exemplary multiple-benefit strategies presented above and their implementation as part of an integrated landscape approach. Almost 30 years after the Rio de Janeiro Earth Summit, the international community has a framework of institutions at its disposal to address these problems. However, in view of the crisis of multilateralism, committed and rapid action by like-minded states is more important than ever. Political will, creativity and courage are required for the urgently needed global transformation of land use towards sustainability. It requires pioneers who explore and pursue new ways; states that set framework conditions, enforce the necessary measures and cooperate with each other; and mechanisms for achieving a fair balance between stakeholders. This can be driven forward by a supportive EU policy and a stronger focus on land in international cooperation, as well as new alliances of like-minded states. This report aims to vigorously advocate making the global land-use transformation a political priority.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Introduction 1

Land is the basis of human life. With advancing climate change, the human-caused mass extinction of biological diversity and an often dysfunctional food system, we are experiencing three colliding global crises that are directly linked to the way we manage land. Land use has therefore become increasingly important in international environmental, development and sustainability policy in recent years. The land and its biologically productive ecosystems are under more pressure than ever before. Stewardship of the land means not only land use, but also the conservation and restoration of ecosystems. This is the starting point of the present report:

- Which strategies for managing terrestrial ecosystems are most suitable for defusing the existing competition between different forms of land use and simultaneously ensuring climate-change mitigation, biodiversity conservation and food security?
- How can transformative change towards sustainable land use be promoted and which actors need to be mobilized and involved?
- What challenges does this pose for research and for Germany's role in global environmental and development policy?

Land stewardship as an essential key for climate-change mitigation, biodiversity conservation and food security

The ways in which we humans currently use land worldwide – e.g. practise agriculture and feed ourselves, manage or clear forests, build infrastructure and develop cities – have far-reaching, mostly negative ecological impacts. Terrestrial ecosystems and soils are being degraded and destroyed at great speed. Human activities are furthermore causing an unprecedented loss of biodiversity. The common overuse of natural resources impairs basic functions of terrestrial ecosystems and thus also endangers humanity's natural life-support systems (IPBES, 2018a, 2019b; IPCC, 2019b; SCBD, 2020; Independent Group of Scientists, 2019; UNCCD, 2017b).

With the IPCC's Special Reports on 'Global Warming of 1.5°C' and on 'Climate Change and Land' (IPCC, 2018, 2019b), as well as the internationally agreed goal of limiting global warming to well below 2°C, the need to extract carbon dioxide (CO_2) from the atmosphere has, among other things, moved into the focus of policy-makers and researchers. Terrestrial ecosystems are discussed as a key option in this context. Intact terrestrial ecosystems are also a prerequisite for ensuring sufficient and high-quality food supplies for everyone worldwide (IPCC, 2019b).

New diseases such as COVID-19, which were transmitted from animals to humans, are also related to terrestrial ecosystems. Their occurrence and distribution are encouraged by the destruction and fragmentation of natural ecosystems, by intensive livestock farming and the wildlife trade.

There is an acute need for action

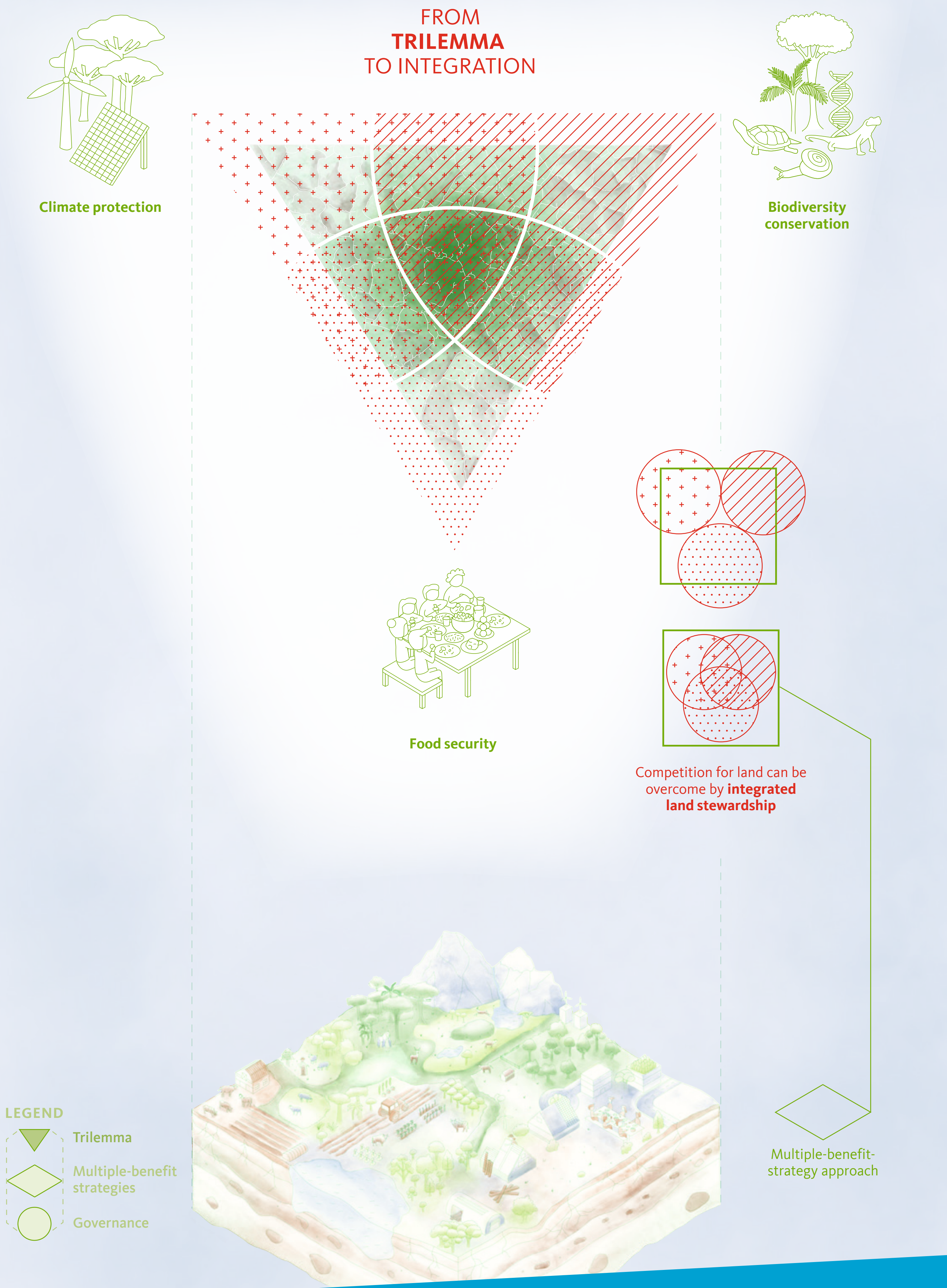
As early as 1992, at the UN Conference on Environment and Development in Rio de Janeiro, the international community of states set up important negotiation processes for sustainable development by agreeing the UN Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) and the UN Convention to Combat Desertification (UNCCD). The objectives of these three Rio Conventions are to prevent dangerous global warming, to protect biological diversity and use it sustainably and equitably, and to combat land degradation.

Almost 30 years later, societal movements like Fridays For Future and Extinction Rebellion are calling for a more determined implementation of measures to protect the climate, biodiversity and the environment. At the same time, multilateralism is in crisis; the process of implementing the goals of the Rio Conventions is cumbersome. The most recent milestone in environmental and development policy are the 17 UN Sustainability Goals adopted in 2015, which are to be achieved by 2030. Whether they will have a sufficient impact is an open question (Zeng et al., 2020). Despite all the ongoing political processes involving land issues, to date the international community has not sufficiently addressed land stewardship as an overarching challenge and focus for action. The COP of the CBD planned for 2021 in China and the UN Decade on Ecosystem Restoration, which also begins in 2021, could, however, herald a trend reversal.

This report develops options for the stewardship of the land and its natural resources that can help defuse existing competition for land use; it also identifies challenges for research.

An overview of the report

- *The trilemma of land use:* Chapter 2, 'Land as the key to sustainability: a systemic view', describes as a starting point the interwoven and mutually reinforcing global crises of climate, biodiversity and the food system. Due to their different and competing demands on global land use, they are seen as the 'trilemma of land use'. To overcome this trilemma, it is necessary to defuse competition for land use and to halt or reverse land degradation. Against this background, the WBGU outlines its vision for a transformation towards sustainable land use.
- *Multiple-benefit strategies for sustainable land stewardship:* In Chapter 3 the WBGU develops examples of 'Multiple-benefit strategies for sustainable land stewardship' to overcome the trilemma. Multiple-benefit strategies are strategies that aim for multiple concomitant benefits. First, the restoration of degraded ecosystems can do more than just remove CO_2 from the atmosphere. Second, networked systems of protected areas with participatory management can conserve biodiversity and ecosystem services and help create and secure a sustainable livelihood system. Third, diversified farming systems and fair and sustainable trade support food security, climate-change mitigation and biodiversity conservation. Fourth, changing dietary habits away from diets with a high proportion of animal products can also help overcome the trilemma of land use. Fifth, as part of a responsible bioeconomy, timber-based construction can make a contribution not only to climate-change mitigation but also to other challenges of sustainable development.
- *Governance for multiple benefits instead of competition:* An effective implementation of multiple-benefit strategies is needed to pave the way for the urgently needed transformation of our land stewardship. Policy-making and the involvement of a wide range of actors at all levels are key conditions for success. Chapter 4, 'Transformative governance for solidarity-based land stewardship', looks at (1) how change agents assume responsibility, (2) how a proactive state and (3) the European Union in particular create framework conditions for the implementation of multiple-benefit strategies, (4) how existing international cooperation can be strengthened, and (5) how the establishment of new multilateral cooperation alliances of like-minded states can drive the land-use transformation towards sustainability.
- *Key messages and recommendations:* The report concludes in Chapter 5 with 'Key messages for a global transformation of land use', which summarize the main statements of the report. The recommendations for action and research on individual multiple-benefit strategies and on governance are presented at the end of the relevant sections in Chapters 3 and 4 and are summarized in the Overview of Recommendations section.


FROM
TRILEMMA
TO INTEGRATION
Climate protection
Biodiversity conservation
Food security
Competition for land can be overcome by integrated land stewardship
Multiple-benefit-strategy approach
LEGEND
Trilemma
Multiple-benefit strategies
Governance

Land as the key to sustainability – a systemic view

2

The way we manage land urgently needs to be transformed to make a sustainable future possible. In addition to the climate crisis, today we are experiencing a crisis of the food system and a biodiversity crisis. These are all connected to the destructive way we treat terrestrial ecosystems. Here, the WBGU presents its normative basis and its future vision of systemic, synergistic and solidarity-based land stewardship.

Land represents more than just the area on which we live. According to the definition of the United Nations Convention to Combat Desertification (UNCCD), land is the "terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system" (UNCCD, Art. 1e). Terrestrial ecosystems provide humankind with an enormous variety of valuable regulatory, material and non-material services (IPBES, 2018b-e, 2019a; Section 2.2.3), whose estimated annual monetary value is approximately equivalent to global GDP (IPCC, 2019b:7; Box 4.2-4). Land ownership, access to land and land stewardship are thus key aspects of the fight against poverty and hunger and for gender equality. The UN Sustainable Development Goals (SDGs 14 and 15) explicitly refer to the protection of the sea from pollution coming from land and to the protection of land and terrestrial ecosystems themselves. Furthermore, all the other SDGs also contain an indirect reference to land stewardship.

Humankind has already fundamentally transformed the terrestrial biosphere (Ellis, 2011; Figures 2-1, 2-2). Around the year 1700 most of the world's land was still largely in its natural state; today, however, only about 23% of the global land surface can be designated as wildlands (Watson et al., 2016b; IPBES, 2018a; Figure 2-2c). Working on the assumption that ecosystems that have undergone a certain degree of transformation under largely natural conditions can still exhibit a high degree of biological diversity, a recent study has calculated that around 37% of the world's land surface is near-natural (Gosling et al., 2020). As convincingly shown by global assessment reports in recent years, humanity is increasingly destroying this natural life-support system, partly as a result of the growing global demand for land and terrestrial ecosystem services (IPBES, 2018a; IPCC, 2019a; UNCCD, 2017b). Terrestrial ecosystems are under increasing pressure from overexploitation, degradation and negative climate impacts (Section 2.1). The need to reverse these trends is increasingly attracting social and political attention. Under the heading 'nature-based solutions', measures are currently under discussion that protect and sustainably manage natural ecosystems and restore degraded ecosystems, while simultaneously addressing societal challenges such as climate change or food and water security, and promoting human well-being (Cohen-Shacham et al., 2016).

The COVID-19 pandemic, too, has drawn attention to the destruction of ecosystems and humankind's land stewardship. COVID-19 is the most recent example of a long series of zoonoses, i.e. diseases transmitted from animals to humans. Incidence of these diseases is accelerated, among other things, by hunting and trading in wild animals and by habitat destruction (WWF International, 2020b; Johnson et al., 2020; Karesh et al., 2012; Box 2.2-2).

This chapter begins by describing the status and change dynamics of terrestrial ecosystems (Section 2.1) and placing them in the context of key challenges to sustainability (Section 2.2), before presenting the WBGU's normative basis and an overarching vision for sustainable land stewardship in Section 2.3. Marine ecosystems are not dealt with in this report; they were

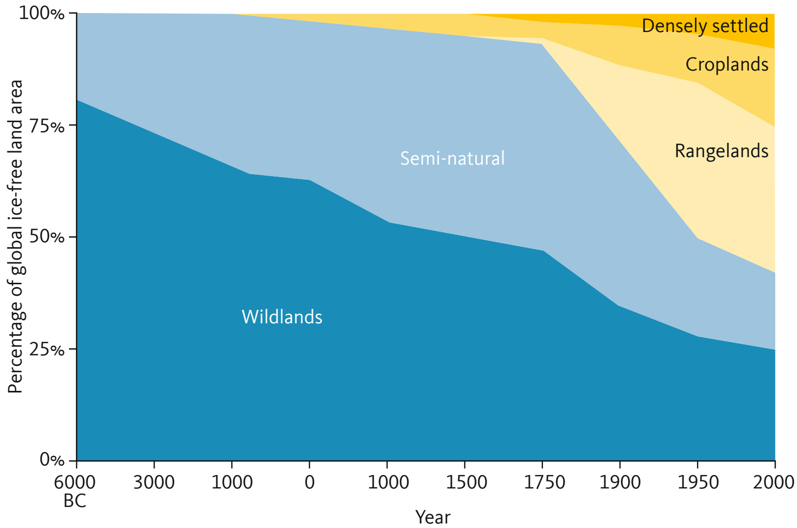


Figure 2-1
Transformation of the ice-free land surface by humans in the last 8,000 years.
Source: UNCCD, 2017b

the focus of the flagship report entitled 'Governing the Marine Heritage' (WBGU, 2013).

2.1
Land resources under pressure: overexploitation, degradation, competition for use

The pressure on terrestrial ecosystems from overexploitation and competition for use has never been greater than it is today (UNCCD, 2017b; Olsson et al., 2019). Land ecosystems are "the terrestrial portion of the biosphere that comprises the natural resources (soil, near surface air, vegetation and other biota, and water), the ecological processes, topography, and human settlements and infrastructure that operate within that system" (FAO, 2007; UNCCD, 1994 quoted by van Diemen, 2019:816). Typical natural terrestrial ecosystems are temperate deciduous and coniferous forests, tropical rainforests, grasslands (e.g. savannas and steppes), tundra, taiga and deserts, riverine landscapes and wetlands. Managed terrestrial ecosystems are areas that are used for agriculture, forestry or grazing.

A considerable proportion of managed and natural terrestrial ecosystems has already been damaged and is further threatened by climate change and biodiversity loss. This trend is alarming, especially in view of the increased demand particularly for animal products (UNCCD, 2017b:11; Box 2.1-1).

The process of human-caused (anthropogenic) land degradation involves the long-term deterioration in the status of terrestrial ecosystems. This in turn impairs biological productivity, ecological integrity and biodiversity, and thus also the benefits the land provides for humans (van Diemen, 2019). In view of the valuable services that terrestrial ecosystems provide for sustaining the natural life-support systems and the well-being of humankind (Figure 2.1-1; Section 2.2.3), this is extremely worrying.

2.1.1
Scale of and trends in the degradation of terrestrial ecosystems

Around a quarter of the Earth's ice-free land surface is affected by human-caused degradation (IPCC, 2019b). A look at the loss of fertile soils gives an indication of the dynamics of land degradation: it is estimated that soil erosion on agricultural fields is currently 10 to 20 times (with no tillage) to more than 100 times (with conventional tillage) higher than the rate of soil formation. At present, the degradation of the Earth's land surface by human activities is affecting the well-being of at least 3.2 billion people. Closely linked to these degradation processes is the fragmentation and loss of habitats, which is simultaneously a key factor in the biodiversity crisis (Section 2.2.3).

Researchers agree that land degradation represents a serious global problem (Olsson et al., 2019:365). However, to date there is no undisputed measure that reliably maps the scale and dynamics of terrestrial ecosystem degradation. Moreover, the terms land and soil degradation are often used synonymously (Gomiero, 2016:24). There are conceptual (how is land degradation defined?) and methodological reasons (how is land degradation measured?) behind this: in the early 1990s, degradation processes were predominantly measured in terms of soil degradation, i.e. focusing on the uppermost weathering layer of the Earth's crust (e.g. Oldeman et al., 1990; WBGU, 1994). Compared to soil degradation, the term land degradation is more compre-

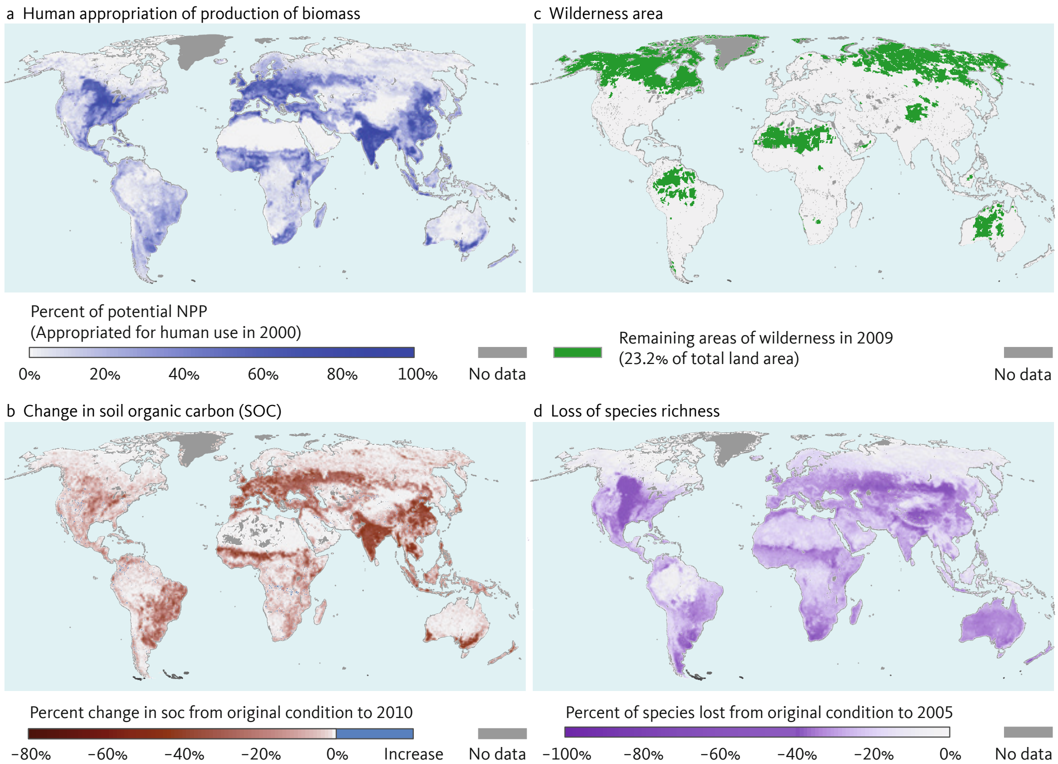


Figure 2-2
Effects of human activities on land surfaces.
Source: IPBES, 2018a: XXXIII

hensive and includes the degradation of all terrestrial ecosystems (IPBES, 2018a:662). Especially under the influence of the Millennium Ecosystem Assessment of 2005, the focus shifted to changes in ecosystem services. Neither the 1990 Global Assessment of Soil Degradation (GLASOD), nor the 2008 Global Assessment of Land Degradation and Improvement (GLADA) provided a comprehensive, quantitative and unequivocal picture of global land degradation (IPBES, 2018a:536).

More recent studies measure land degradation as the loss of net primary production, often using satellite data (Jackson and Prince, 2016). One way of estimating degradation trends in a region is to observe the dynamics of the land's primary production. Net primary production describes the amount of carbon that ecosystems accumulate through photosynthesis, minus the carbon released by plant respiration. A study by the European Commission's Joint Research Centre concludes that between 1999 and 2013 about 20% of the Earth's vegetation-covered land surface showed persistently declining trends in land productivity (Cherlet et al., 2018). This indicates ongoing soil and/or land degradation. The changes observed in this long-term study of cropland, pasture, grassland and forest landscapes, broken down by continent, showed declining or unstable productivity, particularly in Australia and Oceania (affecting 37% of the area), South America (27% of the area) and Africa (22% of the area). Declining or unstable productivity affected 14% of terrestrial ecosystems in Asia, 12% in Europe and 18% in North America. Cherlet et al. (2018:114) describe it as "alarming that 20% of the world's croplands show declining or stressed land productivity, particularly considering that immense effort and resources are being committed to maintain and enhance the productivity of arable and permanent cropland, as well as the fact that there are clear limitations to the further expansion of cropland." Overall, the approaches and methods used to measure global land degradation vary, ranging from expert estimates to on-site observations and measurements, remote-sensing data and simulation models.

The third edition of the European Commission's World Atlas of Desertification, with the participation of the UNCCD, attempts to present the different facets of degradation as a "convergence of evidence" against the background of the different methods (Cherlet et al., 2018:143). To this end, 14 "global change issues" (e.g. tree loss, water stress, decreasing land productivity, livestock density, population density) were selected whose interaction points to degradation processes. Further

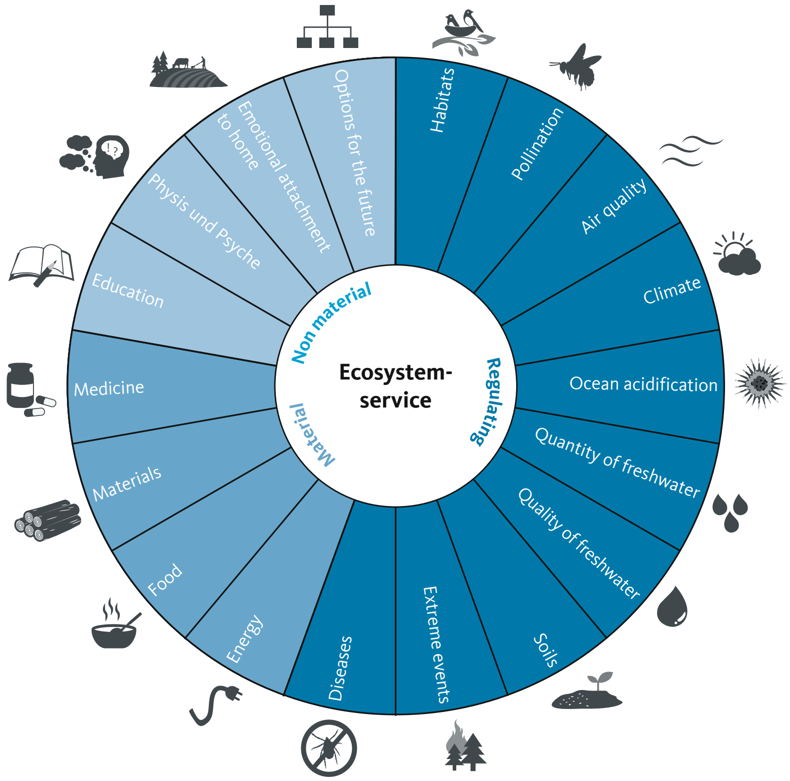


Figure 2.1-1
There are a total of 18 ecosystem services which can be divided into three categories: 'regulating' (e.g. climate and water quality), 'material' (natural resources) and 'non-material' (e.g. education).
Source: WBGU, based on IPBES, 2019a

evaluation with the aim of identifying critical areas of soil or land degradation requires an analysis of the interplay between the different indicators using additional (regionally specific) information (UNCCD, 2017b:53).

The key message is that soil and land degradation is a complex global phenomenon with marked differences between regions and between the most important systems of land cover and land use, which cannot be measured by one or a small number of indicators. The Global Land Outlook (GLO; UNCCD, 2017b), first published in 2017 – the next edition of which is planned for 2021 – also follows the "convergence of evidence" approach. This approach includes the synopsis of data on land cover and land use as well as biophysical and socio-economic factors relevant to land degradation.

2.1.2
Drivers of land degradation and consequences

The most important direct drivers of terrestrial ecosystem degradation (also land degradation) are the conversion of natural or near-natural vegetation into arable and pasture land, non-sustainable agricultural and forestry practices, climate change, and in some regions the extraction of raw materials, as well as infrastructure development and urban sprawl (IPBES, 2018a:XX). Although human settlements occupy only about 5% of the Earth's terrestrial surface, they are often located in particularly fertile areas (UNCCD, 2017b:42). Unsustainable cultivation of arable and pasture land (Section 3.3) is currently the biggest direct driver of land degradation (IPBES, 2018a).

Between 1963 and 2005, the global area under food crops increased by about 270 million hectares. During this period, 26% of the expansion was attributed to dietary changes and 74% to population growth (Kastner et al., 2012, quoted in IPBES, 2018a:150). One example of massive soil erosion triggered by unsustainable soil management was the Dust Bowl event in the USA and Canada in the mid-1930s (Worster, 1987). Large-scale cultivation of the Great Plains prairie landscapes primarily to grow wheat, intensified by years of drought, led to soil erosion (deep-rooted prairie grass had previously protected the soil) and devastating sandstorms. Harvests were destroyed and numerous farms were almost buried in sand. Many farmers had to leave their land. As a reaction, the US Soil Conservation Service (today Natural Resources Conservation Service) was founded a few years later.

The Green Revolution, which has achieved significant successes in increasing the production of rice,

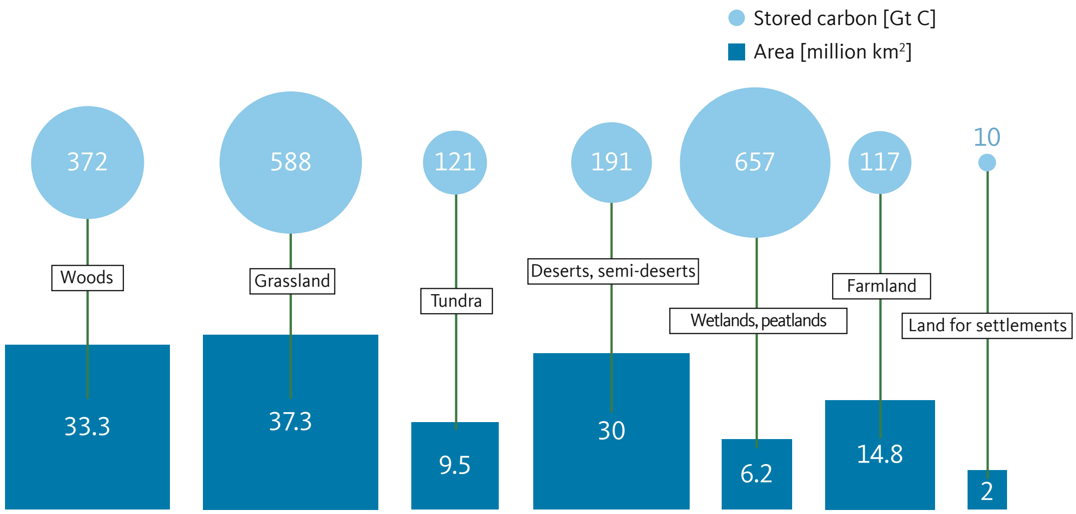


Figure 2.1-2
Carbon storage in terrestrial ecosystems.
Source: Bodenatlas, 2015; Bartz/Stockmar, CC BY-SA 3.0

wheat and maize since the 1960s, has also contributed greatly to land degradation. Examples of these degradation processes include the lowering of the water table as a result of irrigation, salinization due to irrigation errors, soil erosion caused by using flawed tillage methods and the exposure of uncovered soil to the effects of weather, the monocultivation of maize, the contamination of the environment through the excessive use of fertilizers and liquid manure (over-fertilization), the overuse of pesticides, and the impoverishment of species and varietal diversity as a result of the spread of monocultures. Soil and land degradation are also generated by 'soil mining', i.e. the cultivation of crops without adequately replacing the nutrients removed by the crops (under-fertilization, as in the case of resource-poor subsistence farms). The expansion of industrial agriculture was accompanied by the de-integration of functions in cultivated landscapes. Well-known examples of this are the land consolidation process in West Germany from 1954 onwards and the consolidation of agricultural land during the establishment of agricultural production cooperatives in the GDR in the 1950s. These land-consolidation measures, during which the landscape was adapted to the use of machinery by clearing hedges and orchards, destroying field margins or canalizing watercourses, exacerbated biodiversity loss and soil degradation through wind and water erosion. Overall, the creation of large-scale agricultural units led to a loss or monotonization of historical cultural landscapes. This is a pattern of landscape transformation that can be observed worldwide, but varies in its manifestation.

The main drivers of forest degradation and loss (Box 2.1-1) are changes in land use (e.g. for agriculture, including slash-and-burn and settlements) and timber production for use as construction material or fuel. 55% of the global timber harvest is used exclusively for cooking and heating with firewood and charcoal – this affects 2.8 billion people (Bailis et al., 2015), mainly on the African continent.

Finally, the degradation of terrestrial ecosystems is both a driver and a consequence of climate change (IPBES, 2018a:XIII). The effects of virtually all direct causes of land degradation are exacerbated by climate change. These include accelerated soil erosion on degraded land as a result of extreme weather events, an increased risk of forest fires and changes in the distribution of invasive species, harmful insects and pathogens. Examples include the granaries of Asia, e.g. rice cultivation in the Indus and Ganges deltas (salinization; Patel, 2011), rice cultivation in the Mekong delta (sea-level rise; Bindoff et al., 2007) and increased droughts in the rice-growing regions of northern China (Lin et al., 2013).

Climate change can limit possible ways of combating land degradation, such as ecosystem restoration or the conservation of protected areas. In the long term, changes in the climate in the 21st century threaten to become an increasingly important driver of soil degradation (IPBES, 2018a:XLII). The degradation of terrestrial ecosystems also contributes to climate change, since large amounts of carbon are released into the atmosphere when forests are cleared, peatlands drained or pastureland overused (Figure 2.1-2).

Box 2.1-1

Deforestation: status and trends

Global deforestation is continuing albeit at a slower speed. An estimated 420 million hectares of forest were lost worldwide between 1990 and 2020. From 2015 to 2020, the annual deforestation rate was estimated at 10m ha, compared to 12m ha from 2010 to 2015 (FAO, 2020h; Figure 2.1-3). Tropical forests are the most seriously affected. An intercontinental comparison of the situation over the last decade reveals the following (FAO, 2020h):

- From 2010 to 2020, Africa had the highest rate of annual net forest loss by intercontinental comparison: 3.9m ha. The main reason is the conversion of forest into arable land and the production of charcoal for lack of other fuels.
- From 2010 to 2020, South America had an annual net forest loss of 2.6m ha, although the rate of loss has decreased considerably and is today about half the rate it was from 2000 to 2010.
- Asia had the highest net gain in forest area between 2010 and 2020.
- Oceania recorded net losses of forest cover in the decades 1990 to 2000 and 2000 to 2010.

The most likely hotspots of global deforestation in the future will be Amazonia, the Congo Basin, parts of East Africa, Sumatra, Borneo, New Guinea, parts of Southeast Asia and eastern Australia (Figure 2.1-4).

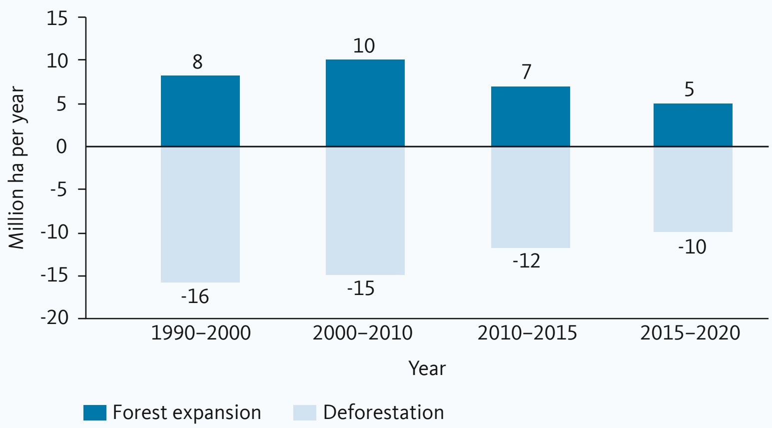


Figure 2.1-3
Annual rate of deforestation and forest expansion.
Source: FAO, 2020g

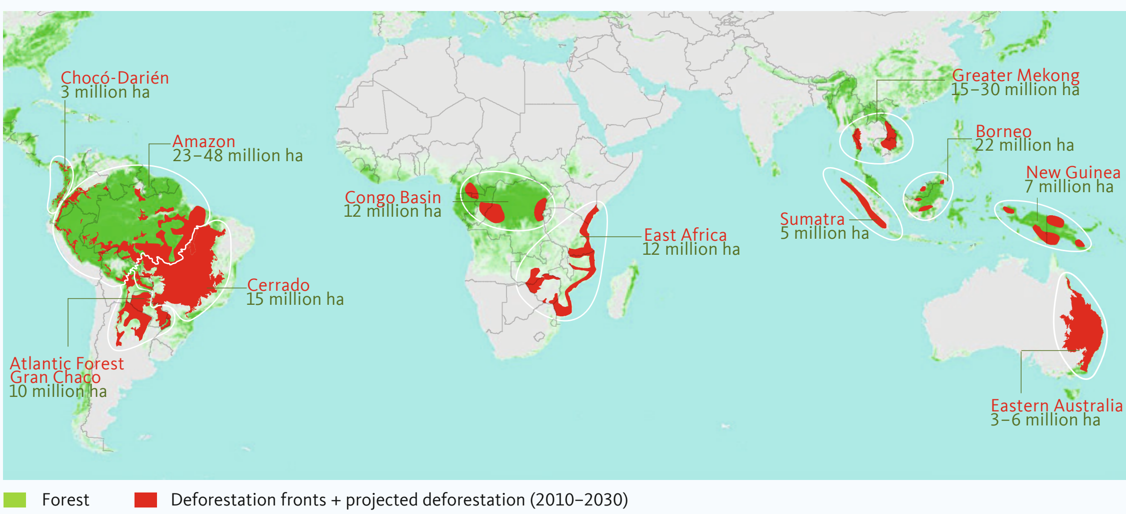


Figure 2.1-4
Expected hotspots of global deforestation up to 2030.
Source: IPBES, 2018a: 285; ©Text and graphics: 2015 WWF

2.1.3
Land Degradation Neutrality as a goal of international sustainability policy

The fight against land degradation and the issue of sustainable land stewardship are an integral part of the UNCCD in particular. With the inclusion of the goal of Land Degradation Neutrality (LDN) in the list of SDGs, the target of achieving a "land degradation-neutral world" by 2030 was agreed in 2015 (SDG 15 and 15.3). This goal is about offsetting land degradation caused by economic development in a different location (e.g. by ecosystem restoration), so that overall no further degradation takes place and the net effect in terms of land degradation is zero (Wunder et al., 2018b). Land degradation neutrality "is a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD, 2015). The goals of land degradation neutrality are (Cherlet et al., 2018:237)

- to maintain or improve ecosystem services;
- to maintain or improve land productivity in order to enhance food security;
- to increase the resilience of terrestrial ecosystems, for example against natural disasters;
- to search for synergies with other environmental objectives;
- to strengthen good governance of land tenure.

These goals are also set out in the UNCCD Strategic Framework 2018-2030 (UNCCD, 2017a). In summary, the protection, sustainable use and restoration of terrestrial ecosystems are a prerequisite for protecting biodiversity and the climate and for establishing a sustainable food system. The pressure to act is greater in the Anthropocene than ever before in the history of humankind.

2.2
The trilemma of land use

In its analyses on land stewardship, the WBGU focuses on three global crises: the climate crisis (Section 2.2.1), the food-system crisis (Section 2.2.2) and the biodiversity crisis (Section 2.2.3). The current destruction, degradation and fragmentation of terrestrial ecosystems is accelerating anthropogenic climate change, driving biodiversity loss and impairing food security. All three crises, each in its own way, are related to the use of land or terrestrial biomass and, in turn, have an impact on global land use and terrestrial ecosystems. Attempts to mitigate these crises can further increase the pressure on the land and increase competition: 'negative emissions', i.e. measures for the removal of CO_2 from the atmosphere, which are increasingly being discussed in the context of climate-change mitigation, add another new and potent 'customer' for the services of terrestrial ecosystems and land. The conservation of biodiversity is not possible without an expanded and upgraded system of protected areas, comprehensive ecosystem restoration and the sustainable use of cultivated areas. Right up to today, the task of feeding a growing world population has been accompanied by a continuous increase in land-intensive dietary habits. As a result, there are warnings against growing global competition for land use (Smith, 2018). In the present report, the WBGU refers to the potential competition between these three dimensions as the 'trilemma of land use' (Figure 2.2-1). Further demand – e.g. for space for housing and roads or from the bioeconomy – intensifies this competition.

The WBGU has chosen the term 'trilemma' because it initially looks as if each of these crises can only be overcome at the expense of the other two. For example, in many cases it seems we have to make a choice: expand agricultural land or expand protected areas; produce animal feed or create carbon reservoirs; protect near-natural areas or increase the use of biomass. Finding solutions here will be a determining factor for sustainable land stewardship.

The global land surface is limited, as is the amount of biomass that can be produced by the ecosystems. Humans currently use about a quarter of potential terrestrial net primary production for their needs such as food, feeds, fibre, wood and energy (IPCC, 2019b:5; Krausmann et al., 2013). An unlimited expansion of use is obviously not possible, so it must be a matter of reconciling and, where necessary, prioritizing the different increasing claims. This also means that the drivers of these claims on use must be taken into account to reveal ways of reducing uses. The following sections initially examine the three crises and their systemic linkages, before a positive vision for land stewardship is developed in Section 2.3.

2.2.1
The climate crisis

Anthropogenic climate change continues unabated despite the political agreement reached in Paris in 2015. The last decade was the warmest decade on record and 2015 to 2019 were the five warmest years since records began. The global average increase in temperature since the beginning of industrialization is currently 1.1°C (WMO, 2019). The Intergovernmental

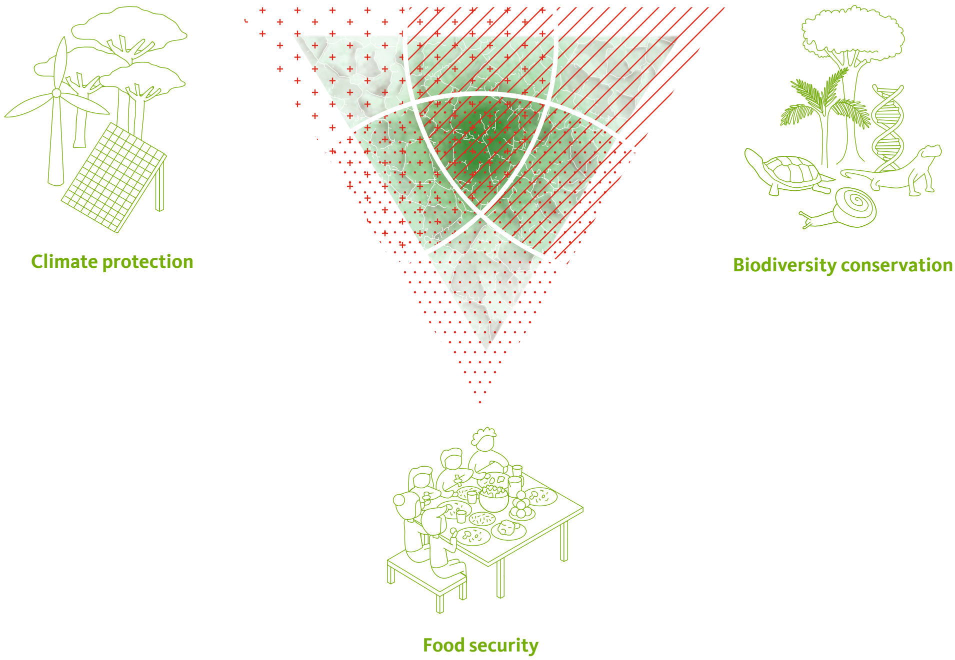


Figure 2.2-1
The 'trilemma of land use': climate protection, food security and the conservation of biological diversity are already in competition with each other, and land degradation will have a negative impact on all three aspects in the short or long term. Reversing the trends of the increasing destruction of terrestrial ecosystems and land degradation is therefore a *sine qua non* for overcoming this competition.
Source: WBGU, graphics: Ellery Studio

Panel on Climate Change's Special Report 'Global Warming of 1.5°C' published in 2018 shows unequivocally that the impacts and risks of climate change already significantly intensify with an increase of between 1.5°C and 2°C, and will rise even more sharply if temperatures increase above this level (IPCC, 2018). This can lead to so-called tipping points being exceeded, beyond which distinct system changes occur that would no longer be reversible even if the temperature were to fall – e.g. the melting of the Greenland ice sheet (Lenton et al., 2019). A study (Steffen et al., 2018) also indicates the possible existence of a threshold value beyond which a greatly accelerated rise in temperature could be triggered by biogeophysical feedback mechanisms ('Hothouse Earth').

Changes in our approach to land use are necessary for three reasons related to climate change:

1. Current land use and land-use changes cause greenhouse-gas emissions that must be reduced to stop climate change;
2. Unlike the steel industry for example, land can not only reduce emissions, it can also remove carbon dioxide (CO_2) from the atmosphere. It can be a significant, though not always permanent, sink for CO_2;
3. Even if global warming can be limited to a small increase, the massive impacts of the remaining climate change will require an adaptation of land use. A change in land use or land stewardship can also strengthen resilience to climate impacts.

Between 2007 and 2016, agriculture, forestry and other land-use activities accounted for 13% of total anthropogenic CO_2 emissions, 44% of anthropogenic emissions of methane (CH_4) and 81% of anthropogenic emissions of nitrous oxide (N_2O) (IPCC, 2019b:8). Although the various greenhouse gases behave very differently in the atmosphere, they are often grouped together using CO_2 equivalents, which refer to the average radiation effect over a 100-year period (Box 2.2-1). According to this perspective, agriculture, forestry and other land uses were responsible for a total of 23% of anthropogenic greenhouse-gas emissions between 2007 and 2016 (IPCC, 2019a:18), whereby this figure does not take into account CO_2 emissions caused by the loss of soil carbon on croplands (IPCC, 2019a:151).

CO_2 plays a special role because it does not chemically decompose in the atmosphere. About half of the CO_2 emitted into the atmosphere by humans is directly absorbed by the oceans and the biosphere at the lower edge of the atmosphere via the processes described below; in the medium term, the oceans absorb more and more CO_2 until they become saturated. However, about 20-35% remains in the atmosphere in the long term, i.e. for many centuries, and is only degraded slowly over time scales of several millennia by rock weather-

Box 2.2-1

CO_2 and the other greenhouse gases

Different greenhouse gases behave very differently – they last for different lengths of time in the atmosphere ('atmospheric lifetime') and have different effects on radiative transfer in the atmosphere, i.e. their contributions to global warming differ. Unlike CO_2, nitrous oxide (N_2O) and methane (CH_4) chemically decompose in the atmosphere: N_2O is split by UV radiation in the stratosphere and has an atmospheric lifetime of 114 years; CH_4 reacts with the OH radical in the troposphere and has an atmospheric lifetime of only 12 years. Nevertheless, the gases are often presented according to a uniform unit of measurement: the CO_2 equivalent. For this purpose, the average radiation effect of other greenhouse gases (i.e. their contribution to warming) over a defined period of time is compared with that of CO_2. The Kyoto Protocol of the UNFCCC laid down a period of 100 years for this; this period has no scientific justification, but was negotiated at the political level (Victor et al., 2014). However, this can lead to considerable false conclusions, especially for short-lived greenhouse gases such as methane, which does not remain in the atmosphere for 100 years anyway. That is to say, which greenhouse gases or radiatively active substances are reduced is by no means irrelevant for climate-change mitigation. Whereas the reduction of short-lived greenhouse gases such as CH_4 or aerosols has a primarily short-term impact on the climate, the long-term temperature development is dominated by the emissions of long-lived gases. The relative importance for global climate protection of different measures to reduce radiatively active substances ultimately depends on what target is pursued. For example, Bowerman et al. (2013) argue that, with a view to the 2°C guard rail, reducing short-lived greenhouse gases is not of major importance until a point in time when the emissions of long-lived greenhouse gases are already falling. As long as CO_2 emissions continue to rise, the reduction of short-lived gas emissions only postpones the point in time at which the guard rail is exceeded; if CO_2 emissions are already falling, the reduction of short-lived gases can lower the peak temperature. Although an immediate reduction in emissions of short-lived radiatively active gases could therefore lengthen the timeframe for adaptive measures by weakening short-term global warming, it would not extend the timeframe for the necessary reduction in CO_2 (Bowerman et al., 2013).

These differences are also important, e.g. for measures like the restoration of peatlands: while rewetting can stop the considerable CO_2 emissions of drained peatlands, there are conversely climate-impacting methane emissions. Günther et al. (2020) show that, due to the short lifetime of CH_4, this negative effect is less relevant than the positive effect of stopping CO_2 emissions: continuous CH_4 emissions reach a steady state in which the same amount of CH_4 decomposes as is released into the atmosphere. While continuous CH_4 emissions are therefore compatible with climate stabilization, this is not the case with continuous CO_2 emissions, since the CO_2 keeps on accumulating in the atmosphere.

ing, i.e. the chemical reaction of CO_2 with minerals (Archer et al., 2009). In this respect, CO_2 differs from CH_4 and N_2O, which have a limited lifetime in the atmosphere (Box 2.2-1). Therefore, anthropogenic emissions of CH_4 and N_2O, unlike those of CO_2, do not need to be reduced completely to zero in order to halt climate change. Reducing these emissions can, however, make an important and rapidly effective contribution to climate protection and should therefore definitely be a goal. In addition, there is a further wide range of interactions between land use and the local climate, for example via aerosol emissions, changes in the albedo of land areas or in the regional water cycle as a result of land-use changes (IPCC, 2019a).

Figure 2.2-2 gives an overview of the anthropogenic disturbance of the global carbon cycle. To halt climate change, it is necessary to reduce net anthropogenic CO_2 emissions to zero (Rogelj et al., 2018:108). The extent of future warming depends to a considerable extent on the cumulative total amount of anthropogenic CO_2 emissions. Studies therefore frequently mention a total budget of possible future CO_2 emissions that can only be emitted in order to halt global warming below a certain temperature. For example, the IPCC estimates the budget still available as from the beginning of 2018 that allows climate change to be limited to 1.5°C with a probability of 50%, at 580 Gt of CO_2 (IPCC, 2018:14). Given current annual emissions of around 42 Gt of CO_2 (Friedlingstein et al., 2019), this budget has probably shrunk to less than 500 Gt of CO_2 by now. However, the exact budgets are subject to various uncertainties, including methodological ones. The vast majority (86%) of anthropogenic CO_2 emissions stems from the ever increasing use of fossil fuels and cement production, while CO_2 emissions from land-use changes (mostly the conversion of natural areas into agricultural land) have not decreased significantly in absolute terms, but now only account for about 14% (Figure 2.2-3).

The main processes that can remove CO_2 from the atmosphere on a large scale are firstly the solution of CO_2 in the oceans, and secondly photosynthesis, i.e. the ability of plants to break down CO_2 with the aid of sunlight and convert the carbon it contains into biomass. The ocean and the land thus act as 'natural sinks', which currently absorb 23% (ocean) and 29% (land) of anthropogenic CO_2 emissions. Only 45% of our emissions remain directly in the atmosphere (mean values for the period 2009-2018; Friedlingstein et al., 2019; Figure 2.2-2). Even if these sinks are often considered 'natural', they are ultimately the result of human activity: the ocean and land only absorb CO_2 continuously from the atmosphere because humans have caused an increase in atmospheric CO_2 concentration, so that the

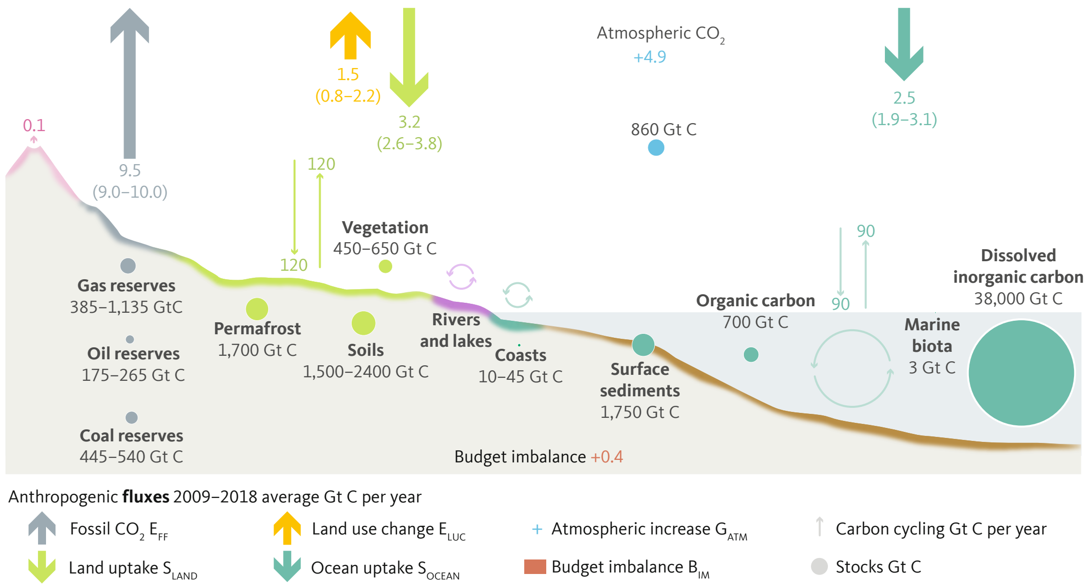


Figure 2.2-2
Schematic diagram of the global carbon cycle and its perturbation by human activities, averaged over the period 2009–2018. The perturbation is marked by the broad arrows: these relate firstly to emissions from human activities such as the use of fossil fuels and deforestation, and secondly to the increased absorption of CO_2 by the ocean and vegetation. The anthropogenic perturbation takes place on top of an active carbon cycle which is independent of humans; it is marked by the narrow arrows. Detailed background information on the determination of these figures can be found in Friedlingstein et al. (2019). It should be noted that the flows are shown here in units of Gt C (billion tonnes of carbon). To convert to Gt CO2 (billion tonnes of CO_2), multiply the figures by 3.66.
Source: figure from Friedlingstein et al., 2019 (CC BY 4.0)

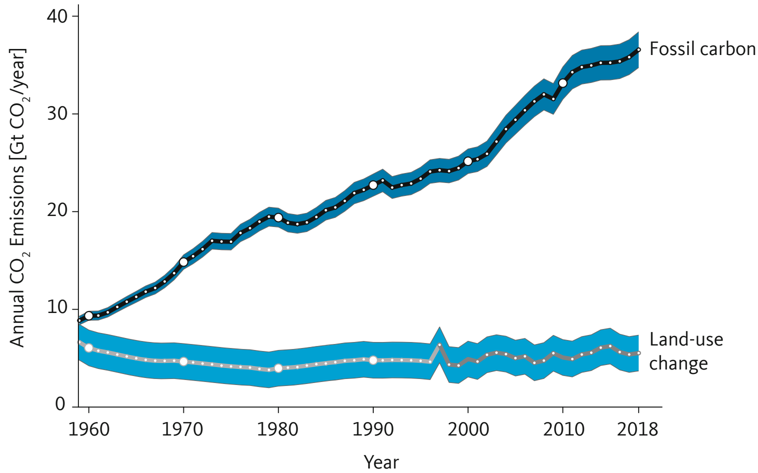
systems are therefore not in equilibrium. The sink function is expected to weaken as atmospheric concentrations of CO_2 stabilize or decrease (e.g. if CO_2 is removed from the atmosphere) and the land and the ocean eventually become sources of CO_2 (Hoegh-Guldberg et al., 2018:219). If CO_2 emissions continue, negative climate impacts such as droughts and heat waves could destroy the sink effect of the terrestrial biosphere and lead to the release of CO_2 (Peñuelas et al., 2017). The sink effect is thus fragile and not reliable in the long term (Keenan and Williams, 2018).

Mitigation pathways with the aim of limiting climate change to 1.5°C, which were analysed by the IPCC, predominantly involve the calculated CO_2 budget being first exceeded and CO_2 being extracted from the atmosphere thereafter. This means that further sinks must be created in addition to the ‘natural’ sinks described above, so-called ‘negative emissions’ (Minx et al., 2018). Such methods for removing CO_2 from the atmosphere are also used in the scenarios for offsetting emissions from sectors that are difficult to decarbonize (Rogelj et al., 2018). Scenarios that aim to limit climate change to 2°C also often rely on CO_2 removal (Section 3.1).

However, the creation of large-scale negative emissions is highly controversial (Field and Mach, 2017). Possibilities discussed include large-scale afforestation and the use of bio-energy in combination with carbon dioxide capture and storage (BECCS), which, in turn, can cause considerable sustainability problems and increase the pressure on global land use (Section 3.1). Furthermore, the IPCC itself describes a strategy that relies on future CO_2 removal from the atmosphere as highly risky in terms of achieving the targets (Rogelj et al., 2018:96). It is abundantly clear, therefore, that the rapid reduction of CO_2 emissions from the use of fossil fuels is indispensable if the global community’s climate goals are to be met. Nevertheless, land stewardship will have a considerable influence on how well the climate crisis can be overcome – this was also made clear by the latest IPCC Special Report on Climate Change and Land (IPCC, 2019a).

Even if limiting global temperature rise as agreed in Paris succeeds, additional policies and strategies for adapting to the impacts of climate change are necessary. The temperature rises faster over land than over the ocean; on land, a warming of more than 1.5°C has already been reached (IPCC, 2019b:5). Today, the

Figure 2.2-3
Anthropogenic CO_2 emissions over time.
Source: GCP, 2019



effects already mean more frequent, more intense and longer-lasting heat waves worldwide. Many regions are experiencing more frequent and more severe droughts, and the intensity of heavy rainfall events has increased worldwide (IPCC, 2019b:9). Warming has already led to a shift in climate zones and this has had an impact on the distribution areas of plants and animals (IPCC, 2019b:6). The risks – e.g. of water shortages in arid regions, damage from wildfires, degradation of permafrost and unstable food supplies – increase with rising temperatures. The negative economic impacts of unsustainable land management are also expected to be further exacerbated by climate change (IPCC, 2019a: 17).

Climate-change mitigation, adaptation to climate change and sustainable land use are therefore closely interwoven. On the one hand, effective climate protection is a decisive prerequisite for sustainable land use because the effects of climate change also increase the pressure on productive land areas (via extreme weather events, forest fires, changes in precipitation patterns, and shifting climate zones leading, for example, to thawing permafrost soils). On the other hand, ambitious climate-change-mitigation scenarios, as described above, often rely on a future large-scale conversion of land areas for the absorption and storage of CO_2 from the atmosphere, which, in turn, can endanger sustainable land stewardship. In particular, measures aimed at limiting global warming to 1.5°C must therefore be assessed in the context of a comprehensive sustainability transformation that includes land stewardship.

The climate crisis and ways to deal with it also have far-reaching consequences for the biodiversity crisis and the crisis of the food system. The reduction in CO_2 emissions from land-use changes (above all deforestation) can have major synergies with the conservation of biodiversity (Section 2.2.3). Measures to remove CO_2 from the atmosphere can, on the other hand, interact both positively and negatively with the biodiversity crisis – depending on which of the above-mentioned options is pursued (Section 2.2.3). The creation of such sinks should therefore be looked at in a differentiated way. This is discussed in greater depth in Section 3.1. Possibilities for reducing CH_4 and N_2O emissions are closely related to agricultural practices and dietary habits and are discussed in Sections 3.3 and 3.4. They must in any case be considered in interaction with the crisis of the food system (Section 2.2.2).

In the context of the crises of biodiversity and the food system, the impacts on the climate are an additional stressor which will become more acute as climate change progresses. In mid-latitudes, for example, the climate zones to which the ecosystems are adapted are shifting towards the poles, while in tropical regions new kinds of climate conditions may arise (IPCC, 2019a). However, many land-based options for adaptation to climate change can also simultaneously contribute to combating land degradation or to improving food security. Some responses to climate change have in turn repercussions on climate change. For example, Hannah et al. (2020) show that, as a result of shifting climate zones, new areas could be used to grow various crops such as coffee and wine – a development which would release considerable amounts of CO_2. It is therefore important to make the adaptation of land use to climate change itself climate-friendly.

2.2.2
The food-system crisis

The global food system, i.e. the interplay of the production, processing, trade and consumption of food, shows different characteristics and forms of cultural embedding worldwide. Overall, the food system can be described as being in crisis: adequate and healthy diets are far from guaranteed for all people and, at the same time, food production is having considerable negative impacts on the environment and the climate (Willett et al., 2019).

A quarter of humanity is suffering from structural shortages and another quarter from structural, health-damaging overconsumption, so that for half of humanity their diet cannot be regarded as the basis for an active and healthy life (IPCC, 2019a:446). The most pressing problem is undernutrition: SDG 2 aims to end hunger worldwide by 2030. The proportion of chronically hungry people in the world population decreased for many years, but has been stagnating since 2015. The absolute number has actually increased since 2015 by nearly 60 million to 690 million people today (FAO, 2020j). Many more people suffer from malnutrition in the broader sense, the so-called 'hidden hunger' that is characterized by a lack of proteins or micronutrients, i.e. vitamins, minerals and trace elements. The FAO speaks of 1.3 billion people, or 17.2% of the world's population being affected by moderate food insecurity, i.e. people who do not have regular access to enough food with sufficient (micro)nutrients. This is associated with various health problems and predominantly affects people in low- to middle-income countries but also about 8% of people in Europe and North America (FAO, 2019d:xvii). Overall, this means that about 2 billion people, or over a quarter of humanity, are affected by moderate to severe food insecurity (FAO, 2019d).

The current COVID-19 pandemic is exacerbating the situation further: the pandemic is expected to have a devastating impact on the livelihoods and food security of many people, especially vulnerable groups and those working in the informal sector both within and outside agriculture; there are fears that a global recession will massively disrupt global food-supply chains (FSIN, 2020a:3). At the time of writing, however, it is not yet possible to foresee the full extent of this disruption, especially on a global scale (Box 3.3-2).

Theoretically, the amount of food currently being produced would be more than enough for everyone, at least in terms of calories: citing FAOSTAT (2018) and Hiç et al. (2016), the IPCC puts the current global amount of available food at 2,884 kcal per person per day (IPCC, 2019a:445). However, according to analyses by KC et al. (2018), in terms of a healthy diet, too little fruit, vegetables and protein but too much sugar, oil and grains are produced overall (KC et al., 2018).

The availability of low-cost commodity crops, i.e. crops that can be easily stored, transported and traded, is rising – and with it the consumption of food with a high energy density (IPCC, 2019a:446). As a result, in parallel with the continuing problem of malnutrition, overweight and obesity are on the rise globally and now affect more than 2 billion people; no continent is exempt from this trend, with schoolchildren and adults particularly badly affected (FAO, 2019d). Even this ostensible abundance is partly a consequence of scarcity: particularly in high-income countries, obesity can be promoted by poverty-related food insecurity, which manifests itself in a lack of access to (micro)nutritious, i.e. high-quality food (IPCC, 2019a:446).

So the food system is far from providing a good basis for all people. At the same time, today's food production is extremely resource-intensive. Current agricultural practices have multiple negative global to local environmental effects (Campbell et al., 2017). Gerten et al. (2020), for example, show that about half of today's agricultural production is based on transgression of planetary boundaries. The production and application of fertilizer has a massive impact on global cycles of nitrogen and phosphorus (Willet et al., 2019:465). As agriculture has become industrialized, the global nitrogen cycle has undergone the most severe changes in 2.5 billion years due to the anthropogenic fixation of atmospheric nitrogen for the production of mineral fertilizers, the effects of which include the eutrophication (overfertilization) of inland waters and coastal zones (Canfield et al., 2010). Modern agriculture also draws heavily on the limited deposits of rock phosphate (Blackwell et al., 2019), the use of which also contributes to overfertilization (Section 3.3). Greenhouse-gas emissions associated with agricultural production increased from 3.1 Gt of CO_2eq per year to 5.8 Gt of CO_2eq per year between 1961 and 2016, mainly due to the increase in livestock production, the increased use of fertilizers, and the expansion of rice cultivation (IPCC, 2019a:445). This mainly relates to the greenhouse gases methane and N_2O, whose lifetime in the atmosphere is shorter than that of CO_2 (Box 2.2-1). However, the expansion of arable land and non-sustainable agricultural practices are also important drivers of land degradation (Section 2.1). This usually leads to CO_2 being released from the vegetation or soil and promotes climate change (Sanderman et al., 2017); in addition, land conversion accelerates the loss of biodiversity (Section 2.2.3). Pesticide use is also an important driver of the loss of biodiversity and ecosystem services (Brexit and Taller, 2019; Dudley et al., 2017; Beketov et al., 2013; Geiger et al., 2010).

The Lancet Commission on Obesity (Swinburn et al., 2019) describes a systemic connection between the problems of over- and malnutrition and the environmental problems connected with industrialized agriculture: the food system has become increasingly industrialized and globalized and is now dominated by a small number of major players that benefit from 'economies of scale' and can maintain and control long supply chains – across several stages of the value chain and in some cases globally. Although it produces sufficient food in terms of quantity, the emphasis is on energy-rich staple foods, while (micro)nutrient-rich foods are neglected. In many regions, fruit, vegetables, and animal products are expensive or unavailable, and highly processed foods continue to drive obesity trends (Swinburn et al., 2019:806). The current market concentration, for example in the case of seeds, also promotes the monotonization of landscapes and the loss of biodiversity (Folke et al., 2019).

In addition to population growth, which will lead to a rising demand for food, increasing influences of climate change are expected to affect food production in the future. Ensuring sufficient and healthy food for all people on a sustainable basis is therefore a key challenge for the future and an important constraint on our stewardship of the land (Gerten et al., 2020; Willett et al., 2019). However, agriculture must not be geared solely to producing the greatest possible quantities of food. Rather, the aim should be to produce a wide variety of micronutrient-rich foods in sufficient quantities, and to gear food systems also towards promoting biodiversity instead of focusing on a small number of crops.

In relation to the trilemma, the question of the future conversion of near-natural terrestrial ecosystems for food production is of great importance: both climate change and the loss of biodiversity and ecosystem services are directly fuelled by land conversion. But the quality of agricultural practices is also key: livestock densities on grasslands, and tillage and fertilization practices on cropland determine the release of CO_2 from soil carbon and of N_2O; ruminants and rice cultivation emit methane. Decisions on the use of pesticides or the size and homogeneity of cropland management have a direct impact on biodiversity. There are also additional aspects such as energy use, emissions and the release of toxic substances during the processing and transport of foodstuffs, which are not dealt with in depth in this report. Finally, dietary habits have repercussions on production, processing and transport. Losses, inefficiency and waste also have an impact on the total amount of food to be produced. Alexander et al. (2017) show that – after taking into account losses due to food waste, trophic losses due to animal production, and overconsumption (the excessive amount of food consumed compared to nutritional needs) – only 38% of harvested energy and 28% of harvested protein are used in the form of necessary food consumption in the current food system.

A transformation of our food system, including everything from production systems to dietary habits, is a prerequisite for ensuring reliable and healthy diets for a global population that will grow to more than 9 billion people by 2050, while meeting the challenges of anthropogenic climate change (Section 2.2.1), the loss of biodiversity and ecosystem services (Section 2.2.3), and key aspects of the UN Sustainable Development Goals such as health and poverty reduction (FOLU, 2019; Willett et al., 2019). This will require an integrating view that strategically links the dimensions of the trilemma and aims for synergies.

2.2.3
The biodiversity crisis

Biodiversity, i.e. the biological diversity of genes, species and ecosystems (CBD 1992, Art. 2), is distributed very unevenly across the Earth (Figure 2.2-4a). Biodiversity is highest in the tropics and around the equator, the so-called biodiversity hotspots (Figure 2.2-4b; Myers et al., 2000; Kleidon and Mooney, 2008). In the mid-latitudes, on the other hand, biodiversity is much lower (Gaston, 2000; Platnick, 2007) but by no means less important.

The diversity of terrestrial (i.e. land) ecosystems can be illustrated by their division into 14 biomes, or 846 ecoregions, within each of which specific biological communities have formed based on the prevailing climate (Figure 2.2-4c; Dinerstein et al., 2017; Olson et al., 2001). Aquatic ecosystems are divided into marine (saltwater) and limnic (freshwater) ecosystems, the latter being found as inland waters integrated into terrestrial ecosystems, e.g. lakes and rivers.

Currently, about 1.5 million species have been described (Costello et al., 2013). Estimates of the total number of species worldwide are only approximate. Based on taxonomic assessments, these range from 3 to 100 million (May, 2010); systematic calculations suggest around 8.7 million (Mora et al., 2011) or around 5 ± 3 million species (Costello et al., 2013). At around 82.5%, plants account for the biggest proportion of global biomass. Animals account for only about 0.4%, divided into about 29% fish, 46% marine and 24% terrestrial animals. Of the total animal biomass, about 42% are arthropods (e.g. insects), 4% are farm animals, 2.5% are humans, and only 0.3% are wild mammals (Bar-On et al., 2018; Figure 2.2-5).

The ecosystem services

Biodiversity has an immense value for humans and their well-being, and this is based mainly on ecosystem services (Costanza et al., 2017). These are services provided to humans by ecosystems that are themselves

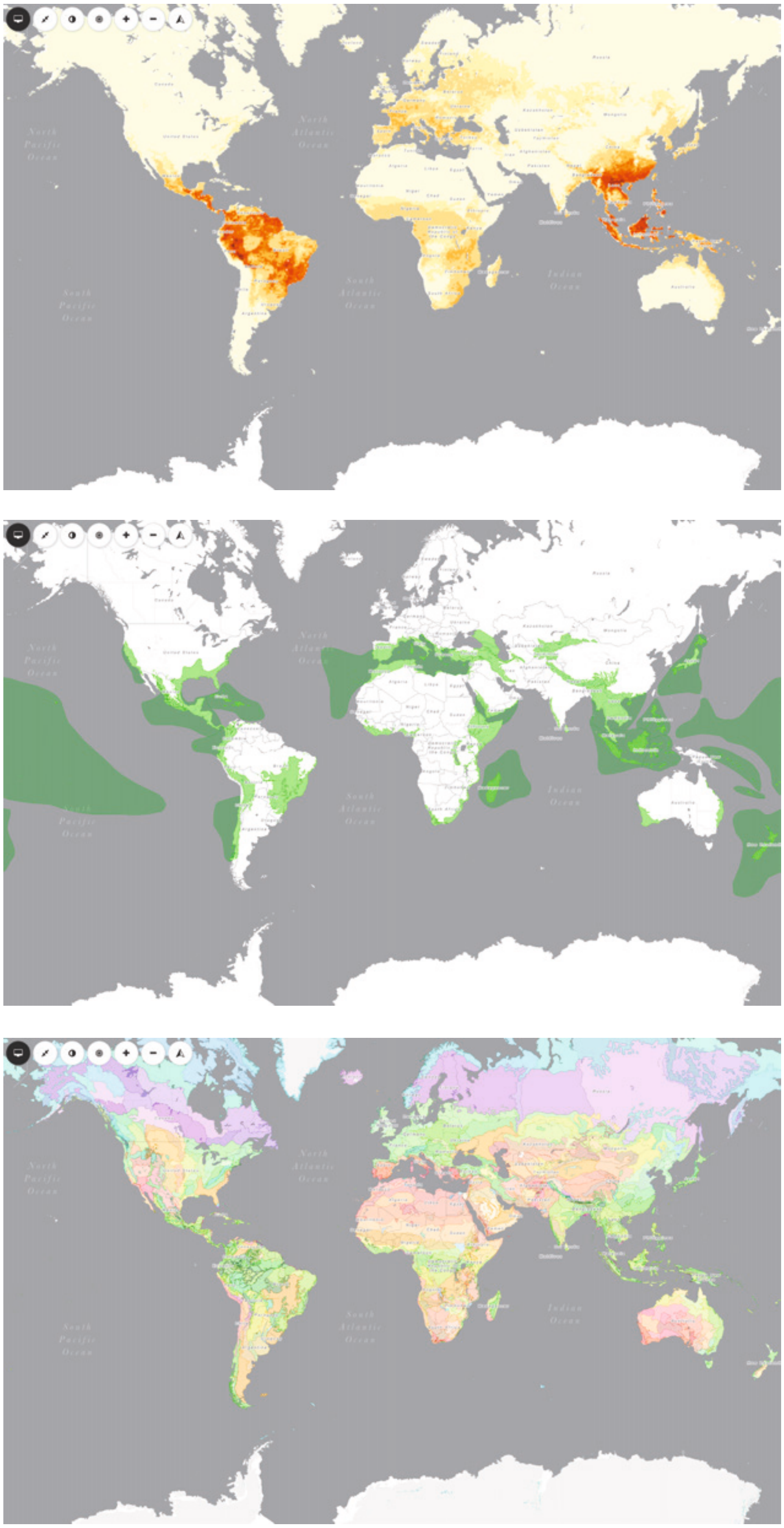


Figure 2.2-4
Global perspectives on biodiversity.
a) Species diversity of mammals, amphibians and birds – the darker the red, the higher the number of species (IUCN, 2017);
b) Biodiversity hotspots – in green (Hoffman et al., 2016);
c) Terrestrial ecoregions – each shade of colour represents one of a total of 846 ecoregions (Dinerstein et al., 2017, see also ecoregions2017.appspot.com for an interactive map of ecoregions and biomes)
For better comparability, the maps are shown using MapX.org (Lacroix et al., 2019).

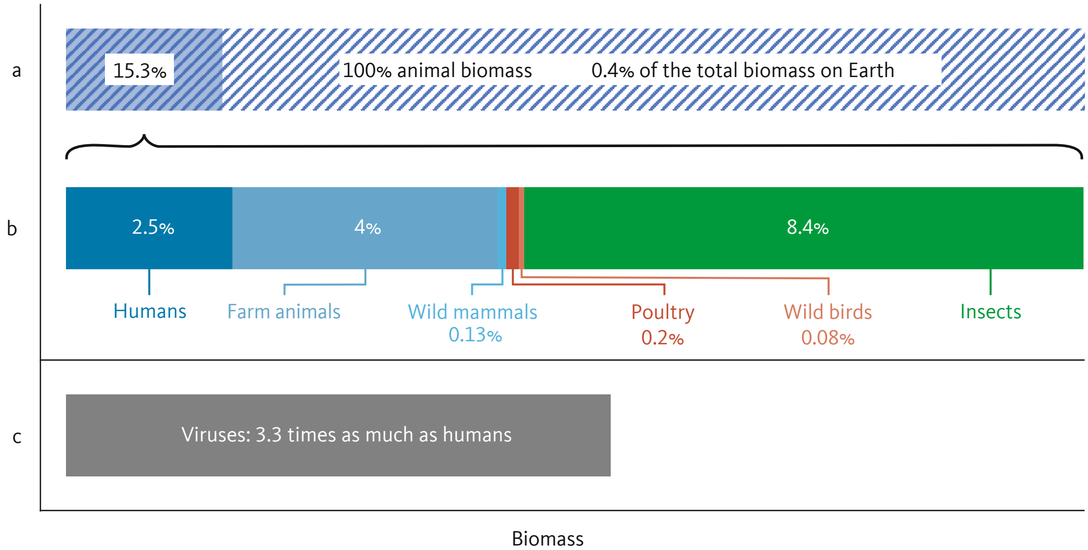


Figure 2.2-5
Biomass distribution of selected groups of species.
a) Animals account for 0.4% of the Earth's total biomass. 15.31% of these are further differentiated as terrestrial taxa in b). All wild mammals and birds living on land account for only 0.21% of total global animal biomass, compared to 4.2% for farm animals and poultry. The biomass of farm animals is 31 times larger than that of wild mammals. (c) The total biomass of viruses is 3.3 times the biomass of humans. The values are rounded.
Source: WBGU, based on figures from Bar-On et al., 2018

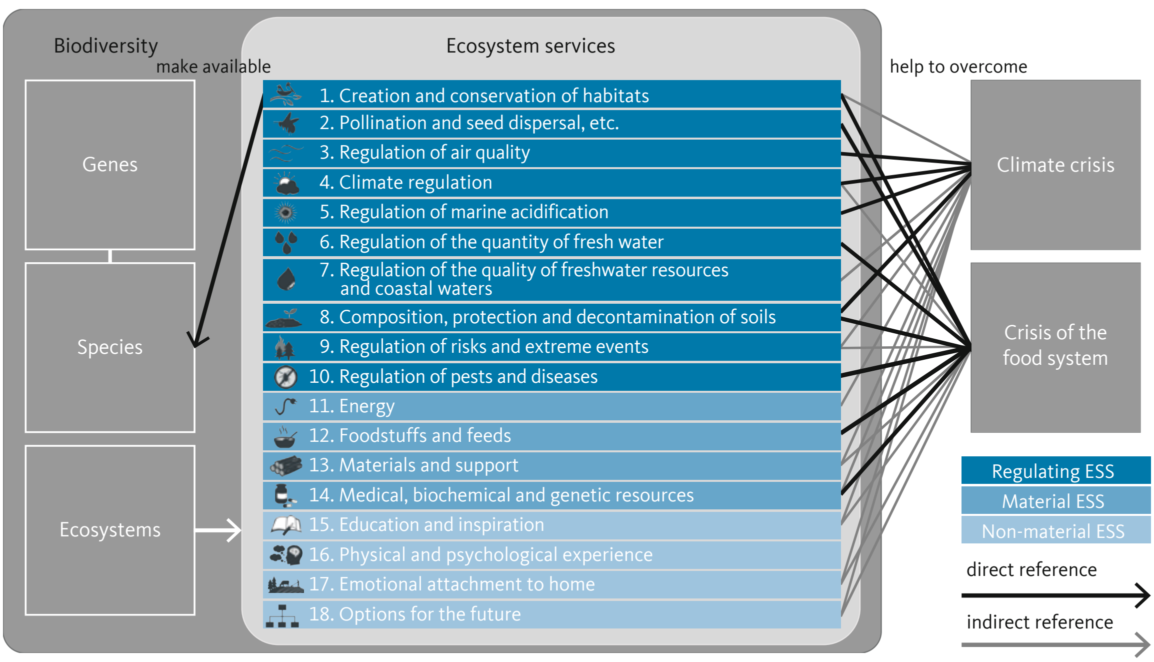


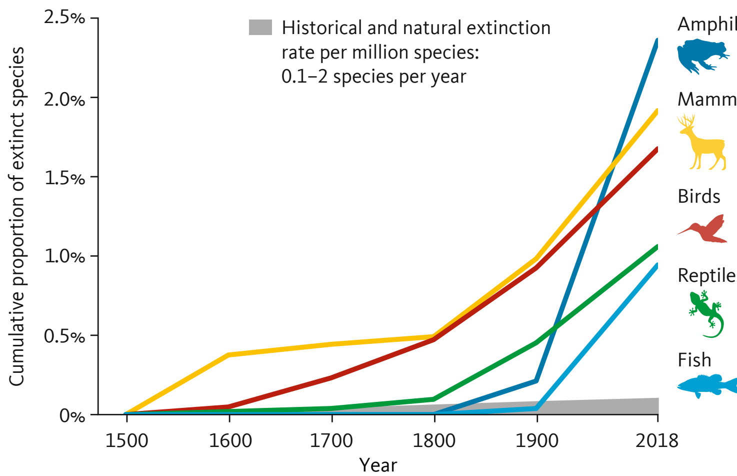
Figure 2.2-6
Relationship between biodiversity and ecosystem services; contributions of ecosystem services to overcoming the trilemma of land use. Biodiversity, or biological diversity, consists of the diversity within (i.e. of genes) and between species, and the diversity of ecosystems (CBD 1992, Art. 2). The latter provide 18 ecosystem services (ESS), which are described in Table 2.2-1. By providing habitats, ecosystem conservation contributes directly to species protection. Whereas, on the one hand, the anthropogenic demand for material ecosystem services makes a fundamental contribution to the biodiversity crisis, on the other hand, almost all ecosystem services contribute directly and indirectly to overcoming the climate crisis and the crisis of the food system.
Source: WBGU; icons from IPBES (2019b)

Table 2.2-1
Description of the 18 ecosystem services and nature's contributions to humankind used in this report.
Source: IPBES, 2019b; Diaz et al., 2018

	Ecosystem service	Description
Regulatory	1. Habitat creation and maintenance	The formation and continued production of ecosystems and ecological framework conditions that are necessary or favourable for living creatures and humans, e.g. nesting and mating sites for animals, resting and wintering areas for migratory animals, cultivation areas for plants
	2. Pollination and dispersal of seeds, etc.	Movement of pollen between flowers and plants by animals, spreading of seeds, larvae or spores of organisms useful or harmful to humans
	3. Regulation of air quality	Regulation of atmospheric gases, e.g. carbon dioxide (CO_2), aerosols and allergens by ecosystemic processes, e.g. by filtration, fixation, degradation or storage of pollutants that can have a direct impact on human health
	4. Regulation of climate	Climate regulation by ecosystems, including regulation of global warming, e.g. by effects on greenhouse-gas emissions, biophysical feedbacks from vegetation into the atmosphere, cloud formation and regulation of biogenic volatile organic compounds and aerosols by plants
	5. Regulation of ocean acidification	Regulation of atmospheric CO_2 concentrations and thus the pH value of seawater by photosynthetic organisms on land and in water
	6. Regulation of the quantity of fresh water	Ecosystemic regulation of the quantity, location and timing of surface and groundwater flow, which acts e.g. as a habitat, protection against flooding or salinization, or can be used as drinking water, for irrigation or for hydropower
	7. Regulation of fresh-water and-coastal-water quality	Regulation and filtration of particles, pathogens, excess nutrients and other chemicals by ecosystems and organisms living in them, e.g. as drinking or bathing water
	8. Formation, protection and decontamination of soils	Formation and long-term conservation of soils and soil structures, including sediment retention and erosion control; preservation of soil fertility and decomposition or storage of pollutants
	9. Regulation of hazards and extreme events	Regulation by ecosystems of the effects and frequency of hazards caused e.g. by floods, storms, heat waves, fires, tsunamis, avalanches or landslides
	10. Regulation of pests and diseases	Regulation of pests, parasites, pathogens, predators and other potentially harmful organisms by ecosystems or other organisms
Material	11. Energy	Production of fuels based on biomass, e.g. biofuel crops, animal waste, firewood and agricultural residues that can be processed into residue pellets
	12. Food and feed	Production of food from wild, farmed or domesticated organisms on land and at sea, and production of feeds, e.g. fish, meat, dairy products, field crops and forest fruits, mushrooms or honey
	13. Materials and assistance	Production of materials obtained from organisms in cultivated or natural ecosystems, e.g. for construction, paper or clothing, and use of organisms for e.g. decoration, transport, protection or as pets
	14. Medical, biochemical and genetic resources	Production of materials obtained from organisms for medical, veterinary or pharmacological purposes; production of genetic information, e.g. for animal and plant breeding or biotechnology

Non-material	15. Learning and inspiration	Opportunities for skills development through education, knowledge acquisition and inspiration for art and technological design through e.g. biomimicry or bionics
	16. Physical and psychological experience	Opportunities for physically and mentally beneficial activities, e.g. for healing, relaxation, recreation, leisure and aesthetic enjoyment
	17. Supporting identities	Basis for the religious, spiritual and social experience of living together, e.g. the sense of belonging, rootedness or attachment, as well as basis for stories and myths, rituals and celebrations
	18. Options for the future	Ability of ecosystems, habitats, species or genotypes to sustain human options in order to support a good quality of life in the future, e.g. through ecosystemic resilience to environmental change and opportunities for new discoveries in nature, e.g. of medically useful species and genetic information or sustainable means of pest control

Figure 2.2-7
The extinction rate of species has been increasing continuously since the 16th century.
Source: IPBES, 2019a



part of biodiversity and simultaneously provide a habitat for animal and plant species (Costanza et al., 2017; MA, 2005; Figure 2.2-6). Different classification systems of ecosystem services have been proposed over the years (Costanza et al., 2017); furthermore, the concept of 'nature's contributions to people' (NCP) has been developed (Díaz et al., 2018, Pascual et al., 2017). In particular, this claims to take into account the globally diverse human/nature relationships (e.g. specific local and cultural aspects as well as human values) (Kadykalo et al., 2019). Since the concept of NCP includes the ecosystem services (IPBES, 2018d), and the individual categories of NCP correspond to the current state of development of the "common international classification of ecosystem services" (CICES; Haines-Young and Potschin, 2018), the terms ecosystem services and NCP are used largely interchangeably in this report.

Ecosystem services can be conceptually divided into regulatory, material and non-material services (Table 2.2-1). Regulating ecosystem services are natural processes without which no ecosystem would be able to function. They include, for example, water purification (e.g. by forests or microorganisms living directly in bodies of water), global climate regulation (e.g. CO_2 storage by trees or peatlands), protection against natural disasters (e.g. mountain slopes stabilized by trees, or coasts by mangroves) and pollination (e.g. by insects). They are the basis of our life on earth; natural pollination services are an essential factor in agricultural food production and global food security and thus of great value to humans (IPBES, 2016). Human well-being is also based in particular on the use of valuable material ecosystem services, such as water, food and resources such as wood, feeds and fertilizer. The value of biodiversity for humans is rounded off by non-material, often cultural, ecosystem services, which e.g. serve our recreation, science and education. Biodiversity and the ecosystem

Box 2.2-2

The COVID-19 pandemic – another zoonosis

The 2019 Global Risks Report lists infectious diseases as a major societal threat (WEF 2019). The COVID-19 pandemic highlights the danger of new infectious diseases. UNEP (2020) estimates that the total cost of the COVID-19 pandemic could be as much as US$9,000 billion.

The origin of the COVID-19 pandemic cannot be clearly identified at this stage. A wet market (traditional Chinese market for live and recently slaughtered animals) is often suspected as the location of the pandemic's outbreak (Lu et al., 2020). However, there were early cases of COVID-19 that had no epidemiological link to this market (Huang et al., 2020; Forster et al., 2020). There are therefore different theories about where the SARS-CoV-2 virus (the cause of COVID-19) comes from. Laboratory origins have been ruled out, and SARS-CoV-2 is thought to have originated within the animal kingdom (Andersen et al., 2020; Latinne et al., 2020). The most likely ancestor of this virus seems to be a bat corona virus, which is 96% identical to SARS-CoV-2. COVID-19 is therefore most likely to be a zoonosis, i.e. a disease that can be transmitted from an animal to humans and vice versa, but stems originally from an animal (Calisher et al., 2020).

The COVID-19 pandemic is an example of globally increasing incidences of Emerging Infectious Diseases (EIDs) (Jones et al., 2008; Smith et al., 2014a), more than 60% of which are zoonoses. More than 70% of these outbreaks originate from wildlife, and the frequency of such outbreaks originating from wildlife is increasing (Karesh et al., 2012; Jones et al., 2008). Known zoonotic viruses, for example, are HIV, Ebola virus, MERS-CoV, SARS-CoV, and H5N8 influenza virus ('bird flu'). The rising prevalence of wildlife-derived zoonoses can be explained by various human influences, primarily related to increasing human-to-wildlife contact, e.g. land-use changes, urbanization, increasing mobility, deforestation, habitat fragmentation, climate change, the global food system, the wildlife trade and wildlife consumption (Cascio et al, 2011; Jones et al., 2013; Allen et al., 2017; Rohr et al., 2019; FAO, 2020f; UNEP, 2020; Huong et al., 2020; Walzer, 2020).

Global changes in climatic conditions influence, for example, the local and global composition of species and could thus also affect the spread of pathogens. Furthermore, the thawing of permafrost soils can release pathogens. A further effect of the climate crisis is the threat to food production in sub-Saharan Africa (SSA), which, as a result of the effects of the COVID-19 pandemic, could lead to dramatic famines and thus encourage the consumption of bushmeat (Box 3.3-1). SSA is a region where bushmeat was already a source of food or income before this crisis (Nielsen et al., 2018).

The development of zoonoses requires a spatial overlap between a virus and a new host. Human encroachment into biodiversity-rich areas and land-use changes, particularly the associated deforestation and livestock farming, lead to more contact between pathogens, their hosts and new potential hosts (Dobson et al., 2020). Increased contact leads to a greater risk of a pathogen jumping to a new host population (Murray and Daszak, 2013). Such a jump can be reduced to three interfaces: wild animal/human, farm animal/human and wild animal/farm animal/human.

The size of the wildlife/human interface is massively increased by ecosystem destruction and habitat loss. Wherever people enter habitats, new contact points are created. More open access (e.g. via roads) is also being created, making it easier to hunt and poach. Habitat destruction also forces wildlife populations (e.g. bats) to relocate. They might then resettle near villages, increasing the likelihood of contact with humans and their livestock. This can be seen in the increase in the number of viruses shared between humans and animal species threatened by habitat loss. In addition, it is mainly generalists (animals with a high level of adaptability to different habitats) that can survive on destroyed areas of land, and they also have more frequent contact with humans and exhibit many common (zoonotic) viruses (Johnson et al., 2020). Global demand for bushmeat leads to an increased prevalence of the wildlife/human interface (Dobson et al., 2020), with consumption particularly high in emerging economies and developing countries (Box 3.2-3). Ebola, for example, spread to humans via the consumption of bushmeat (Kock et al., 2020).

The use of newly cleared woodland for livestock farming increases contacts between farm animals and wild animals and the risk of infection via the wild animal/farm animal/human interface. Not only hunting but also keeping wild animals has increased over the past 60 years (UNEP, 2020). This also creates new contact possibilities for viruses previously living in wild animals. For example, the MERS coronavirus spread from dromedaries to humans; it probably originated from bats (Gruber, 2017; Anthony et al., 2017). SARS-CoV was also transmitted from bats to an intermediate host (viverrids and possibly raccoon dogs) before it spread to humans at a wet market in Guangdong Province (Wang and Eaton, 2007; Gruber, 2017). China has banned 20,000 wildlife farms and markets as a consequence of the COVID-19 pandemic (Li et al., 2020).

Intensive livestock farming often leads to many genetically similar animals living in a small area. Since the contact rate at the farm animal/human interface is particularly high and farm animals share the most common viruses with humans, intensive livestock farming favours the development of zoonoses (Johnson et al., 2020). Intensified livestock farming often provides optimum conditions for the transmission and spread of pathogens (Liverani et al., 2013) and is thus often associated with zoonoses (Rohr et al., 2019; UNEP, 2020). This is also reflected in the emergence of avian and swine flu (Box 3.4-2).

The ongoing destruction of ecosystems leads to a fragmentation of these systems. The 'coevolution effect' is believed to be a connection between the growing fragmentation of habitats and the increased prevalence of zoonoses (Zohdy et al., 2019). This hypothesis is based on three conditions:

1. A decrease in habitat connectivity increases the isolation and thus the genetic diversity of the host population and, accordingly, of the parasites, leading to genetic divergences between the habitat fragments.
2. This local separation allows hosts, parasites and pathogens to develop along different pathways. These units that live at the fragment level are called coevolutionary engines. They accelerate genetic divergence within the habitat fragments and thus lead to a greater genetic diversity of pathogens in the landscape than in a coherent habitat.
3. Bridge vectors living at the borders of fragmented habitats (e.g. mosquitoes) take various pathogens into human communities and increase the probability of emerging diseases.

SARS-CoV-2 and earlier zoonoses (e.g. Ebola and HIV) most likely have their source within the wildlife kingdom (Alexander et al., 2015; Leroy et al., 2005; Sharp and Hahn, 2011).

Given the great importance of natural systems for human health, a holistic approach to health in the sense of 'planetary health' (UN ESCAP, 2020) is recommended. Investments to deter tropical deforestation and limit the wildlife trade, as well as improved monitoring (including early warning systems for outbreaks), have been proposed as concrete measures to prevent outbreaks of zoonoses and avert future pandemics (Dobson et al., 2020). Huong et al. (2020) also argue that in order to minimize the risk of virus spillover and to safeguard livestock, preventive measures (limiting the killing, commercial breeding, transport, trade, storage, processing and consumption of wild animals) should be taken, while at the same time increasing the capacity to detect the spread of viruses at an early stage and providing better information to change human behaviour.

services it provides are thus essential foundations for human existence and life as we know it. Complex conflicts of interest between people can arise in relation to land, land management and the ecosystem services provided by the land. The concept of NCP, Ellis et al. (2019) argue, can help overcome conflicting interests. It offers approaches for disentangling the importance of social relations in land-management systems, connecting individual and community dimensions of well-being with the land, and taking into account different, even conflicting, perspectives on an equal basis (Ellis et al., 2019; ESPA, 2018). In this way, decision-making processes in the context of land management can be better understood and conflicts between different interest groups and power relations better mediated on the basis of social justice, so that increasingly complex social challenges can be solved. This is particularly true for land-management situations under less well-functioning governance mechanisms (Ellis et al., 2019).

Biodiversity makes a decisive contribution to achieving several SDGs and thus to sustainable development (Blicharska et al., 2019). Apart from possible trade-offs between individual ecosystem services, more than half of all ecosystem services contribute directly to overcoming the climate crisis or the crisis of the food system (Figure 2.2-6).

The value of biodiversity

Alongside their intrinsic value (Pearson, 2016), there are a number of approaches to assigning a monetary value to biodiversity, although these involve major challenges and are not uncontroversial (Deutscher Bundestag, 2015; Box 4.2-1). This applies in particular, but not exclusively, to the valuation of ecosystem services whose value is not assessed via markets (non-market valuation). One example is the implicit benefit of biodiversity or the cost of its loss, e.g. that of food. The value of biodiversity is thus pluralistic (Zafra-Calvo et al., 2020; Pascual et al., 2017; Spangenberg and Settele, 2016) and depends on a person's relationship to the biodiversity around them and the ecosystem services they use (Schröter et al., 2020).

The global loss of biodiversity

The world is currently experiencing a biodiversity crisis (Pimm et al., 1995; Vitousek et al., 1997; Newbold et al., 2015; IPBES, 2019a). It is characterized most strikingly by the worldwide loss of species (Figure 2.2-7) and ecosystems and has far-reaching consequences, also for humans. Not one of the Aichi goals for biodiversity conservation proclaimed by the CBD (Section 3.2.2) has been fully achieved (CBD, 2020). The loss of biodiversity leads to direct interactions with the climate (e.g. via a rising frequency and intensity of storms and floods caused e.g. by inadequate vegetation, Seddon et al., 2019; Ferrario et al., 2014) and with human nutrition (e.g. via locust infestations and the lower crop yields they cause in Africa; Humphrey et al., 2019). Last but not least, the biodiversity crisis impacts on our human well-being and health (e.g. through the increased probability of the occurrence of new types of diseases, including pandemics like COVID-19; Afelt et al., 2018; Boxes 2.2-2, 3.3-1). The increasing loss of the regulatory services provided by biodiversity means that the ecosystem services it provides are also in crisis (IPBES, 2019a; Figure 2.2-8).

The first anthropogenic mass extinction of biodiversity

With the biodiversity crisis we are currently experiencing an unprecedented anthropogenic loss of biological diversity across all biological and spatial scales. It is comparable with the major extinction events in the Earth's history (Ceballos et al., 2017; Barnosky et al., 2011). The loss of genetic diversity has a massive impact on the need for species-conservation efforts and on the complexity of these efforts (e.g. black rhino; Moodley et al., 2017). It is also a threat to sustainable and long-term food security (Dempewolf et al., 2010; Esquinas-Alcázar, 2005).

The rate of species extinction is now estimated to be 100 to 1,000 times higher than in pre-human times and is accelerating further (Pimm et al., 2014; De Vos et al.; 2015, Ceballos et al., 2015). Approximately a million species are threatened with extinction within the next decades (IPBES, 2019a). The planetary network of ecosystems as a whole is being affected by profound and

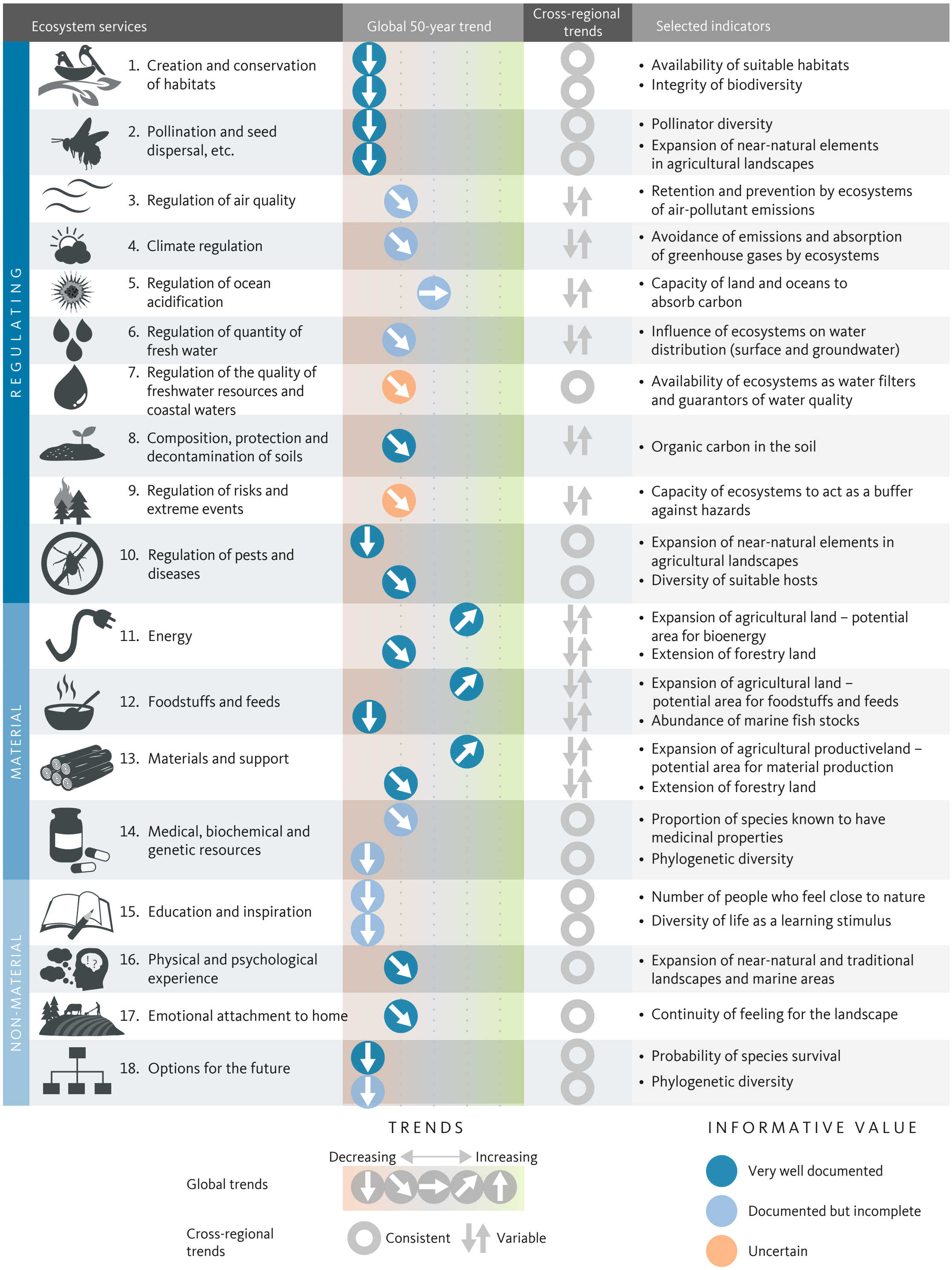
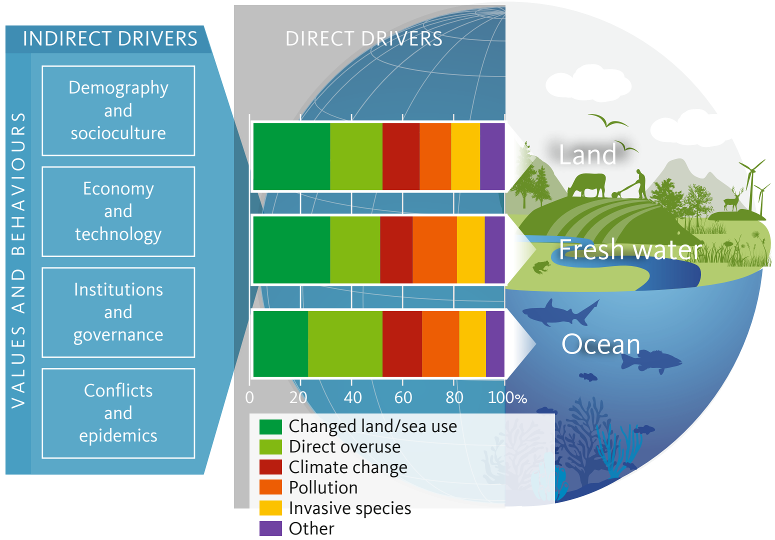


Figure 2.2-8
Nature and ecosystems provide humans with numerous benefits, which are summarized in 18 ecosystem services. The provision of individual services is subject to different trends; only material services, i.e. the provision of energy, food and feeds, as well as materials and assistance, show rising trends. While the regulation of ocean acidification, i.e. CO_2 sequestration by organisms on land and in water, is stable (while anthropogenic carbon input is increasing), the trends of all other services, e.g. the creation and maintenance of habitats, climate regulation and regulation of detrimental organisms and biological processes, are negative.
Source: IPBES, 2019a

Figure 2.2-9
The drivers of biodiversity loss. Land stewardship and the direct use of resources account for around 50% of the direct drivers of biodiversity loss.
Source: IPBES, 2019a



difficult-to-predict change (Barnosky et al., 2012). Half of the world's most biodiverse regions have now lost 90% of their vegetation (Sloan et al., 2014). All biomes and ecoregions, both terrestrial and limnic, are affected by biodiversity loss (Hoekstra et al., 2004; Handa et al., 2014). The degradation of ecosystems has led to a considerable reduction in the distribution range of wildlife populations (Dirzo et al., 2014; Ceballos et al., 2017): 60% over the last 40 years (WWF International, 2018). In Germany, too, a massive insect die-off of up to 75% of the insect biomass has been observed (Hallmann et al., 2017; Seibold et al., 2019). However, not only insects, but also other animal groups such as breeding birds or bats, as well as ecosystems in Germany have been found to be in an inadequate to poor state (Leopoldina et al., 2018; Leopoldina, 2020; BMU, 2020b). While the global loss of biodiversity and the associated threat of the complete loss of individual ecosystem services are irreversible (Loreau et al., 2006; MA, 2005), the worldwide degradation of ecosystems and the reduction in species populations leading to the extinction of species, can be limited and partially reversed by ecosystem restoration (Section 3.1) and conservation measures (Section 3.2).

The drivers of biodiversity loss

In addition to the unsustainable use, including the direct exploitation of organisms, e.g. in fishing (Worm, 2016), hunting and poaching (Ripple et al., 2019; Chase et al., 2016) and illegal logging (Brancalion et al., 2018), IPBES has identified the following key direct drivers of biodiversity loss: changes in the use of land and sea, climate change, environmental pollution and invasions by alien species (Figure 2.2-9; IPBES, 2019a). Large-scale land-use changes in favour of agriculture, mining and infrastructure construction, e.g. roads and buildings, lead to a massive loss of natural ecosystems, to habitat fragmentation and population decline, even to the extinction of species (IPBES, 2019b; Marques et al., 2019). Anthropogenic climate change alone could mean the extinction of a sixth of all species (Urban, 2015). The environmental pollution taking place worldwide includes air, water and soil pollution, with plastics pollution representing a core problem (IPBES 2019b; Geyer et al., 2017). The increasing spread of non-native species, leading to the displacement of native species, is another important cause of the biodiversity crisis (Linders et al., 2019).

Globalization is a contributory factor driving this loss of biodiversity (Díaz et al., 2019). International trade and its effects (Lenzen et al., 2012), demographic and economic development and the associated production and consumption patterns are changing people's lifestyles (Díaz et al., 2019; Wilting et al., 2017) and also have remote effects (Lenschow et al., 2016), which contribute to the biodiversity crisis as indirect drivers. It is not least through global technological developments and economic and political control systems that humans indirectly influence the status of biodiversity, e.g. in that the costs and particularly the externalities of biodiversity loss are as yet insufficiently internalized in production processes or not at all; i.e. up to now they have hardly been taken into account and offset (IPBES, 2019a; Section 4.2.1).

The individual actions of humans have a manifold, mostly indirect and hardly visible influence on biodiversity. When human influence by individuals is aggregated by the same or at least similar actions by many people, the rising demand for material ecosystem services in particular becomes noticeable in the form of an overuse of natural resources. However, the supposedly positive trend in the demand for material ecosystem services has a negative impact on ecologically regulating ecosystem services in particular. As the result of a deterioration in or loss of resilience of many ecosystems, i.e. their resistance to ecological disturbances such as storms and floods, the crises of the land-use trilemma are exacerbated. Ecosystem services and human interaction with terrestrial ecosystems are thus at the centre of the trilemma. At the same time, this means that the restoration of degraded ecosystems (Section 3.1) and systemic approaches to ecosystem conservation (Section 3.2), which stabilize and strengthen especially the regulating ecosystem services, can help defuse the trilemma. It should be borne in mind in this context that all ecosystems are worth protecting on principle, whether rich or poor in biological diversity (e.g. with particularly unique biological communities).

Human beings must radically change their actions and the way they interact with nature. Policy-makers must create appropriate framework conditions for such a change and offer incentives for business and society to achieve greater sustainability (Chapter 4). Global biodiversity is under massive pressure – and yet its ecosystem services make it an essential basis for a stable climate and for ensuring food security. A new, sustainable approach to land stewardship is needed to combat the three great crises of climate, the food system and biodiversity (SCBD, 2020; Leclère et al., 2020).

2.3 Future vision for sustainable land stewardship

The WBGU's future vision of sustainable land stewardship and terrestrial ecosystem management is based on the SDGs internationally agreed in the 2030 Agenda, the objectives of the Paris Agreement and the goals of the CBD and the UNCCD. The WBGU's normative compass is also based on these goals (WBGU, 2016a; 2019b; Box 2.3-1), which put people at the focus of attention.

Sustainable land stewardship affects people's immediate living environment. In many cases, not only the conservation of life-support systems (including the supply of food and clean drinking water or keeping the air clean and maintaining soil fertility) but also inclusion (e.g. access to land and ecosystem services) and *Eigenart* (biocultural diversity) are not guaranteed today and are increasingly threatened by the overuse and destruction of terrestrial ecosystems. As the previous sections show, reversing the trends of ecosystem destruction and land degradation is a *sine qua non* for the way to a sustainable future envisaged by the international community.

The use of terrestrial ecosystems, above all in agriculture and forestry, must be fundamentally redirected towards sustainability. Land stewardship can only be sustainable if it (1) locally respects the needs and the dignity of the people living there and of future generations, (2) respects their culture and diversity, and (3) takes into account planetary guard rails and objectives for sustaining the natural life-support systems and, against this background, appreciates, conserves and restores terrestrial ecosystems and their services. To this end, it is important to keep the multifunctionality of landscapes in mind. This perspective also makes it possible to overcome perceived contradictions between nature and (land) use for everyone.

2.3.1 Sustainable land stewardship: systemic, synergistic, solidarity-based

In 2011, the WBGU identified land use – alongside the global energy-system transformation and the sustainable management of rapid urbanization – as an important field of transformation (WBGU, 2011:302ff.). Without a transformation of our stewardship of the land – a global land-use transformation – the many and varied sustainability goals will not be achievable. In this context it is necessary that the goals – above all food security, climate-change mitigation and the conservation of biological diversity and ecosystem services – are not pursued in isolation, i.e. in competition with each other, but that synergetic linkages between them are sought. Strategies for achieving these sustainability goals can only be successful overall if they are designed *a priori* to achieve a number of goals and do not ignore repercussions on other goals. Such multiple-benefit strategies should be pursued at all levels of governance – from the global to the national, regional and local levels. Against this background, the WBGU's vision can be summarized by three attributes. First, sustainable land stewardship requires a *systemic* view: the interactions between different claims for use and biophysical parameters are immense, and their reach can be considerable. Systemic connections range from the local to the global level and require a cross-sectoral perspective. Second, the problems of our land stewardship can only be solved *synergistically.* In order to overcome competition for land and avoid overuse, the focus must be placed on the multifunctionality of terrestrial ecosystems (Figure 2.3-1). It must not be a question of pursuing different interests of use and protection in isolation from one another, but rather of striving for constructive cooperation. Third, a global land-use transformation can only take place on the basis of *solidarity.* All actors

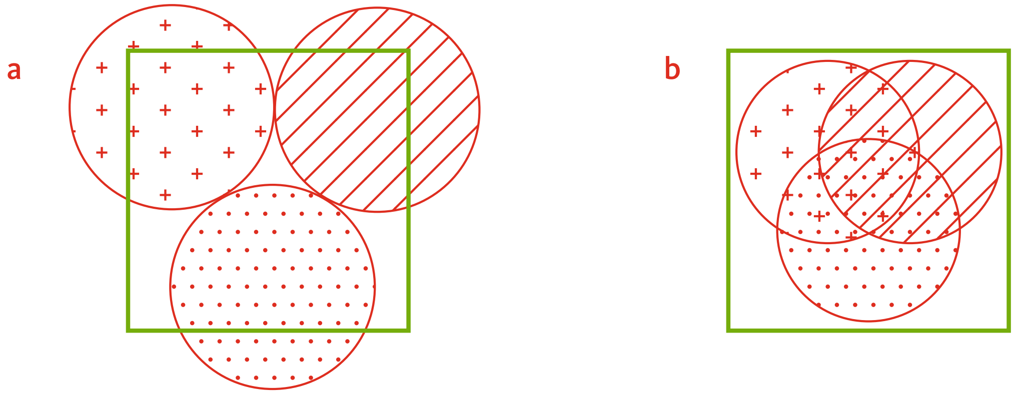


Figure 2.3-1
Schematic representation of the potential for synergies: a) The land-use claims for climate protection, food security and the conservation of biodiversity exceed the sustainably available global area if the various functional claims are realized on separate areas of land. b) An integrated form of land stewardship that combines the multiple goals and, where possible, realizes them on one and the same area can secure all three goals in the long term.
Source: WBGU, graphics: Ellery Studio

have a responsibility, whereby potential and capacity are unequally distributed. At the same time, sustainable land stewardship requires a fair distribution of burdens and benefits. Particular attention should be paid to gender equity (Box 2.3-2).

The vision of systemic, synergistic and solidarity-based land stewardship can be put into more concrete terms with the help of three strategic perspectives: the integration of protection and use at the landscape level, the consideration and design of remote effects (telecoupling) and the assumption of responsibility at all levels. These are explained below.

Governance, planning and use at the landscape level

An integrated landscape approach is suitable for implementing the vision of a systemic, synergistic and solidarity-based form of land stewardship at the local level (Box 2.3-3). Landscape is described by the IPBES (2018a) as a spatially heterogeneous mosaic of interacting terrestrial ecosystems and coexisting uses.

The landscape approach is a design concept comprising ecological, spatial-planning and governance aspects. At its core is the issue of reconciling competing forms of land use as well as the interests and – in some cases culturally influenced – values of stakeholders in the ecological and cultural context of the landscape. Integrated landscape planning, which is part of the landscape approach, can unite the claims of the different land uses and protection needs in a joint creative process, adapt them to the local conditions and moderate negotiations on the trilemma outlined above (Section 2.2) in the spirit of sustainable use (Section 3.6). It is therefore important not to address land-use conflicts in the sense of local land-use competition, which often leads to an expansion of the total used area, but to pursue a qualitatively better form of land stewardship in the landscape in everyone's interests. Contributions to overcoming global challenges can be integrated in the context of the landscape (Kremen and Merenlender, 2018). Examples include climate-change mitigation and increasing the resilience of terrestrial ecosystems (including heavily used agricultural and forestry ecosystems) to the effects of climate change, e.g. an increase in extreme events or altered precipitation patterns. In this sense, the WBGU has adopted the concept of an integrated landscape approach as part of its vision.

Considering and shaping regional and global telecoupling

However, a landscape approach cannot solve all challenges, since every landscape is also influenced by interactions over long distances – for example through the exchange of energy, material or information, in some cases on a global scale. The systemic perspective must therefore go far beyond the local framework and there also requires solidarity-based, synergistic strategies. In the Anthropocene, for example, many ecosystemic material cycles and energy flows have been broken up and altered, e.g. nutrient cycles like those of phosphorus and nitrogen, which in the meantime are partly determined by global trade flows and by anthropogenic nitrogen fixation (Haber-Bosch process). Furthermore, international trade leads to a decoupling of the interrelations of ecosystem services, e.g. when large quantities of protein-rich animal feed are imported to Europe from Latin America, which contributes to ecosystem destruction there and to disposal problems in

Box 2.3-1

The WBGU's normative compass

The normative compass presented by the WBGU in its most recent reports can provide orientation for the necessary transformation of the way we deal with land (WBGU, 2016a, 2019b). In addition to sustaining natural life-support systems and societal inclusion for everyone, the compass contains the dimension of *Eigenart*, which, among other things, emphasizes the importance of socio-cultural diversity (which in many ways is linked to biological diversity) as a goal dimension and a resource for the transformation towards sustainability. The key reference point for all dimensions is the respect for and protection of human dignity.

Sustaining natural life-support systems

This dimension covers firstly compliance with planetary guard rails and, secondly, the avoidance of local environmental problems. The concept of planetary guard rails developed by the WBGU since 1994 defines "quantitatively definable damage thresholds, whose transgression either today or in future would have such intolerable consequences that even large-scale benefits in other areas could not compensate these" (WBGU, 2011:32). The WBGU quantified global guard rails first for anthropogenic climate change (WBGU, 1995, 1997) and later also for other global environmental changes such as soil degradation (WBGU, 2005), biodiversity loss (WBGU, 2000) and ocean acidification (WBGU, 2006). The concept was taken up by Rockström et al. (2009a, b) and Steffen et al. (2015) in the formulation of "planetary boundaries" and is also increasingly found in political goals. In this report, the WBGU refers to the following six guard rails (WBGU, 2014):

1. *Limit climate change to a maximum of 2°C*. This guard rail is now found in an even more ambitious form in the Paris Agreement, with the goal of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (UNFCCC, 2015).
2. *Limit ocean acidification to 0.2 pH units*. The United Nations' Sustainable Development Goals (SDGs; UNGA, 2015) include the aim of minimizing the impacts of ocean acidification (SDG 14.3), although no quantitative targets are set here. Although ocean acidification is not explicitly mentioned in the Paris Agreement, limiting climate change to below 2°C, if achieved primarily by means of a corresponding reduction in CO_2 emissions, should simultaneously lead to compliance with this guard rail. However, some of the options discussed in climate policy to remove CO_2 from the atmosphere could also lead to an increase in ocean acidification. These include BECCS (bioenergy with capture and storage of the resulting CO_2; Box 3.5-3), if the CO_2 is stored in the seabed and leaks occur there, and ocean fertilization, i.e. the targeted release of nutrients (e.g. iron) into the ocean with the aim of forcing increased CO_2 uptake via algal blooms (IPCC, 2019c: 542). Furthermore, temperature stabilization based on Solar Radiation Management (SRM) would not limit ocean acidification.
3. *Halt the loss of biodiversity and ecosystem services*. This goal is laid down in the SDGs (SDG 15.5) and in the Convention on Biological Diversity (CBD). The CBD's first strategic plan already contained the goal of halting the loss of biological diversity (CBD, 2002). The second current strategic plan underlines this aim (CBD, 2010a; Section 3.2.2) and calls its vision 'Living in Harmony with Nature'; its aim is to achieve by 2050 an appreciation and the conservation, restoration and wise use of biodiversity, as well as the maintenance of ecosystem services. The WBGU's interpretation of the plans is that, according to the CBD, at least the anthropogenic drivers of a further loss of biodiversity must be stopped by 2050.
4. *Halt land and soil degradation*. The SDGs include the goal of achieving a "land degradation-neutral world" by 2030 (SDG 15.3; Section 2.1.3).
5. *Limit the risks posed by long-lived and harmful anthropogenic substances*. The SDGs include the aim of substantially reducing the number of deaths and illnesses from hazardous chemicals and from air, water and soil pollution and contamination by 2030 (SDG 3.9). With regard to land use, special attention should be given to long-lived pesticides, which are included in the Stockholm Convention among others, and mercury, which is regulated by the Minamata Convention.
6. *Halt the loss of phosphorus*. Global food production is highly dependent on the use of limited rock phosphate resources, which is concentrated in a small number of deposits worldwide (Blackwell et al., 2019). Some SDGs relate indirectly to better nutrient management. However, there is a lack of strategic approaches that take an integrated view of the harmful effects of over-fertilization and eutrophication and the problem of raw materials (Kanter and Brownlie, 2019).

In addition to compliance with the guard rails, the aim is to avoid local and regional environmental problems: here the focus, among other things, is on the sustainable use of water resources, ecosystem conservation and preventing local and regional environmental pollution caused, for example by eutrophication (over-fertilization) or pesticides (Section 3.3).

Inclusion

One of the goals of the transformation towards sustainability is to achieve the inclusion of all people, which is also the guiding principle of many SDGs. "Without inclusion, neither a good life nor sustainable development is possible" (WBGU, 2016a:137). For the WBGU, firstly, inclusion means substantive inclusion, i.e. among other things appropriate access to land or terrestrial ecosystem services such as sufficient and healthy food, clean drinking water and a healthy, pollution-free environment. Many aspects of substantive inclusion are thus closely linked to sustaining the natural life-support systems. Secondly, it is about economic and political inclusion. People must have the opportunity of "being integrated into an economic system and having access to formal and informal markets" (WBGU, 2016a:139). They must also be able to actively participate in shaping society and their living environment (political inclusion). In the case of land, for example, this can be achieved within the framework of a landscape approach that provides for extensive participation opportunities (Box 2.3-3).

Eigenart

With the third dimension of the normative compass, *Eigenart*, the WBGU emphasizes the great importance of cultural and biological diversity for resilience and quality of life. Firstly, it is a matter of recognizing the value of diversity. Like cities, landscapes and cultural landscapes and their uses also have emotionally and physically experienced singularities and unmistakable characteristics (*Eigenarten*) with which people feel connected and which often represent an important part of a culture. They are closely related to cultural peculiarities such as agricultural practices (Section 3.3), dietary habits (Section 3.4) and the use of materials, for example for building (Section 3.5). These specific characteristics must be preserved and further developed. There is also a connection here with political inclusion in that people are granted creative autonomy to shape their immediate physical environment. Secondly, the WBGU sees biocultural diversity as a resource for the transformation towards sustainability and as a basis for resilience to future changes and shocks. The issue here is to maintain and create a pool of ideas, examples and alternative ways of living in order to shape positive changes and to be able to respond to changing framework conditions such as climate change.

Dignity

Human dignity is the normative compass's central point of reference. The SDGs give some idea of the connection between human dignity and land: the first two goals – overcoming poverty and hunger – which simultaneously form the basis of a dignified life, explicitly include the secure ownership and control of land and natural resources as well as the sustainable cultivation of agricultural land. An intact natural environment with its ecosystem services is also an essential component of a dignified life. Such an environment is the prerequisite for economic prosperity, the *Eigenart* (character) of a landscape and cultural identity.

Europe's intensive livestock farming, and leads to corresponding pressure on aquatic ecosystems and groundwater. Yet, in principle, trade can also relieve ecosystems if, for example, water-intensive products are imported from water-rich to dry regions (virtual water). The challenge is to find a way of integrating this 'metabolism of civilization' (which, alongside global trade flows, is characterized by the intensive use of mineral resources, mineral fertilizers, new chemicals and new possibilities of energy conversion such as wind energy and photovoltaics) with ecosystemic products and services to create a functioning whole.

All in all, the aim must not be to seek a return to an earlier, supposedly better 'primal state'. Rather, it is a matter of shaping the human influence in a useful manner, also with a view to a changed, more sustainable future. At the same time, this influence, and thus also the total amount of biomass withdrawn for human use, must remain limited, as otherwise compliance with development goals and planetary guard rails will be at risk. These challenges require a far-reaching consensus beyond the landscape level, i.e. also supraregional and international strategic cooperation.

Recognize ecosystems and their services as global commons

In order to achieve a transformation in land stewardship, therefore, more individual, local, national and global creative responsibility needs to be assumed and integrated. All human beings depend in a systemic way on the continued existence of the terrestrial ecosystems, and the effects of their destruction and degradation do not stop at borders. In this sense, terrestrial ecosystems and many of their services should be regarded as global commons whose protection, restoration and sustainable use require people at all levels to assume responsibility (Willemen et al., 2020; Creutzig, 2017). Integrated strategies for assuming responsibility based on solidarity affect the international community as well as the internationally operating food and agricultural industry, the timber industry, small-scale agriculture, consumers, research and educational institutions and non-governmental organizations. The strategically integrated assumption of responsibility for intact ecosystems and multifunctional land areas must synergistically ensure the provision of diverse ecosystem services and equitable access to them. In this way an opportunity is opened up to overcome the trilemma identified by the WBGU.

2.3.2 Shape the transformation towards sustainable land stewardship

The pressure on terrestrial ecosystems and the associated threat to ecosystem services for both humans and nature has never been greater than it is today. Current reports by international institutions give a clear picture of the situation and simultaneously identify important options for action (SCBD, 2020; IPCC, 2019a; IPBES, 2018a-e, 2019a; Independent Group of Scientists appointed by the Secretary-General, 2019; FAO, 2018a, i; UNCCD, 2017b). The reports contain recommendations for improved practices in agriculture and forestry, practices for ecosystem restoration, the protection of ecosystems and environmentally friendly spatial planning. Measures along value chains are also mentioned. In addition, various (legal, economic, social and standards-based) policy instruments are presented (Table SPM 4 in IPBES, 2018b). In particular, the governance recommendations mentioned in the reports deserve attention in the creation of sustainable framework conditions. However, the current implementation and effectiveness of the recommendations still appear limited. A crucial point will be adapting these individual

Box 2.3-2

Gender equity in the 'trilemma of land use'

The WBGU's approaches to solving the trilemma of land use, i.e. land-use competition between climate-change mitigation, biodiversity conservation and food security, also relate to the complex, interdependent issue of gender equity. Women* are the largest discriminated group. At the same time, as versatile change agents, they are key to the success of the Great Transformation towards Sustainability (Röhr et al., 2018). With this in mind, the international community committed itself in Goal 5 of the 2030 Agenda to overcoming all gender-specific inequalities in the next decade, recognizing gender equity as a cross-cutting issue for achieving the sustainable development goals. Factors that lead to the discrimination of women* are not the only issues. The keyword 'intersectionality' (Collins and Bilge, 2016) emphasizes that gender-based discrimination interacts with aspects such as income, education, age, geographical location and racism. This sometimes leads to multiple discrimination and a concentration of deprivation and exclusion along such diverse development goals as ending hunger, ensuring decent work (including in the agricultural sector) and providing affordable, clean energy (UN Women, 2019).

With reference to this challenge of the 2030 Agenda, the UN Women's Progress Report (UN Women, 2019) makes it clear that only individual indicators of gender equity are showing positive trends; overall, however, the situation remains "alarming". There has been no progress on the structural root causes of discrimination, e.g. reducing "legal discrimination, discriminatory social norms and attitudes, low levels of decision-making on the part of women and girls in sexual and reproductive health issues, and less than full political participation" (UN Women, 2019:10). In order to ensure the success of the land-use transformation in the Anthropocene in an area strongly marked by gender-based discrimination, and to prevent transformative measures from perpetuating or even intensifying gender-based discrimination, a gender-sensitive study must be made of the status quo, and the future land-use transformation must integrate gender equity as a precursor and goal of the Great Transformation (Röhr et al., 2018).

For example, the IPCC (Shukla et al., 2019) argues that a gender-inclusive approach would boost sustainable land management: it says that women* play a key role globally in the shift towards sustainable agriculture and in rural economies, yet this is restricted by discriminatory laws, norms and social structures. "Acknowledging women's land rights and bringing women's land management knowledge into land-related decision-making would support the alleviation of land degradation, and facilitate the take-up of integrated adaptation and mitigation measures" (Shukla et al., 2019:43). At present, however, all current indicators show that, compared to men*, women* are at a significant disadvantage in all aspects of agricultural land rights, i.e. ownership, management, transfer and economic rights (FAO, 2018f). Furthermore, they are more vulnerable to the impacts of climate change, since they often have fewer social and economic resources (Shukla et al., 2019).

The World Biodiversity Council, too, emphasizes the "interdependence of gender, biodiversity conservation and the sustainable use of resources" (IPBES, 2018a). It goes on to say that women* play a key role in agriculture and forestry, fisheries and tourism, water management and nature conservation, underlining the need for their effective participation in decision-making processes (FAO, 2011b). They are also particularly affected by the destruction of nature, as negative impacts are disproportionately felt by people in vulnerable situations, i.e. women*, indigenous peoples and local communities in particular. Governments should therefore promote the mainstreaming of gender aspects, for example in politics (e.g. in national biodiversity strategies) or at the organizational level (e.g. through anti-discrimination training for managers and gender-sensitive budget planning). However, it is especially difficult to assess the close relationship between nature and SDG 5 of the 2030 Agenda as the current focus and formulation of SDG 5 fails to recognize and measure this interaction (IPBES, 2018a).

Food security, as a component of the trilemma, is also strongly linked to gender equity. Despite important context-specific differences, women* play a central role in food security worldwide in the production, distribution and preparation of food (FAO et al., 2019d). Yet they are more affected by food insecurity than men* on every continent (FAO, 2018f). Moreover, in the context of the globalization of the agricultural sector and the emigration primarily of men*, a precarious "feminization of the agricultural sector" can be observed, especially in vulnerable areas of subsistence farming and agro-industrial jobs with the lowest wage levels (Radel et al., 2012). Gender-inclusive approaches to sustainable land management can thus also strengthen food security at the household and regional level. Here, the IPCC underlines the key role of the cross-cutting issue of gender equity for the trilemma: "The overwhelming presence of women in many land-based activities [...] provides opportunities to mainstream gender policies, overcome gender barriers, enhance gender equity and increase sustainable land management and food security" (Shukla et al., 2019:70).

Greater gender equity can thus promote synergies between food security, climate-change mitigation and biodiversity protection and, not least, strengthen the human rights of women* and gender minorities. To realize this potential, two aspects in particular would have to be taken into account. First, there is a national and global lack of scientific data collection, low-threshold dissemination and political application of disaggregated data on the nexus of gender and environmental issues, which would make certain gender-related forms of research, evaluation and measures possible in the first place (UNEP and IUCN, 2018). This shortcoming is also reflected in the indicators of the environment-related goals of sustainable development (SDGs 12-15), where only one gender-specific indicator is envisaged, i.e. in the area of climate-change mitigation (UN Women, 2019). Differentiated data are indispensable for classifying the living conditions of all genders realistically and context-specifically and for understanding barriers, constraints and transformation possibilities, for example with regard to the socio-ecological management of natural resources (UNEP and IUCN, 2018). Continuous data surveys are also necessary because climate impacts and migration in particular are dynamically changing traditional gender roles (Meinzen-Dick et al., 2014). The UNEP and IUCN have drawn up recommendations for differentiated gender-environment indicators to support the strategies of national decision-makers (UNEP and IUCN, 2018). However, new indicators should also take into account other discriminated gender groups besides women* and allow for at least one third category (WBGU, 2019b). Without gender-sensitive information, "environmental analyses remain inadequate and partial, and it becomes almost impossible to establish benchmarks, review progress and measure results" (UNEP, 2016).

A second central aspect for a gender-related transformation in land stewardship is the often narrowed or shortened focusing of the issue of gender equity on 'women' and, in the land-use context, on "women as subsistence farmers in rural areas of the global South" (Röhr et al., 2018). Gender equity is sometimes treated as a caricatured or de-politicized issue to be "ticked off" (Bock, 2015:731) and the relevance of the topic is scientifically and politically underexposed in industrialized countries (Sellers, 2016). In Germany, too, the unequal ownership distribution of agricultural land is dominant (at only 8.5% for women* it is almost the lowest in Europe; FAO, 2018f.) as is political under-representation (the proportion of women* in parliament is declining at just over 30%). Furthermore, a re-traditionalization of gender roles is becoming apparent in the context of climate impacts such as floods (UNEP, 2016) or the COVID-19 pandemic (Kohlrausch and Zucco, 2020). Ultimately, the narrow focus on women* means that too little attention is paid to the cultural norms and economic, political and legal structures underlying discrimination (Röhr et al., 2018). Without a revised understanding of gender as a socially constituted, intersectionally interlinked and changeable power relationship (Kronsell, 2017), so-called difference approaches (woman vs. man) threaten to consolidate traditional role attributions in science and in practice and to reproduce gender hierarchies (Röhr et al., 2018). Combined with the lack of gender-sensitive data collection in a society that tends to understand women* as a deviation from an implicitly male norm (androcentrism), there is widespread favouritism of men* at the expense of women* (Criado-Perez, 2019) and other discriminated gender groups in research, technological development and policy-making.

In order to make the land-use transformation gender-equitable and successful, a stronger focus on structural power differences and drivers of gender inequality is important (Resurrección, 2013). At the same time, stereotypes that are widespread in some sustainability sciences – for example stylizing women as being 'naturally' more physical and closer to the environment – should not be perpetuated (Hofmeister et al., 2013). Social-science approaches can make an important contribution here and should be promoted to a greater extent (Röhr et al., 2018). One example is feminist political economy, which explores the extent to which gender – intersectionally intertwined with other power dimensions such as racism or economic inequality – influences the way natural resources and ecosystems are dealt with (Bauhardt and Harcourt, 2019; Harcourt and Nelson, 2015). In concrete terms, gender-equitable economic and political inclusion is necessary at both the international and the national level. It could be promoted by gender-sensitive social policy and political and economic representation based on gender equality (Röhr et al., 2018). This should also apply to positions and offices of the German Federal Government that shape its land stewardship in the context of global environmental change – e.g. in federal ministries and on advisory councils.

measures to local and national conditions and orchestrating them synergistically.

The consensus of the cited reports is that the recommended measures can be most effective when implemented in a cross-sectoral, polycentric, inclusive and participatory manner. In the WBGU's view, what is at stake is nothing less than a transformation of the way we use and treat land. And the direction is predefined: the internationally recognized target vision of sustainable development has clearly taken shape since the Rio Conference in 1992 and most recently in 2015 in the 2030 Agenda with its 17 SDGs. In the multilateral agreements, the international community has already set itself concrete goals and targets, developed programmes for action, set up financing mechanisms and backed up political action with scientific assessment reports. There are thus already many creative proposals on how to shape land stewardship and in this way also help overcome the climate, biodiversity and food crises. However, there are several challenges regarding implementation that need to be overcome (Phang et al., 2020). These include for example the crisis of multilateralism, populist autocracies, and often simply a lack of political will for effective implementation.

Building on the internationally negotiated system of goals and linking up to current global initiatives and negotiation processes, this report aims to contribute to framing and better integrating sustainable land-stewardship approaches into the implementation of these goals. The transformation towards sustainable land stewardship requires political will, creativity and courage. It requires pioneers who test and pursue new ways, strong partnerships of multiple actors, states that lay down the framework and enforce necessary measures, and mechanisms for achieving a fair balance between winners and losers. In this spirit, the WBGU has described such a transformation as a societal search process (WBGU, 2011). In the present report, the WBGU focuses on the three crises described above: the climate crisis, the crisis of the food system and the biodiversity crisis, each of which gives rise to potentially high additional claims on land use. These claims arise, for example, from the creation of land-based CO_2 sinks, the production of food for a growing world population with increasingly land-intensive dietary habits, and the expansion of protected areas and areas used in a biodiversity-friendly manner to preserve biodiversity. The pressure exerted by these crises on global land areas already affected by overuse and degradation, the 'land-use trilemma' (Section 2.2), is the starting point for a number of multiple-benefit strategies that the WBGU proposes in the following Chapter 3 to advance the global land-use transformation. The aim of these strategies is to overcome the various forms of competition

Box 2.3-3

The integrated landscape approach

The spatial level of the landscape plays a particularly important role in sustainable land stewardship. This is where societal interests collide, uses coexist and land-use conflicts arise, where concrete decisions taken locally or on a larger scale are implemented in practice. Landscapes are characterized by specific geographical, physiographic, ecological and historical similarities and interactions that distinguish them from other landscapes (Kerkmann, 2017: 73). Landscapes exhibit a spatially heterogeneous diversity of interacting terrestrial ecosystems and coexisting uses (IPBES, 2018a). They fulfil central functions for humans and nature, as they are a source of food, water and raw materials. The landscape is suitable as a framework for governance because it connects people spatially and culturally. This frame of reference is small enough to keep decision-making processes manageable, but large enough to accommodate the different interests of civil society, private and public actors (IPBES, 2018a:12). Landscapes also provide settlement space and livelihoods for people, fulfil cultural, aesthetic and recreational needs and safeguard biodiversity and ecosystem services (IPBES, 2019a).

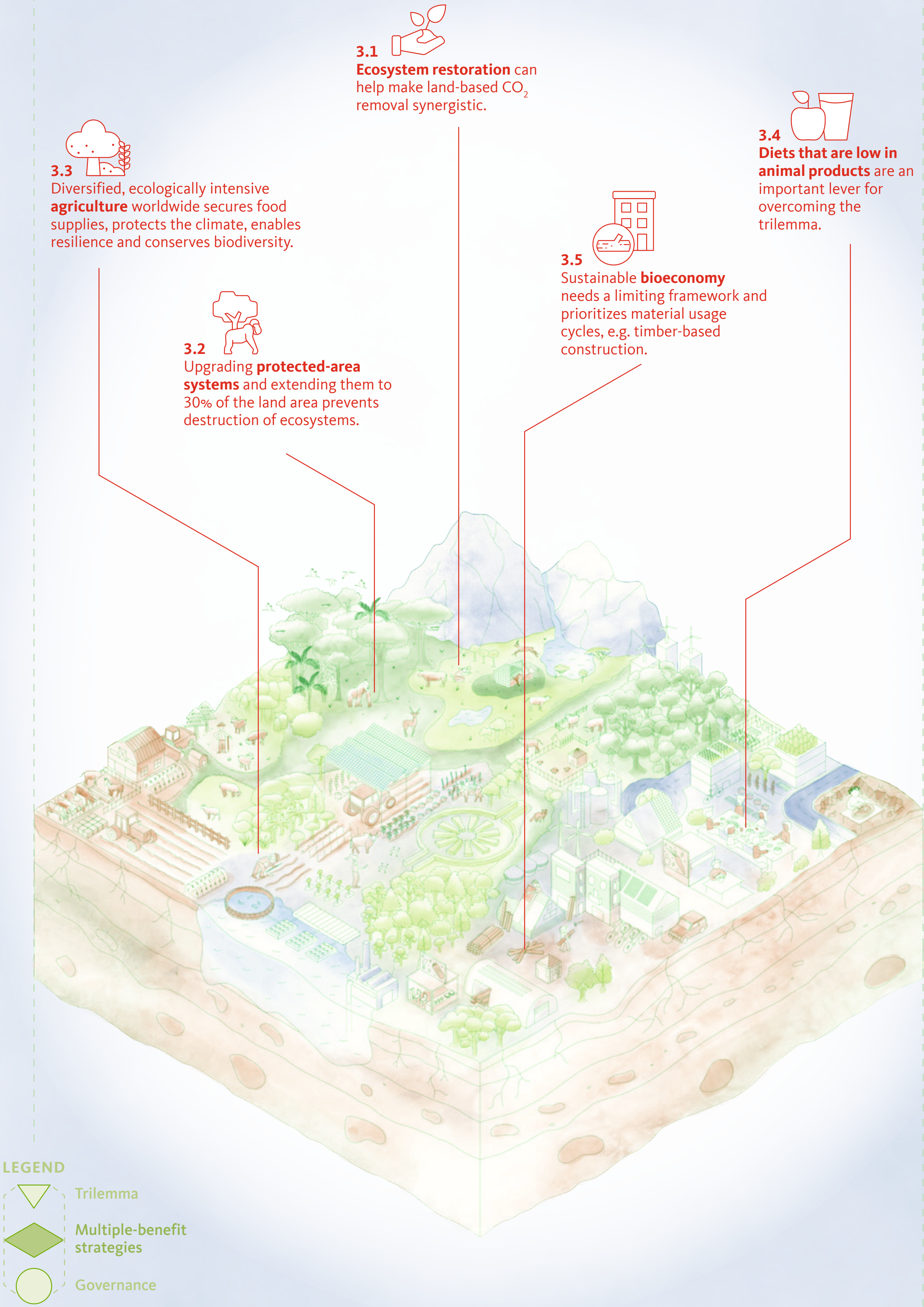
Various contents and interpretations of the term 'landscape approach' have been developed in research (Reviews in Arts et al., 2017; Reed et al., 2015, 2016). One common feature is that landscape approaches develop solutions for conflicting interests in land stewardship through negotiation processes. They offer an arena for the distribution and management of land in order to reconcile social, economic and ecological objectives in areas where agriculture, forestry, water supply, poverty reduction and regional development, infrastructure (energy, mining, transport, cities) and other land uses compete with environmental and biodiversity objectives (Sayer et al., 2013). Similarly, Reed et al (2020) characterize "integrated landscape approaches" as governance strategies for integrating multiple and conflicting claims to land with the needs of people and the environment, in order to establish a more sustainable, socially just and multifunctional form of land stewardship. In a landscape, uses should be designed and ecosystems protected in such a way that the provision of goods and services is ensured in the long term without endangering biological diversity and ecosystem services, and at the same time involving the best possible adaptation to and resilience towards climate change (Kremen and Merenlender, 2018). IPBES has also taken up this interpretation and recommends integrated landscape approaches for ecosystem restoration and to avoid land degradation (IPBES, 2018a:4, 12ff.).

In this report, the WBGU uses the 'integrated landscape approach' as an essential component of its vision for a transformation towards sustainable land stewardship, as it offers an important basis for overcoming the land-use trilemma. Integration is meant on two levels here: on the one hand, physiographic and ecological linkages are to be considered in context and – where possible – different uses integrated in one and the same land area; on the other hand, the different claims and associated interests of the relevant actors are to be better reconciled. In the WBGU's view, the integrated landscape approach is characterized by the following features:

- *Multifunctionality and multiple benefits:* The WBGU's normative compass and the idea of using synergies in land stewardship that can overcome the trilemma offer a basis for identifying a target system that can be shared by the different actors, as well as for strengthening multifunctionality in the entire landscape and for developing solutions that are viable in the long term – in the sense of the multiple-benefit strategies introduced in Chapter 3. The aim is to generate multiple benefits by the multifunctional use of suitable land and the combination of different areas of land (e.g. croplands that are also home to a wide range of agrobiodiversity, and pastures that are also carbon sinks).
- *Actor participation:* The private, public and civil-society actors representing different interests should not only be identified and informed; above all they should be encouraged to participate in the decision-making processes on how land should be managed. Institutionalization – in the form of multi-stakeholder platforms with a long-term orientation that meet regularly – is suitable for this purpose. The purpose of these platforms is to bring together the key actors for the specific design of the landscape and to provide transparent processes for the purpose, to identify and integrate the stakeholders' rights and responsibilities, and to empower them to reduce imbalances of knowledge and power.
- *Joint framework for monitoring and evaluation:* This is an essential prerequisite for putting negotiation processes on land stewardship on a common evidence base. In the sense of transdisciplinary approaches, local actors, especially indigenous peoples, should be encouraged and trained to each contribute their respective different, often traditional knowledge to facilitate joint learning.
- *Adaptive management:* Processes in – or impacting on – landscapes are dynamic and often non-linear. Adaptive management has proved its worth in coping with these potentially unpredictable and disruptive dynamics (e.g. economic or climate crises; Holling, 1978). In this way, the changes jointly identified during monitoring and evaluation are used to readjust synergies and adapt management accordingly. Learning from the results of the changed management then serves iteratively as an input for further decision-making.

The concept of the integrated landscape approach, when understood in this sense, can provide valuable assistance in dealing with complex problems and overcoming competition for land use, but it certainly cannot achieve consensual solutions in all cases (Sayer et al., 2017). In the application of the integrated landscape approach, also in tropical countries, conflicts of interest – which in some cases are profound – can be dealt with better if suitable state framework conditions are available with a polycentric governance structure (Section 4.2; Reed et al., 2017) and appropriate financing that can be relied on in the long term (Sayer et al., 2015; Berghöfer et al., 2017). Spatial and landscape planning (Section 4.2.3) is one of the important practical instruments for implementing the integrated landscape approach.

caused by the trilemma of land use, to reduce the pressure of use and to enable sustainable land stewardship. Other claims for use are also considered where relevant, but are not the focus of the analyses. In this sense, the multiple-benefit strategies should be seen as examples. Building on this, Chapter 4 shows the options for action available to individual actors and both national and international institutions, and outlines new governance structures for sustainable land management.


3.1
Ecosystem restoration can help make land-based CO_2 removal synergistic.
3.3
Diversified, ecologically intensive **agriculture** worldwide secures food supplies, protects the climate, enables resilience and conserves biodiversity.
3.4
Diets that are low in animal products are an important lever for overcoming the trilemma.
3.5
Sustainable **bioeconomy** needs a limiting framework and prioritizes material usage cycles, e.g. timber-based construction.
3.2
Upgrading **protected-area systems** and extending them to 30% of the land area prevents destruction of ecosystems.
LEGEND
Trilemma
Multiple-benefit strategies
Governance

Multiple-benefit strategies for sustainable land stewardship

3

The transformation of land stewardship towards sustainability can only succeed if systemic interrelationships are taken into account and utilized. Strategies for using land for climate-change mitigation, conserving biodiversity and safeguarding food security for a growing global population should therefore be coordinated. In particular, the aim must be to find synergies for reducing competition for, and the pressure on, land use.

With this in mind, the WBGU identifies examples of multiple-benefit strategies with transformative potential to illustrate how the land-use trilemma can be overcome in an innovative and hope-oriented manner and, in an ideal scenario, how different interests can be balanced. These strategies relate to the thematic fields of ecosystem restoration, ecosystem conservation, agriculture, dietary habits and the bioeconomy.

On the one hand, there are strategies that are directly related to areas of land:

- *Restoration – organize land-based CO_2 removal in a synergistic way:* Synergies can be achieved by restoring degraded areas of land worldwide. The reforestation of former forest landscapes in particular is regarded as an important climate-change-mitigation strategy, but the restoration of peatlands and grassland ecosystems can also make a considerable contribution to climate-change mitigation by absorbing CO_2 from the atmosphere. Restoration can simultaneously rehabilitate biodiversity and ecosystem services on the affected land, thereby also making sustainable food production possible. Therefore, in Section 3.1, the WBGU presents the restoration of degraded ecosystems as a multiple-benefit strategy.
- *Expand and upgrade protected-area systems:* It is also important to prevent the further loss and degradation of near-natural terrestrial ecosystems. Protecting ecosystems not only benefits biodiversity conservation, it also offers additional benefits and important qualitative potential for climate-change mitigation and nutrition ('triple win'): biodiversity, genetic resources and ecosystem services are prerequisites for agricultural systems and thus for food security. Furthermore, intact, natural ecosystems provide food and fibre, clean water and timber for indigenous peoples and rural populations in developing countries and emerging economies; they contribute to their food security and food sovereignty as well as to their cultural identity. Therefore, in Section 3.2, the WBGU proposes the expansion and upgrading of protected-area systems as a multiple-benefit strategy.
- *Diversify agricultural systems:* Another strategic approach is the diversification of agriculture towards ecologically intensive, multifunctional and sustainable agricultural systems. When properly managed, agricultural soils can sequester considerable amounts of CO_2; at the same time, the industrialized agricultural system in the EU becomes more ecologically oriented and the cultivation practices of resource-poor farms in sub-Saharan Africa are sustainably intensified. In Section 3.3, the WBGU proposes corresponding diversified agricultural systems.

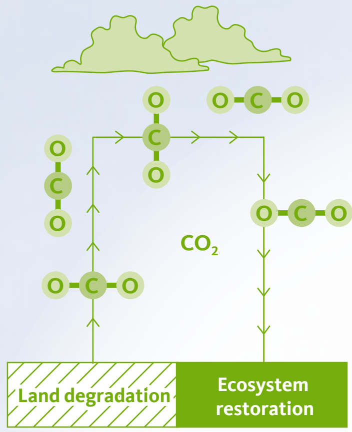
On the other hand, there are strategies that affect the demand for biomass in the form of food or for making materials or generating energy; these have an indirect impact on land stewardship:

- *Promote the transformation of diets heavy in animal products in industrialized countries:* Dietary habits have a considerable impact on land use. In particular, the consumption of animal-based products from factory farms drives the conversion of near-natural land into agricultural land, in some cases at a great distance from the consumers. Changing dietary patterns affects the use of cropland and grasslands and their cultivation, and this has considerable consequences for greenhouse-gas emissions, CO_2 sinks and land-use changes, which in turn can affect biodiversity. Section 3.4 discusses ways to promote sustainable dietary habits as a multiple-benefit strategy.

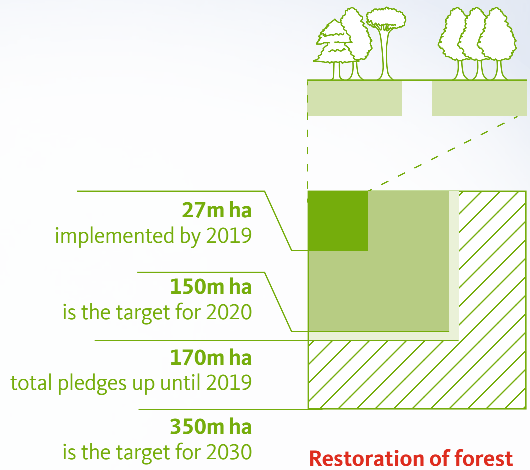
- *Design the bioeconomy responsibly and promote timber-based construction:* Another focus concentrates on the sustainable, economic use of biomass that is not used for food. There is potential here for using bio-based products above all in material applications for climate-change mitigation, while at the same time an excessively high or growing demand for these raw materials could undermine food security and biodiversity conservation. Therefore, in Section 3.5, the WBGU proposes a suitable framework for the bioeconomy and features sustainable construction with timber as an example of a multiple-benefit strategy.

Finally, Section 3.6 takes an overarching look at the interplay and implementation of the added-value strategies.

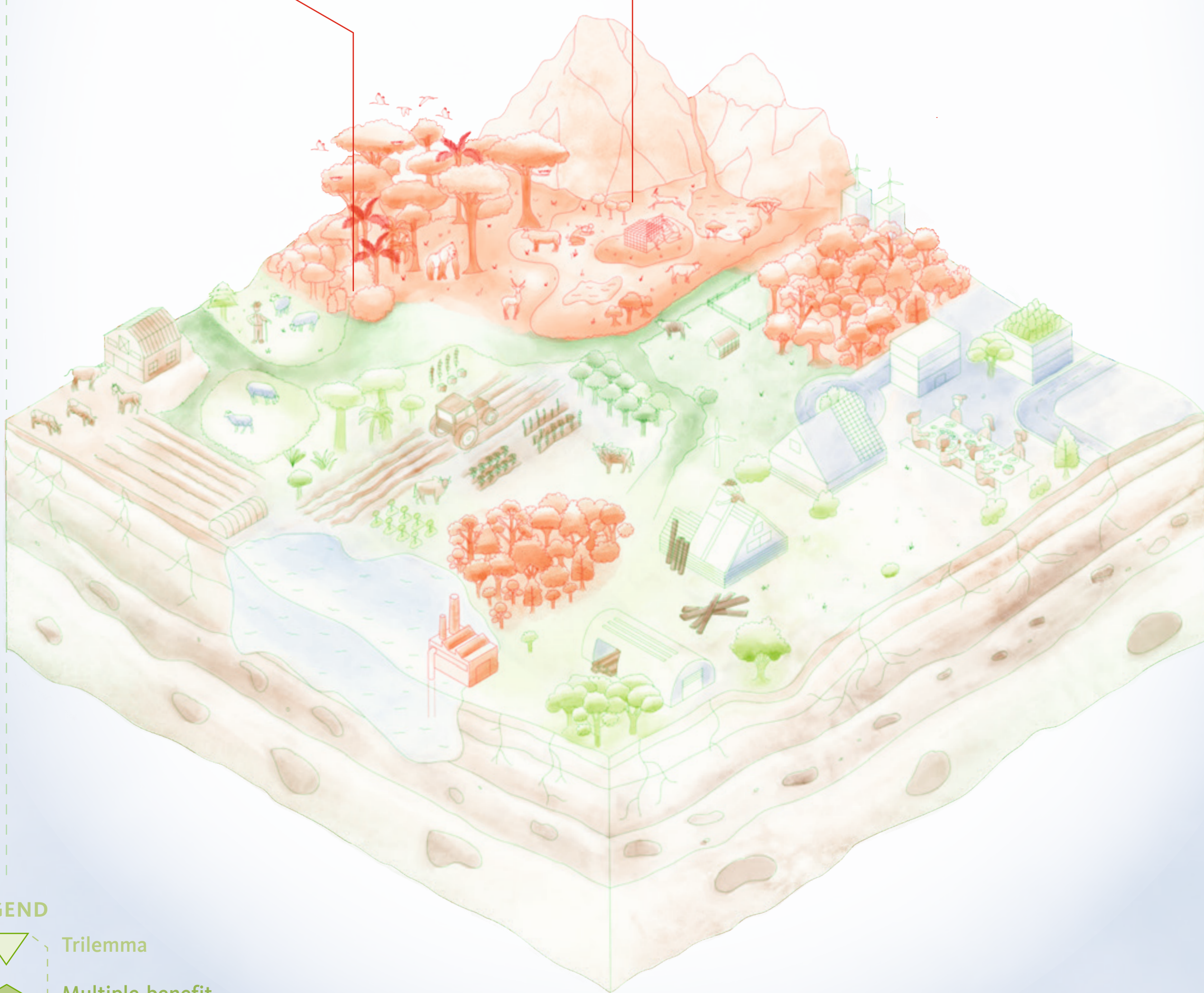
18% of the 2020 target had been implemented by 2019; unfortunately, half of the implemented pledges consisted of **plantations or monocultures low in biodiversity**.

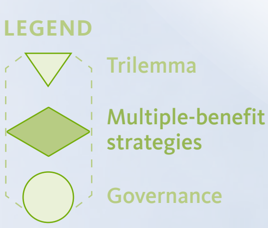


While land degradation causes the release of CO_2, ecosystem restoration can **remove** considerable quantities of **CO_2 from the atmosphere**.

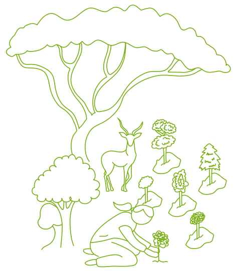


Restoration of forest landscapes: targets, pledges and implementation (by comparison: 170m ha corresponds to four times the area of Germany).





3.1
Ecosystem restoration: organize land-based CO_2 removal in a synergistic way



Measures for removing CO_2 from the atmosphere are no substitute for a massive reduction of CO_2 emissions with the aim of cutting them to zero. However, in order to reach the climate-protection goals of the Paris Agreement, such measures can hardly be avoided, although they involve considerable uncertainties depending on method, scope and implementation and can potentially increase the pressure on land. The WBGU recommends stepping up research on costs, feasibility, permanence and land-area potential, and making early use of the diverse additional benefits of low-risk ecosystem-based approaches like the restoration of degraded land.

The fact that progress on decarbonizing the global economy has hitherto been slow with ongoing rises in global CO_2 emissions is making it less and less likely that the Paris Agreement's climate-protection goals can be achieved solely by avoiding future greenhouse-gas emissions. A later, permanent removal of CO_2 from the atmosphere will probably be necessary. In this context, the various options for removing CO_2 from the atmosphere are being discussed more and more intensively worldwide. Section 3.1.1 offers an overview of this discussion, as well as of the various methods of CO_2 removal, their stage of development and potential, but also the risks their use entails for land-based ecosystems and their wider concomitant effects. Relying on the possibility of removing large quantities of CO_2 from the atmosphere in the future is a risky strategy from the point of view of climate protection. Many methods of CO_2 removal still lack technical maturity at the present time. The mitigating effect of CO_2 removal on climate change is also generally uncertain. Furthermore, many approaches are land-based, especially those that are currently at the focus of attention such as afforestation or BECCS. They thus generate new claims on the use of land and land-based ecosystems; if applied on a correspondingly large scale, they threaten to cause major conflicts of use over land areas and ecosystems as outlined by the land-use trilemma described in Chapter 2. The consequence would be corresponding socio-economic risks and negative ecological effects, especially on forests, grasslands, wetlands or agriculturally used areas.

Against this background, Section 3.1.2 develops principles for a sustainable strategic approach to CO_2 removal options in climate policy in order to address and minimize the multiple risks. Firstly, climate-policy strategies should emphasize consistent, early avoidance of emissions in order to limit as far as possible the amount of CO_2 removal that will be necessary in the future. Secondly, they should focus more on close-to-nature, ecosystem-based methods of CO_2 removal, which not only bind CO_2, but in particular promise diverse multiple benefits and synergies to mitigate the land-use trilemma.

In Section 3.1.3, the WBGU takes an in-depth look at the restoration of degraded terrestrial ecosystems such as forests, grasslands and wetlands as an ecosystem-based option for CO_2 removal. This is a proven, low-risk and cost-effective option for removing CO_2 from the atmosphere. Restoration promises multiple benefits in relation to the land-use trilemma and beyond, but its potential for removing CO_2 from the atmosphere is limited in terms of quantity and permanence of storage. At the same time, restoration is currently high on the international political agenda, as shown by the upcoming UN Decade on Ecosystem Restoration. The WBGU is therefore convinced that, in view of the current political tailwind, restoration should become a promising component of international climate and sustainability policy.

3.1.1
CO_2 sinks: the starting position

Scientific knowledge of the devastating consequences that unchecked climate change will have for humans and terrestrial ecosystems has been further intensified in recent years by reports from the Intergovernmental Panel on Climate Change and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPCC, 2018, 2019a, c; IPBES, 2018a, 2019a). Even so, global CO_2 emissions again reached a record high in 2019 (Peters et al., 2020; Friedlingstein et al., 2019; Jackson et al., 2019). In addition, the necessary tightening of the national climate pledges under the Paris Agreement already seemed a long way off even before the COVID-19 pandemic. Yet the international community agreed in the 2015 Paris Agreement to limit global warming to well below 2°C and pursue efforts towards limiting it to 1.5°C. If these goals are to be met, only a limited budget of a few hundred Gt CO_2 will be available for CO_2 emissions in the course of the 21st century. In 2018, according to the IPCC, these budgets for limiting global warming to 1.5°C amounted to 420 Gt CO_2 (for a 66% probability of achieving the climate policy target), or 580 Gt CO_2 (for a 50% probability). For a 2°C limit, figures of 1,170 Gt CO_2 (66%) or 1,500 Gt CO_2 (50%) are mentioned (IPCC, 2018:108). It should be noted that these budgets are likely to be even smaller today due to the emissions of recent years. However, they are subject to considerable uncertainty, e.g. because of possible repercussions in the Earth system that cannot be precisely predicted, or the effects of emissions of greenhouse gases other than CO_2. Nevertheless, a mere glance at the scale of these budgets compared to today's annual emissions of about 42 Gt CO_2 (Section 2.2.1) is enough to illustrate the climate-policy challenge. This is all the more true since a wide range of socio-economic path dependencies, needs for adaptation, and distributional challenges involving corresponding political resistance indisputably stand in the way of large reductions in emissions in the short term.

The possible removal of CO_2 from the atmosphere raises some hopes of resolving this growing discrepancy between the ambitious and even strengthened climate-policy goals and the lack of progress on climate-change mitigation. This possibility and the different approaches to CO_2 removal have been discussed scientifically since the early 1990s (Minx et al., 2017). Following their increasingly prominent role in the reports of the IPCC since its fourth Assessment Report in 2007, they have also become more and more visible to the broader public. However, they cannot and should not be seen as a reason to reduce the pressure for action in climate policy. This is clearly shown by the following overview of the stage of development of the main methods of CO_2 removal and the risks associated with their use, in terms of both climate-change mitigation and conflicts as outlined in the land-use trilemma (Section 2.2). Nevertheless, for precautionary reasons in view of the risks of climate change, methods for CO_2 removal from the atmosphere should be further developed and their sustainable potential explored early on.

3.1.1.1
CO_2 removal from the atmosphere: concept and definition

Methods to remove CO_2 from the atmosphere basically involve two steps: (1) capturing and removing CO_2 from the atmosphere, either via the (targeted or accelerated) growth of biomass, by natural inorganic reactions, or using technical processes; and (2) storing the carbon in either ecosystems, terrestrial and marine biomass, mineral compounds, or in gaseous form as CO_2 in geological formations (The Royal Society, 2018:20f.). There is no uniform or recognized categorization of the different procedures. For example, processes can be distinguished according to the form of carbon storage or whether they are terrestrial or marine (Minx et al., 2018). The latter, i.e. processes for injecting CO_2 into the ocean, will not be considered in the following, especially since they are not compatible with agreements under international law (WBGU, 2013:39). Following Field and Mach (2017), a rough distinction can be made between (1) ecosystem-based processes for enriching carbon in ecosystems, for example through restoration or more sustainable management, (2) biological-technical procedures that use natural processes or biomass and combine them subsequently with technical solutions, and (3) purely technical solutions.

Ecosystem-based (and in some cases biological-technical) methods for CO_2 removal ultimately use or enhance processes that already occur in the natural carbon cycle (Section 2.2.1), such as photosynthesis (Rickels et al., 2019:150). They should, however, be clearly distinguished from the natural carbon cycle. Oceans and the terrestrial biosphere already directly absorb over half of anthropogenic CO_2 emissions today, leaving only about 45% of emissions in the atmosphere; in the long term, the ocean absorbs an even higher proportion of emissions (Section 2.1.1; Friedlingstein et al., 2019). By contrast, the removal of CO_2 from the atmosphere is a deliberate human effort to withdraw more CO_2 from the atmosphere than would otherwise happen in the natural carbon cycle (Minx et al., 2018). The removal of CO_2 from the atmosphere (carbon dioxide removal or CDR) is often referred to as 'negative emissions' and corresponding technologies or approaches as 'negative emission technologies' (NET), since the human-initiated removal of CO_2 from the atmosphere can be seen as the opposite of an emission. Misunderstandings can arise here: e.g. when distinguishing between negative emissions that offset residual emissions, and system-wide 'net' negative emissions, which only arise if more CO_2 is removed from the atmosphere than is emitted into it over a certain period, e.g. one year. Moreover, calling emissions 'negative' can be misleadingly related to a valuation rather than to their effect on the emissions balance. To avoid such ambiguities and misunderstandings, the WBGU refers in the following to methods of removing CO_2 from the atmosphere or, more succinctly, to CO_2 removal.

CO_2-removal should furthermore be clearly distinguished from approaches of solar radiation management (SRM). The latter neither address the CO_2 concentration in the atmosphere as the real cause of climate change, nor are they suitable for mitigating effects of the accumulation of CO_2 in the atmosphere that go beyond the greenhouse effect, such as the acidification of the oceans. The use of SRM approaches involves much greater uncertainties and risks, different time scales of (climate) impacts, and different governance requirements (Minx et al., 2018; Bellamy and Geden, 2019). The WBGU therefore rejects the use of SRMs on principle (WBGU, 2016a).

3.1.1.2
Land-based approaches for CO_2 removal: technologies, potential, concomitant effects

A broad portfolio of approaches for removing CO_2 from the atmosphere is currently under discussion. They differ in terms of technical maturity, costs and potential. Apart from protecting the climate, they also have different ecological and socio-economic effects, both positive and negative. These are often referred to in the literature as side effects or concomitant effects and, at their core, they also relate to the conflicts summarized in Chapter 2 as the land-use trilemma insofar as they originate from new claims on land and terrestrial ecosystems. Finally, there are differences between the different approaches to CO_2 removal relating to the reliability and permanence of the carbon storage achieved and thus the long-term climate-change-mitigation effect. More in-depth accounts of the different approaches can be found in several recent review studies (Fuss et al., 2018; National Academies of Sciences, Engineering, and Medicine, 2019). The following section presents and classifies the key land-based approaches and their main features. In addition, Table 3.1-1 summarizes the scientific evidence from the detailed overview study by Fuss et al. (2018). Some of the information on potential given there paints a more pessimistic picture than more recent estimates, such as those included in the overview of the IPCC special report on climate and land (Smith et al., 2019b) and also taken up below. By contrast to the figures on potential in Table 3.1-1, however, it is not always clear in these estimates to what extent socio-economic constraints and other considerations of sustainable development have been taken into account.

Overview of CO_2-removal methods

Afforestation of non-forested areas and *reforestation* of deforested land are key ecosystem-based approaches that are currently being intensively discussed. Atmospheric CO_2 is fixed during tree growth and stored in the form of biomass in the tree population or in wood products (Section 3.5.3). The distinction between afforestation and reforestation is blurred and depends partly on the time horizons assumed (Section 3.1.3.2). For this reason, Table 3.1-1 aggregates afforestation and reforestation. In principle, (re)afforestation offers substantial potential for CO_2 removal, although the literature reveals a wide spectrum: according to the IPCC, the potential of afforestation lies in the range of 0.5–8.9 Gt CO_2 per year, of reforestation between 1.5 and 10.1 Gt CO_2 per year (Smith et al., 2019b:585). Table 3.1-1 also shows similarly wide ranges. In addition to afforestation, adjusting forestry practices, i.e. *improved forest management*, can contribute to increased carbon sequestration in forests and forest soils. Here too, the estimated ranges of potential are considerable, e.g. 0.4–2.1 Gt CO_2 per year (Smith et al., 2019b:585) or 1.1–9.2 Gt CO_2 per year (National Academies of Sciences, Engineering, and Medicine, 2019:110).

Reforestation (unless implemented as monocultures) and in some cases improved forest management are forms of *ecosystem restoration*. Restoration aims to restore ecosystem services (Chapter 2) and includes a higher sequestration of carbon in the biosphere as one of its added values. In addition to forest-related restoration, the restoration of wetlands, for example, distributed across all climate zones, also promises relevant global sequestration potential of about 1.7 Gt CO_2eq per year (freshwater: 0.82 Gt CO_2eq per year; coastal wetlands: 0.84 Gt CO_2eq per year; Smith et al., 2019a:261). The restoration of ecosystems as a strategy for sustainable land management is examined in more detail in Section 3.1.3.

Soil carbon sequestration uses a range of different land-use practices such as adapted harvest cycles, water management and nutrient management or, more generally, the conversion of agricultural methods to increase the carbon content of the soil and thus remove CO_2 from the atmosphere (Section 3.3.2.5). Corresponding practices can be applied to different kinds of land such as pasture, farmland or even forest land. The IPCC, for example, estimates their potential within a wide range of 0.4–8.64 Gt CO_2 per year (Jia et al., 2019:192); even higher estimates of the potential are sometimes found in the literature (Table 3.1-1). Soil carbon sequestration not only contributes to binding atmospheric CO_2 in the soil, it also improves overall soil quality and health, i.e. soil nutrient richness, and reduces its susceptibility to erosion (Smith et al., 2019a: 264).

The most commonly discussed biological-technical approaches include BECCS, biochar application to soils, and enhanced weathering. *BECCS, or bioenergy with CCS* (Box 3.5-3), uses technical processes to capture CO_2 from the emissions released during the use of biomass for heat or electricity generation and store it in geological formations (carbon dioxide capture and storage, CCS). In extreme cases, (technical) estimates of BECCS's potential can reach up to about 85 Gt CO_2 per year (Table 3.1-1), but are considerably lower when targets for sustainable development are taken into account. According to the IPCC, between 0.4 and about 12 Gt CO_2 per year is a realistic range (Jia et al., 2019:193); Fuss et al. (2018) limit the sustainable

Table 3.1-1
Overview of examples of different land-based CO_2-removal methods based on Fuss et al. (2018). Data on potential and costs correspond to the authors' estimates in the overview study; the data in square brackets reflect the full range of estimates from the literature evaluated there. More recent estimates, such as those reported by Smith et al. (2019b) and taken up in part below, expect even greater potential in some cases. However, it is not always clear to what extent socio-economic constraints and sustainability criteria are taken into account in these estimates in the same way as in Fuss et al. (2018).

CO_2-removal method	Annual potential [Gt CO_2/year]	Costs [US$ 2011/t CO_2]	Land-use implications and concomitant effects	Permanence, saturation, upscaling, etc.
BECCS (Bioenergy with Carbon Capture and Storage)	0.5–5 [1–85] (in 2050)	100–200 [15–400]	Positive › Economic development opportunities through technology transfers and integration into biomass production (distribution effects are ambiguous, however) Negative › Climate effects: albedo changes due to biomass cultivation, (in)direct GHG emissions due to induced land-use changes › Land-use conflicts and possible exacerbation of the land-use trilemma: threats to food security (price increases), deforestation and degradation of forests, loss of biodiversity › Possible health effects › Soil and (ground-) water pollution due to increased fertilizer use	› Potentially high permanence of geological storage › Geological deposits limited, but globally sufficient even for 1.5°C scenarios › Main limiting factors are biomass and land: bioenergy potential in the literature 60–1,548 EJ per year (where 1 EJ of bioenergy corresponds to approx. 0.02-0.05 Gt CO_2 of negative emissions) › Upscaling: development of infrastructure for C transport and storage
DACCS (Direct Air Carbon Capture and Storage)	0.5-5 [10–40 in 2100]	100–300 [25–1,000]	Positive › In some cases improvement of indoor air quality (depending on the process) › Only limited direct land-use conflicts Negative › Potential problems with waste and residual materials › Ignorance/uncertainty about environmental effects › (Certain) space requirement › High energy needs (possibly associated with emissions)	› Potentially high permanence when suitable geological storage is available; geological storage capacity sufficient (cf. BECCS) › Upscaling slowed down by high fixed and energy costs for sequestration processes and costs for C transport and storage; primarily dependent on technical progress and/or learning, not on biophysical factors › Currently hardly tested or not tested at all
Afforestation and reforestation (period typically used to distinguish afforestation from reforestation: 50 years)	0.5–3.6 [0.5–7 for 2050; 0.54–12 for 2100]	5–50 [0–240]	Positive › Boosts employment (albeit low-wage and usually seasonal); › possible way of making a living locally › Promotes biodiversity if native and diversified tree species are used (even at the expense of CO_2 storage) › Increases carbon content in the soil › Promotes nutrient richness in the soil and improves water cycles Negative › Land-use conflicts, especially with the food sector (fewer agricultural exports, rising food prices) › Biodiversity losses (in the case of monocultures) › Emissions from direct and indirect land-use changes; › Change in albedo (net effects depend on climate zone)	› Saturation of the storage capacity of forests within decades; limiting factor of the total potential is the availability of suitable land areas, especially in the long term › Vulnerability to human and natural influences, i.e. long-term management still necessary after storage is completed › Critical for impact on climate: whether harvested wood is used for energy or as a material (Box 3.5-3) › Upscaling limited by the speed of tree growth
Enhanced weathering	2–4 [0–100]	50–200 [15–3,460] (high geographical heterogeneity)	Positive › When applied to soils, improves nutrient balance (soil pH rises) › Higher crop/biomass yields Negative › Health hazards due to finely ground (possibly asbestos-containing) rocks, etc. (inhalable sizes) › Rock quarrying and transport, possibly with considerable environmental impact › Direct and indirect land-use change › Influences on aquatic ecosystems (e.g. increase in pH value) › Release of heavy metals › Influence on hydrological soil properties › High energy demand for rock crushing (and transport)	› Saturation of the soil, but basically high stability in the soil (up to geological time periods) › Fertilization effect on biomass growth (possibly complementary with other land-based NETs such as afforestation or BECCS), effects not yet considered in estimates of potential › Large research gaps (no pilot applications under real conditions) and correspondingly great uncertainty about costs, etc.

Biochar	0.5–2 [1–35]	30–120 [10–345]	Positive › Increase in crop yields due to nutrient enrichment of the soil when introduced into the soil (depending, however, on soil type) › Water balance of the soil (less water loss, drought) › Reduction of CH_4 and N_2O emissions from soils › Effects of large-scale application to soils, however, still not fully known Negative › Competition for biomass products or resources › Stimulation of plant growth by biochar can lead to higher susceptibility of plants to insects, pathogens and drought › 'Net climate effects': albedo change (darkening of the surface), but only if applied over a very large area; under certain circumstances, soot aerosols can be released which have warming effects › Possible reduction of air quality due to release of soot aerosols during production and transport	› High stability of the biochar in the soil, time horizon from decades to centuries depending on soil and soil management and natural environment, especially ambient temperature (faster decay at higher temperatures) › Limiting/Critical factor for potential: availability of biomass › High level of uncertainty about potential, costs, side effects due to lack of experience in large-scale applications › (Governance problem: difficult to measure soil carbon, especially in the longer term)
Soil carbon sequestration	2–5 [0.5–11; technical bottom-up potential] for 2050	0–100 [-45–100] (costs basically very context-specific; max. 20% of the potential realizable at negative costs)	Positive › Improved soil quality and resilience › Positive effects on agricultural production › Predominantly positive effects on water and air quality › No land-use changes necessary Negative › Few to none, depending on the process used › Increase in N_2O or CH_4 emissions and release of phosphorus and nitrogen into water cycles possible due to higher nutrient content in soil › Necessary addition of nitrogen and phosphorus to maintain the stoichiometry of organic soil components	› Sequestration potential limited due to saturation (over time), saturation after 10–100 years (new soil equilibrium), depending on soil and climate zone (longer in colder climate zones) › Reversibility of the sink, i.e. management practices must be maintained (and costs borne) even after saturation › Good foundation of knowledge, in many cases directly applicable

potential of BECCS even more to an upper limit of about 5 Gt CO_2 per year (Table 3.1-1). *Biochar*, along with bio-oil and gaseous by-products, is produced from biomass pyrolysis, i.e. the heating and degradation of biomass in the absence of oxygen (Smith et al., 2019a). The carbon contained in the biomass is not released in the process, but is essentially bound in compressed form in the biochar. By incorporating biochar into soils, the soil-carbon content can be increased and thus atmospheric CO_2 can be fixed in the soil. The overall potential of biochar sequestration reported in the literature ranges from 0.03 to 6.6 Gt CO_2eq per year (Smith et al., 2019b:586). Fuss et al., 2018 regard up to 4 Gt CO_2 of sequestration per year as sustainably feasible (Table 3.1-1).

Enhanced weathering aims to speed up the natural but very slow processes of rock weathering and the (bio-) chemical reactions that take place between the atmosphere and rock surfaces through which CO_2 is bound from the air. Targeted rock crushing increases its reactive surface area and thus the CO_2-binding capacity. According to the IPCC, this approach promises a potential of about 0.5 to 4 Gt CO_2 per year (Jia et al., 2019:193). At the same time, spreading the powdered rock onto soils can increase soil quality and thus, for example, improve the productivity of agricultural land or contribute to the restoration of degraded soils (Fuss et al., 2018).

Finally, there is the possibility of direct *sequestration of CO_2* from the air (direct air capture and storage, DACCS) as a purely technical process. In this process, CO_2 is extracted from the atmosphere using technical filters; it is then transported and finally stored in geological formations – either in a gaseous state or in a long-term mineralized form, i.e. by binding it in the rock when it is stored in sufficiently reactive rock strata (Climeworks, 2020). The CO_2 is filtered from the air using chemical sorbents, essentially either liquid chemical solutions or special air filters with a chemical binding effect. Both processes require the subsequent use of (thermal) energy to extract the CO_2 from the chemical binders in pure form (IEA, 2020). The method using liquid chemical solutions is considered more technically advanced, but requires much higher temperatures with a correspondingly higher energy input; it is thus less suitable for modular, smaller-scale plants (Gambhir and Tavoni, 2019; Realmonte et al., 2019). In principle, the challenge lies not so much in the chemical filtration, which has already been used for some time in CO_2-intensive exhaust gases; more of a challenge is designing plants that are able to remove large quantities of CO_2

from the air at a reasonable cost despite the comparatively low concentration of CO_2 in the air. The limits to DACCS's technical potential result from the limited availability of suitable geological storage sites. Limiting factors also result from further open questions, e.g. regarding the progress with technical development to cut costs, suitable locations (depending on infrastructures for transporting CO_2), or the limited capacity for producing the chemical binding agents. Against this background, the scalability of DACCS in particular is considered to be limited (Realmonte et al., 2019; Gambhir and Tavoni, 2019; Bui et al., 2018). This also explains the significantly higher potential that Fuss et al. (2018) expect towards the end of the 21st century compared to 2050 (Table 3.1-1).

Level of development and permanence of the climate-protection effect

Ecosystem-based approaches such as soil carbon sequestration, (re-)afforestation and the restoration of land-based ecosystems in general are among the more mature techniques. They are based on known processes and methods and therefore can already be implemented in many cases today without high technological requirements. Moreover, they are seen as relatively low-cost approaches with potential for high positive ecological and social co-benefits beyond climate protection (Field and March 2017; Griscom et al., 2017; Smith et al., 2019a) that at least do not exacerbate land-use conflicts as outlined in the land-use trilemma (Section 2.2). However, as described, these ecosystem-based approaches tend to have a lower level of annual sequestration potential. It should also be borne in mind that carbon uptake in the biosphere is limited by saturation in many ecosystems (Fuss et al., 2018). Furthermore, as a rule, ecosystem-based approaches involve a greater risk that the stored carbon might be re-released, e.g. via the degradation or destruction of the ecosystems concerned. In the case of carbon accumulation in agricultural soils, for example, the underlying practices of sustainable land use generally need to be maintained even after saturation if the carbon is to remain sequestered in the longer term. Ecosystem-based approaches thus place high demands on the future and long-term stability of institutions and political conditions (Minx et al., 2018:17). Carbon storage in the biosphere, i.e. in forests or soils, is vulnerable not only to human but also to natural influences such as fires, extreme weather events or rising ambient temperatures and thus also to the impacts of ongoing climate change (Jia et al., 2019: 191).

By contrast, biological-technical methods that use natural processes and combine them with technical solutions, e.g. BECCS or the incorporation of biochar into soils, are at an earlier stage of development. As a general rule, their large-scale application and testing still lies in the future, even though the technical components of methods like BECCS are already largely known (Bui et al., 2018). However, the lack of a corresponding (climate-) policy framework means that up to now only individual demonstration plants have been commissioned, as in the case of BECCS (Smith et al., 2019b: 575).

There are even bigger uncertainties and a greater need for development in the case of the direct, purely technical capture of CO_2 from the atmosphere (direct air capture, DAC). Currently, 15 rather small plants are operating worldwide, filtering about 9,000 t of CO_2 from the air per year, mostly for further use, e.g. in industry, rather than for permanent removal from the atmosphere (IEA, 2020).

To some extent, these uncertainties regarding the technical availability of the respective methods are reflected in the ranges of estimates for costs and potential in Table 3.1-1. However, the size of these ranges is also partly due to the fact that different detailed technical procedures lie behind methods such as BECCS and DACCS, or that studies weight the risks of applying the methods differently.

The type of storage is an important factor when it comes to the permanence and resilience of CO_2 storage, and thus the climate impact achieved by the respective biological-technical or technical process. Raising the level of soil-carbon content by spreading biochar is just as vulnerable to externalities as the above-mentioned ecosystem-based approaches. By contrast, the storage of CO_2 in geological formations, as applied in BECCS or DACCS, tends to be regarded as a more resilient approach to storage in the longer term, with definitely large storage potential (Table 3.1-1; Minx et al., 2018:17; Bui et al., 2018:1111ff.). Nevertheless, also the permanence and reliability of geological CO_2 storage depend on both the specific geological situation and the management (Alcalde et al., 2018). Particularly when large volumes of CO_2 are stored in the ground, strict standards should be applied on the reliability of the storage site, because in this case even the gradual seepage of small fractions of the stored CO_2 involves considerable climate risks (WBGU, 2006:78). With regard to the use of geological storage or its feasibility, there are also questions of societal acceptance, at least in some countries such as Germany (IPCC, 2018:326).

Concomitant effects and conflicts relating to the land-use trilemma

Doubts that it will really be possible to remove CO_2 from the atmosphere on a substantial scale in the future stem not only from the lack of technical maturity among many approaches. Rather, many approaches are associated with concomitant effects which, taken together, entail risks for sustainable development. In this context, land-based approaches give rise to new claims to the use of land and its ecosystems, and threaten to provoke and exacerbate conflicts with the goals of biodiversity conservation or food security as outlined in the land-use trilemma (Chapter 2). It is worth noting, however, that some approaches to removing CO_2 from the atmosphere achieve positive concomitant effects in addition to their contribution to climate protection, and can sometimes also help defuse land-use conflicts.

Many methods of CO_2 removal involve negative concomitant effects and/or general risks to sustainable development (Table 3.1-1; Smith et al., 2019a:275f., 2019b). They can reduce the climate impact of CO_2 removal and create environmental or socio-economic trade-offs or conflicts. Moreover, this applies in principle to both ecosystem-based and to the more technology-based approaches. BECCS, afforestation and biochar require large amounts of land if biomass is planted specifically for the purpose (Smith et al., 2016), and this can directly give rise to the kind of conflicts outlined in the trilemma. It is estimated that the annual sequestration of just one tonne of carbon by (re-)afforestation would require about 0.0029 km^2 of forest land; the cumulative removal of about 100 Gt C from the atmosphere over the 21st century would require about 13 million km^2 (Jia et al., 2019:191). The amount of land required can vary greatly according to geographical or climatic location. Estimates of the land intensity of BECCS are 31–58 million ha per Gt CO_2 per year (Roe et al., 2019:821), although in this case, too, the exact requirement will vary greatly depending on the individual case (biomass used, bioenergy technology, etc.).

The climate impact of these approaches also depends on which areas exactly are used for planting trees or other energy crops, i.e. whether carbon-rich soils or ecosystems are converted for afforestation or BECCS and thus ultimately degraded. The release of greenhouse gases or CO_2 on areas of land not directly affected as a result of displacement or adaptation effects (indirect land-use changes) must also be considered in this context (Fuss et al., 2018). The change in surface albedo, i.e. the reflectivity of the land surface, is another relevant factor for the climate impact of BECCS and afforested woodlands. Especially at high latitudes, there is a threat that reflectivity will decline so much that the temperature stabilization achieved by CO_2 removal will be jeopardized by the higher absorption of solar radiation in the surface (Fuss et al., 2018).

The various kinds of competition for use that could be caused by the large land requirements of land-based approaches can have considerable implications for the achievement of international sustainability goals in the context of the land-use trilemma and beyond – especially in relation to biodiversity conservation, food security or traditional bioenergy use (IPBES, 2018:451). Competition with food production in particular can have a considerable distributional impact via rising food prices, thus affecting populations or countries that are already economically disadvantaged (Roe et al., 2019; Fuss et al., 2018). Problems for food security and the protection of biodiversity can also result from the high water consumption of newly afforested woodlands or the cultivation of bioenergy crops for BECCS. The same applies to the use of fertilizers for faster biomass growth, again e.g. in connection with BECCS (Roe et al., 2019). In the case of enhanced weathering, for example, the high energy requirements of rock crushing raise questions about its sustainable feasibility (Smith et al., 2019a:272). There is also uncertainty here with regard to the actual amount of CO_2 binding that can be achieved and the possibility of saturation, but also concerning the possible contamination of water systems and the release of heavy metals (Table 3.1-1; Beerling et al., 2020:

DACCS also requires a large amount of energy, but the general assessment based on current knowledge is that, as a purely technical process, it has a much smaller impact on the land and its ecosystems. One challenge lies in the sustainable handling of the partly toxic components of the chemical binders, their reuse and safe storage. Even though the amount of land required for DACCS itself seems quite limited, the high energy consumption induced by expansion of DACCS could trigger new pressures on the land and land-based ecosystems, since climate-friendly renewable energy is needed to meet energy consumption (Gambhir and Tavoni, 2019). Overall, there is still a considerable need for research to assess more accurately the potential implications of DACCS on sustainable development (Fuss et al., 2018; Gambhir and Tavoni, 2019). Systemic interrelationships should be taken into account as far as possible and the process chains examined as holistically as possible.

The risks and possible negative concomitant effects contrast with positive effects and synergies with ecological or economic objectives (Table 3.1-1). The accumulation of carbon in the soil – whether through changes in the management of the land in question, spreading biochar or improved forest management (Box 3.1-4) – further contributes to nutrient content and more generally to soil quality (Smith et al., 2019a). Similar effects on soil quality can result from spreading rock powder as part of enhanced weathering. (Re) afforestation, too, is associated with multiple positive co-benefits, provided it is adapted to the context and not implemented as monocultures (Smith et al., 2019a:259f.): it helps to stabilize regional water regimes and improve water quality; it also contributes to improving the local climate. (Re)afforestation can benefit (local) biodiversity; it protects against soil erosion and contributes to the nutrient balance of soils. Afforested woods provide new local sources of food and fodder and also open up new livelihood opportunities. Finally, (re)afforestation also supplies wood, a multi-purpose production factor that can replace more climate-damaging materials as a base material and construction material (Section 3.5.3). BECCS, for its part, not only removes CO_2 from the atmosphere, but also simultaneously generates energy (in a climate-friendly way). BECCS also opens up new income opportunities in rural areas, which can also benefit smallholder farms, although this is not certain – like so many of the positive impacts mentioned here (Fuss et al., 2018:13).

When weighing up risks and synergies or negative and positive concomitant effects, it is particularly true of certain ecosystem-based methods of removing CO_2 from the atmosphere, such as soil-carbon sequestration or the restoration of wetlands and forests, that the positive concomitant effects clearly predominate, or that hardly any negative implications are known overall (Smith et al., 2019a:276). In the case of the restoration of ecosystems, its positive concomitant effects and potential to mitigate conflicts relating to the land-use trilemma can sometimes even be dominant in view of its rather limited potential for CO_2 removal. Restoration is examined in greater detail in Section 3.1.3 as a strategy with multiple benefits. As regards the other methods of CO_2 removal, the ratio of positive to negative side effects, and thus the extent to which they can cause or exacerbate land-use conflicts, depends in many cases largely on the scale and implementation of the particular method (Smith et al., 2019a).

Depending on the study or approach, these ecological and societal implications beyond climate protection are included in the assessments of the potential of individual methods and technologies. This applies in particular to the estimates of sustainably achievable potential shown in Table 3.1-1. In the case of (re)afforestation, for example, the consideration of risks relating to the trilemma and other concomitant effects leads to a sustainable potential considerably lower than some extreme scenarios (Box 3.1-1). Other aspects that are included in the estimation of (sustainably) feasible potential are the costs of the respective method and how quickly the respective approach can be scaled up. Information, as provided in Table 3.1-1, on the point in time when a certain annual sequestration potential is expected is therefore relevant. In many cases, the progress still needed in technological development plays a role here – in the case of DACCS, for example, production capacities in the chemical industry (Realmonte et al., 2019) – or, in the case of (re)afforestation, the fact that forests take time to grow and that trees can store different amounts of CO_2 depending on their age (Section 3.1.3.2). Nevertheless, there is a clear overall lack of knowledge about the risks of impending land-use conflicts, concomitant effects, sensible limitations and thus the determination of the sustainable potential of the various methods of CO_2 removal. Determining sustainable potential is challenging not least because it must take into account competing claims to land and terrestrial ecosystems which depend heavily on socio-economic developments that are much more general or go beyond the realm of land use, e.g. the development of mobility behaviour or dietary habits (Hurlbert et al., 2019:687).

In connection with the feasible potential of CO_2 removal, a role can also be played by technical development paths that generate further demand for CO_2 that has been removed from the atmosphere but do not lead to CO_2 being stored. For example, the use of synthetic carbon-based fuels (hydrocarbons) is being discussed to make the transport sector climate-neutral (The Royal Society, 2019). Here, in addition to hydrogen produced with renewable energies, CO_2 that comes, for example, from the direct, technical separation of CO_2 from the atmosphere (direct air capture, DAC) or from biomass is used. Also other industrial applications, which are being discussed under the name of Carbon Capture and Usage (CCU), make use of CO_2 that is extracted from the atmosphere. While such uses of CO_2 obtained from the atmosphere can reduce CO_2 emissions, in many cases they do not permanently remove CO_2 from the atmosphere: in the case of synthetic fuels, the CO_2 is promptly released back into the atmosphere, while in some other uses it is released after a longer period of time (Hepburn et al., 2019). As long as the possibilities of capturing CO_2 from the atmosphere are limited for technical or ecological reasons – due to the lack of availability of DAC and the negative concomitant effects described when ecosystems are over-used – a conflict may therefore arise between the creation of CO_2 sinks and the avoidance of CO_2 emissions with the aid of CCU applications. In particular, where non-carbon-based alternatives to CCU applications will be available in the foreseeable future, e.g. in passenger transport, these alternatives should be pursued and the priority should be to remove the CO_2 extracted from the atmosphere as permanently as possible. Technological breakthroughs in direct CO_2 capture from the atmosphere could expand the scope of CCU and reduce the need for such prioritization. However, even then safeguards should be introduced to make sure that the expansion of CCU does not increase the pressure of use on land-based ecosystems.

The use of a broader portfolio of atmospheric CO_2-removal methods can be a possible strategy for achieving substantial amounts of negative emissions without causing too much conflict in the sense of the land-use trilemma, while maximizing positive side effects and synergies between individual CO_2-removal methods. However, there is also still a considerable need for research into the limits of this multi-pronged strategy and the most suitable combinations, as there is still very limited knowledge of synergies and trade-offs between the different methods. The types of potential shown in Table 3.1-1 should not be generally assumed to be additive, since, for example, there may be competition for land use, e.g. between BECCS, afforestation and biochar, or for geological storage capacity, e.g. between DACCS and BECCS (Smith et al., 2019a:275f.; Hilaire et al., 2019). Conversely, positive synergies might result from the combined application of biochar or enhanced weathering with soil-carbon sequestration practices, for example (Smith et al., 2019a: 277).

3.1.1.3
The role of CO_2-removal methods in climate-change-mitigation scenarios

The IPCC's scenario analyses for the implementation of the Paris Agreement targets (IPCC, 2018) have brought the removal of CO_2 from the atmosphere back into the public debate, after they were scientifically discussed at an early stage and integrated into fundamental 'integrated assessment models' (IAMs) (Fuss et al., 2014; Minx et al., 2018). With the help of scenarios, IAMs are used to explore the space of possibility for future developments, depending on human actions. These are not forecasts in the sense of real developments regarded as probable. The models assume socio-economic development paths (e.g. different assumptions on urbanization, population and economic growth) and scientific and technical framework conditions (e.g. geophysical cycles and the maturity of diverse technologies) and then derive possible emission or climate-change-mitigation paths while minimizing the overall costs of climate protection. Therefore, it is not only geophysical restrictions or necessities for reaching certain climate-policy targets that determine the use of CO_2-removal methods in the models, but also economic motives regarding trade-offs between the costs of different climate-protection options and their use over time. For reasons of simplicity, many IAM analyses in the past have only considered and explicitly modelled two methods of CO_2 removal: BECCS and, to a lesser extent, (re)afforestation. In the meantime, however, analyses are available that also consider DACCS, for example, as an additional method of CO_2 removal (Realmonte et al., 2019).

The inclusion of CO_2-removal methods, and also the additional consideration of DACCS, had/has a moderating effect on costs in many scenarios (Realmonte et al., 2019). Two effects are relevant here. Depending on the assumptions made about the costs and potential of the individual technologies, the option of CO_2 removal extends the portfolio of (more cost-effective) climate-change-mitigation options. This enables the models to bypass the use of especially expensive climate-change-mitigation measures, e.g. emissions reductions in sectors such as air or freight transport or parts of the agricultural sector, which are generally considered to be difficult to decarbonize (Luderer et al., 2018; Geden and Schenuit, 2020) (intersectoral compensation, Fuss et al., 2018:3). At the same time, CO_2 removal increases temporal flexibility in the deployment of climate-change-mitigation measures. In the models, effective and correspondingly costly climate-change-mitigation measures can be postponed in this way in the short term, while the relevant carbon budgets can still be met by removing CO_2 from the atmosphere at a later date (intertemporal compensation, Fuss et al., 2018:3). This shift in the timing of climate-change-mitigation efforts has a cost-cutting effect, particularly since discounting future costs gives more expensive measures less weight in the overall cost picture if they are used in the future (Minx et al., 2018; Hilaire et al., 2019).

Based on current knowledge and available scenario analyses, limiting global warming to (well) below 2°C above the pre-industrial era, as envisaged in the Paris Agreement, appears to be very difficult without the help of CO_2 removal from the atmosphere – and limiting warming to 1.5°C even seems out of the question (IPCC, 2018). This conclusion is especially true if no overshoot, or at least only a limited overshoot, of temperature above the respective temperature target is allowed over the course of the 21st century (Minx et al., 2018; Fuss et al., 2018).

However, the scope and temporal development path of CO_2-removal methods in the scenarios differ, in some cases considerably, depending on the envisaged temperature goal. In the 1.5°C scenarios in particular, the IAMs rely to a substantial degree on CO_2 removal, in some cases calling for the removal of more than 1,100 Gt of CO_2 from the atmosphere in the course of the 21st century (Fuss et al., 2018:4). This would remove nearly half of all historical CO_2 emissions between 1850 and 2018 from the atmosphere (based on Friedlingstein et al., 2019). In the corresponding scenarios, CO_2-removal approaches are being scaled up early and rapidly (0.06–0.8 Gt CO2 annually between 2030 and 2050 and 1–16

Box 3.1-1

Excursus: extreme scenario

In an extreme scenario, Bastin et al. (2019) explored the question of how much CO_2 could be removed from the atmosphere if trees were planted everywhere in the world where areas of land are not already being used for agriculture or settlements. The study estimated the global technical potential for carbon uptake by terrestrial ecosystems through afforestation and reforestation to be 205 Gt C (corresponding to about 750 Gt CO_2), for which the authors estimate that an additional 0.9 billion hectares would have to be afforested or reforested. This corresponds to an area almost the size of Brazil.

Numerous authors attest that the study overestimates the global potential of afforestation and reforestation for the removal of CO_2 from the atmosphere by a factor of between three and five. The following weak points are cited (Veldman et al., 2019; Friedlingstein et al., 2019; Skidmore et al., 2019; Lewis et al., 2019 and Rahmstorf, 2019):

- The gains in soil carbon due to forestation were overestimated by a factor of 2.
- The authors did not take into account the warming effects resulting from the decrease in surface back radiation (albedo) in the course of afforestation and reforestation, especially in the boreal zones of Alaska, Canada, Finland and Siberia identified by the authors as being particularly suitable. Accelerated warming of Arctic permafrost soils would be devastating: permafrost soils store more carbon than all the Earth's forests combined (Rahmstorf, 2019).
- The model included large areas of biodiversity-rich grassland ecosystems and mistakenly called the afforestation of these areas 'restoration'.
- The potential gains in soil carbon were overestimated by nearly 100 Gt C because it was incorrectly assumed that grassland ecosystems do not contain soil organic carbon. In fact, grassland ecosystems contain some of the highest soil-carbon stocks of any land used by humans (National Academy of Sciences, Engineering, and Medicine, 2019: 101). In most terrestrial ecosystems, the contribution of soil carbon to total carbon stocks is very significant.
- Furthermore, the study by Bastin et al. (2019) also classified tree populations in grassland ecosystems as degraded and thus in need of restoration if they exhibited lower densities than the model. However, restoration measures in grassland ecosystems rarely involve afforestation; instead, the biodiversity and ecosystem services of this landscape type are often restored or maintained by cutting back and targeted burning.

Gt CO_2 annually after 2050; Minx et al., 2018). Nevertheless, rapid and strong reductions in CO_2 emissions of 3–7% per year remain necessary before net zero emissions can be achieved around the year 2050. Furthermore, in many of these scenarios there is a temporary overshoot not only of the permitted CO_2 budget but also of the 1.5°C temperature goal (Fuss et al., 2018:3).

By contrast to 1.5°C scenarios, for a 2°C temperature limit IAMs also describe pathways with greatly reduced CO_2 removal or none at all. Driven by economic motives of cost reduction, however, CO_2 removal nevertheless finds application in the vast majority of 2°C scenarios (Hilaire et al., 2019:4), sometimes on a considerable scale with an annual removal of 5–21 Gt CO_2 towards the end of the century (Fuss et al., 2018:6) and a cumulative removal of 320–480 Gt CO_2 (Minx et al., 2018:13). Compared to the 1.5°C scenarios, this involves a slower expansion of CO_2 removal up to 2050 (0.03–0.4 Gt CO_2 per year between 2030 and 2050, Minx et al., 2018:13) and generally a later transition to a net negative emissions balance in the second half of the 21st century.

In addition to the climate-policy goals, two other aspects in the scenarios prove to be particularly decisive for the use and scope of CO_2 removal. Firstly, the assumptions made about the potential for early ambitious emissions reductions are a critical driver. Delaying effective climate-change-mitigation efforts or the global emissions peak until 2030 (or even beyond) drastically narrows the scope for limiting or avoiding the use of CO_2 removal in the scenarios. The 2°C scenarios then also draw on CO_2-removal options throughout, and in a similarly rapid and large-scale manner as the 1.5°C scenarios (Hilaire et al., 2019:16). Secondly, as mentioned above, the underlying general socio-economic development paths have a strong influence: scenarios that assume more sustainable global development paths – characterized, for example, by a higher worldwide level of education, a higher degree of urbanization, lower inequalities and a smaller world population – generally envisage the removal of CO_2 on a much smaller scale than scenarios that essentially perpetuate today's development patterns, in particular because of the lower global demand for energy that would then occur (Minx et al., 2018:17; Fuss et al., 2018:7-8). The use and scaling of CO_2 removal in the scenarios are thus not only the result of climate policy but of many broader policy areas.

In view of the uncertainties and risks discussed above of various methods for removing CO_2 from the atmosphere, it should be emphasized that even 1.5°C scenarios with a greatly reduced use of CO_2 removal are possible in the IAMs in case stringent climate policies are accelerated in the sense of rapid emissions reductions, and accompanied by a shift towards more sustainable development paths (Roe et al., 2019). Recent scenario calculations show that by making even more drastic reductions in energy consumption and changes in (consumption) behaviour than mentioned above, climate change could be limited to 1.5°C warming with a cumulative removal of about 100 Gt CO_2 over the 21st century with the help of (re-)afforestation alone and without BECCS (Grubler et al., 2018). However, the socio-economic, societal challenges of such a policy should not be underestimated (Rickels et al., 2019:149f.).

There are certainly doubts as to the feasibility of really achieving the total volume or expansion rates of CO_2 removal stated in some climate-change-mitigation scenarios (Field and March, 2017; Lenzi, 2018). Indeed, both the in-some-cases extremely ambitious expansion of removal capacity by the middle of this century and the annual target of 20 Gt CO_2 or more in the second half of the 21st century – which would mean doubling the current uptake of CO_2 by the terrestrial biosphere – look highly uncertain, bearing in mind the previous discussion on the state of technological development, scalability problems and the fact that the potential that is sustainably realizable is limited overall.

It looks unlikely that such large amounts of CO_2 can be removed sustainably by means of BECCS and afforestation alone. Such a large-scale expansion of these land-based CO_2-removal methods would mean changing land use or transforming the land system at a historically unprecedented speed and on an unprecedented scale (Jia et al., 2019:195ff.). The risks this poses for the management of land and land-based ecosystems are qualitatively named in several scenario analyses. For example, in the context of possible climate-change-mitigation pathways in a 1.5°C world, the IPCC warns of the negative sustainability implications of a very large-scale deployment of atmospheric CO_2-removal methods (IPCC, 2018:124f.). Furthermore, many IAMs also take into account ecosystem-protection requirements in protected areas and socio-economic constraints such as ensuring food supplies. Up to now however, possible trade-offs with various sustainability aspects are only partially reflected in the models. For example, many of the ambitious mitigation scenarios envisage a considerable reduction in globally available agricultural land in the course of the 21st century; the negative implications for fodder and food production would have to be offset by agricultural intensification and behavioural changes. However, the scenarios address neither the societal issues that are raised concerning the acceptance of these changes and distributional impacts, nor the question of suitable governance (Jia et al., 2019: 197).

IAMs give an important impression of the theoretically possible or necessary role of CO_2 removal from the atmosphere for the implementation of certain climate-policy goals and make it possible to consistently identify framework conditions or climate-policy levers that significantly influence the use of CO_2-removal methods. However, the individual costs and risks occurring within the scenarios (e.g. from emissions reductions or CO_2 removal) are no longer visible in a mere comparison of the total costs of different climate-change-mitigation paths. Different paths may therefore differ substantially in terms of the risks they involve (and their intertemporal distribution), without this being immediately apparent from the scenarios. For example, emissions-mitigation measures are typically delayed in the short to medium term in IAMs once CO_2-removal methods are integrated (Hilaire et al., 2019). As already mentioned, this serves the desired purpose of reducing overall costs by discounting future costs. However, as an idea for the design of a climate-policy strategy, this involves the danger of taking a risky bet on the future – which is often discussed under the heading of 'moral hazard'. After all, it is still uncertain whether sufficient options for removing CO_2 from the atmosphere will still be available and sustainably feasible in the future, as well as whether the removal will be permanent (Minx et al., 2018; Lenzi, 2018).

Gaining a better understanding of the large-scale deployment of atmospheric CO_2-removal measures that occur in IAMs therefore seems to be particularly relevant for research policy (Hilaire et al., 2019). The choice of an appropriate discount rate in the models plays an important role in this context (Emmerling et al., 2019). The general analytical approach of the models should also be examined with regard to the way they take factors of technological, environmental and societal risks and uncertainties into consideration. For example, the focus on the most cost-effective implementation of climate-policy targets at the end of the 21st century does not sufficiently take into account the risks of different emission pathways resulting from possible climatic changes in the course of the 21st century (Hilaire et al., 2019). One of the reasons is that these climatic changes themselves influence the potential for CO_2 removal, e.g. in forests (Erb et al., 2018; Sohngen, 2020).

3.1.2
Principles of sustainable CO_2 removal: highlight uncertainties, limit risks, stimulate multiple benefits

Reaching the goals of the Paris Agreement hardly seems feasible any more without removing CO_2 from the atmosphere. The discrepancy is now too great between the global emission trends, which are still moving in the wrong direction, and what would be needed to limit global warming to well below 2°C. In any case, an absolute prerequisite for limiting climate change is a rapid peaking of global CO_2 emissions, followed by maximum

Box 3.1-2

Digitally supported and continuously updated monitoring of land stewardship

Monitoring is understood here as the systematic observation of objects, processes or surroundings with regard to e.g. their properties, behaviour or compliance with threshold limits. It is important for all multiple-benefit strategies and essential, in particular, for documenting the condition of soils and land areas as well as biodiversity (Box 3.2-2). Digital technologies enable larger-scale and faster observation, even including real-time representation (WBGU, 2019b; Section 3.3.5.1). Electronic devices have become much more powerful, smaller, lighter and cheaper in recent years, making it possible to use them in new, efficient ways for biodiversity monitoring (Bush et al., 2017; Snaddon et al., 2013). Valuable contributions are made here by digitally supported monitoring systems in combination with remote sensing and in-situ sensors (e.g. camera traps, GPS trackers, acoustic recorders, smartphones, DNS barcoding; Turner, 2014). Remote sensing as "contactless information gathering, i.e. recording, measurement or analysis without physical contact with the object to be observed" (Kuechly et al., 2020:4) can be carried out by satellites, from flying or floating platforms such as drones, or from the ground.

In the field of satellite-based remote sensing, the Copernicus Land Monitoring Service (CLMS), which has been operated since 2012 by the European Environment Agency and the Directorate-General of the European Commission's Joint Research Centre (JRC), provides free and open access to information on land cover and land use. The data products made available for land-surface monitoring are based on satellite measurements and in-situ data. They document the status of and changes in land cover, land use, vegetation status as well as water and energy flows in three application scales (global, pan-European and local) and in different temporal resolutions. The CLMS's main components relevant to this report's topic include the mapping and classification of land cover and land use (i.e. products(?) recording tree cover and grassland) and the systematic monitoring of biophysical parameters in long-term time series for the surveillance of vegetation, water and energy flows (land.copernicus.eu).

The Copernicus service 'Sentinel-2 Global Mosaic' (S2GM, s2gm.sentinel-hub.com) provides tailor-made monitoring data for the UN REDD+ initiative (Box 3.1-6). These are currently already being pre-processed for several REDD+ regions (Tanzania, Kenya, Congo, Indonesia, Cambodia, Laos, Myanmar, Vietnam, Thailand, Brazil) (land.copernicus.eu/imagery-in-situ/global-image-mosaics/node/24). REDD+ also benefitted from the Horizon 2020 project EOMonDis (eomondis.info) conducted from 2016 to 2019 to research satellite-based services for the dynamic monitoring of biomass and the spread and condition or degradation of tropical forests (Figure 3.1-1).

Furthermore, the Horizon 2020 project REDDCopernicus (reddcopernicus.info) for sustainable forest management through satellite-based European Earth observation, which runs until 2021, aims to implement coordinated and consolidated forest monitoring as part of a 'European Capacity for Earth Observation Based Forest Monitoring' (EO FM) in REDD+. As well as involving a broad range of stakeholders, the aim is to solve both institutional and technical challenges. The pan-European High Resolution Layer Forest was discussed at the project's stakeholder workshop as a prototype for the planned Copernicus REDD+ service component (Figure 3.1-2).

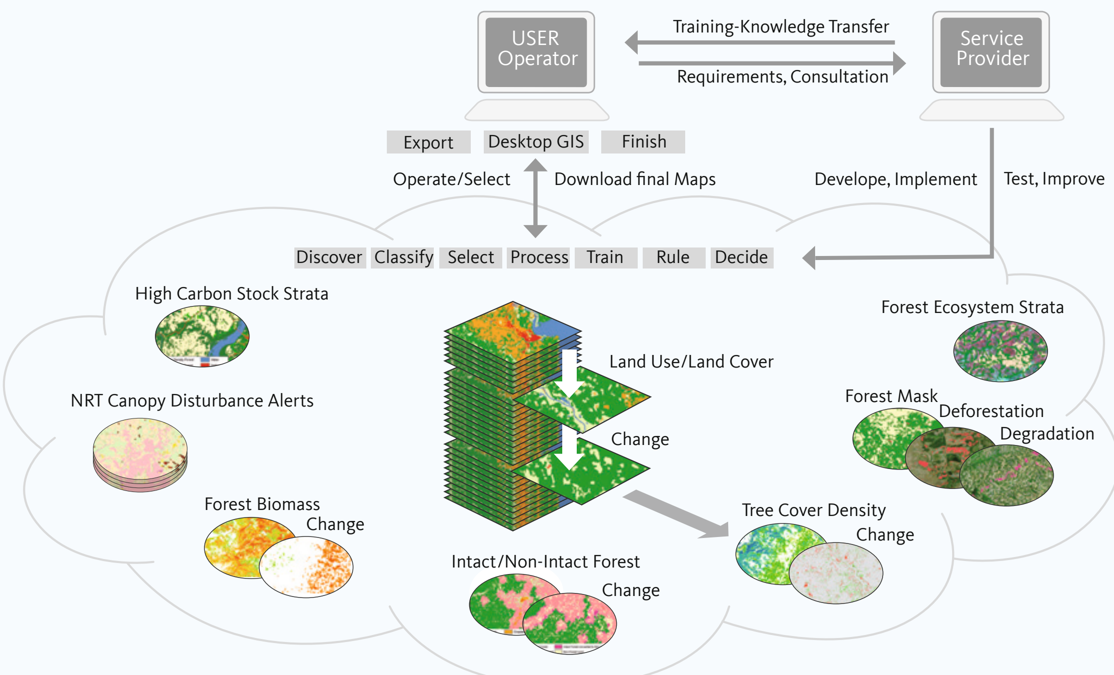


Figure 3.1-1
Components of the portfolio of the EOMonDis project (Bringing Earth Observation Services for Monitoring Dynamic Forest Disturbances to the Users).
Source: GAF AG, 2020:3

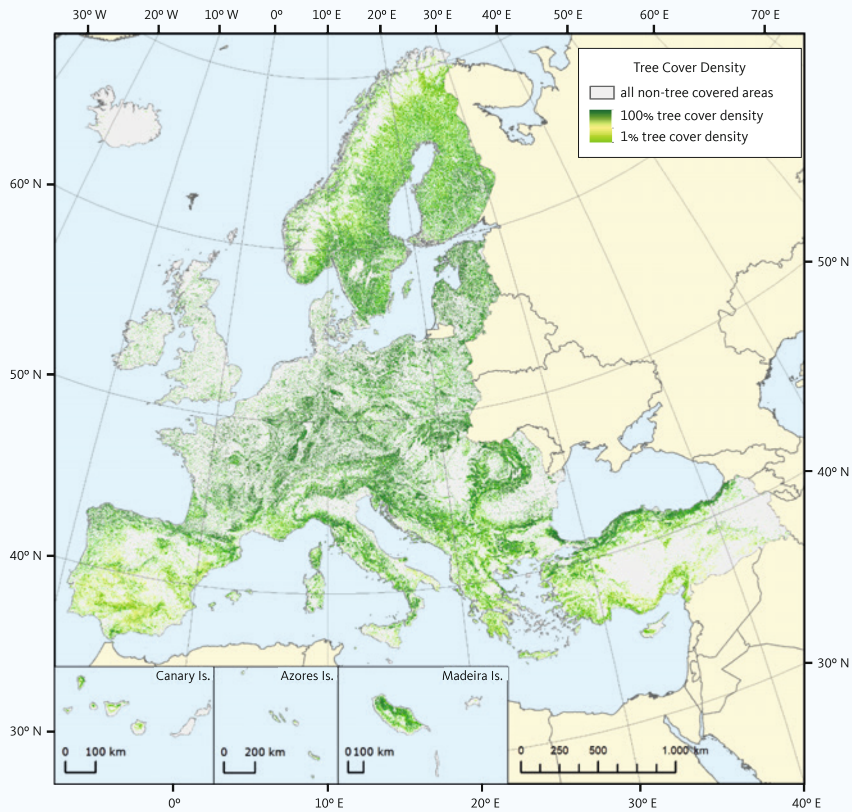


Figure 3.1-2
Pan-European illustration of tree cover density. Source: ©European Union, Copernicus Land Monitoring Service 2018, European Environment Agency (EEA). Produced by GAF AG with funding from the European Union.

Satellite data can also be evaluated using machine learning (WBGU, 2019b; Section 3.3) for a wide variety of monitoring applications such as forest-fire damage (Hawbaker et al., 2020), the cartographic classification of different land uses (Preidl et al., 2020) or for analysing soil degradation (Zweifel et al., 2019). The condition of cereal crops, even including crop damage detection, can also be analysed and evaluated in near real-time thanks to the availability of high-quality satellite data (Chauhan et al., 2020). Beyond academic research, a large number of public and private institutions, together with the FAO, have developed several freely usable open-source tools with 'Open Foris' as part of the 'e-agriculture' project (fao.org/e-agriculture), including 'Sepal' (System for earth observations, data access, processing & analysis for land monitoring; sepal.io). It gives users fast and efficient access to satellite data (historical and current from Landsat and Copernicus) as well as customized analyses according to local needs, using cloud-based high-performance computing and modern geodata infrastructure.

In summary, digitalization enables the permanent evaluation of remote monitoring data which is available at an unprecedented level and thus allows a new quality of monitoring sustainable land use – from research to application on the ground. Despite major progress in recent years and considerable potential for governance in the context of e.g. REDD+ (Box 3.1-6), material infrastructure apart from satellites is also needed on Earth to store and process the incoming data. Sustainable design (WBGU, 2019b) is essential here because if artificial intelligence or machine learning is used, for example, then its methodological quality and energy consumption can not only be reflected upon but also systematically optimized (WBGU, 2019b; Henderson et al., 2020: 13). Independent of this, comprehensive, international monitoring of ecosystems and land-use dynamics is coming within reach, which is also relevant for improved SDG indicators. As the projects cited in connection with Copernicus and REDD+ show, however, implementation as a governance instrument is not a purely technical matter; it is ultimately also a question of political objectives and realization (Chapter 4).

decarbonization by the middle of the century. If there is no trend reversal soon, this can no longer be compensated by removing CO_2 from the atmosphere.

On the basis of the problem analysis in Section 3.1.1, principles can be derived that should provide guidance for researching and implementing a wide range of approaches to creating sustainable CO_2 sinks. The above-mentioned high expectations, complex risks and considerable uncertainties make this seem particularly important, and it can contribute towards a science-based classification of the debate on the potential of CO_2-removal measures. The principles aim at an appropriate management of the multiple risks of climate change, of reliance on the future removal of CO_2 from the atmosphere, and of a large-scale application of corresponding approaches, especially with regard to the possible conflicts relating to the land-use trilemma (Section 2.2): any sustainable removal of CO_2 from the atmosphere for the purpose of mitigating climate change and limiting its risks should promote rather than hinder the protection of biodiversity and food security. The principles are also geared towards the overarching goals for land stewardship in the context of a Great Transformation towards Sustainability (Chapter 2).

- The creation of new sinks should be researched and designed in the light of the multifunctionality of land and ecosystems. The land requirements and ecological side-effects of land-based methods for removing CO_2 from the atmosphere – such as BECCS, afforestation and ecosystem restoration – should be considered and designed with a view to usage priorities and other sustainability goals such as food production and biodiversity protection. The many uncertainties that exist in this context should be examined and technical and systemic risks identified as early as possible.
- The role of removing CO_2 from the atmosphere to comply with the Paris Agreement should not be underestimated, but efforts to remove CO_2 from the atmosphere must not lead to a delay in decarbonization – something which is often criticized under the heading 'moral hazard'. In the WBGU's view, in the light of the risks of climate change, the precautionary principle suggests reinforcing research into and the development of approaches to the sustainable implementation of CO_2 removal. This precludes following the ostensibly positive role model of climate-change-mitigation scenarios with large-scale CO_2 removal and delaying safe climate-change-mitigation measures based on a blind faith in the future removal of CO_2 from the atmosphere. This would create new path dependencies and increase dependence on CO_2-removal methods. As has regularly been the case in climate policy up to now, the risk of such a bet on the future would be borne by future generations and, in particular, by vulnerable population groups. If negative emissions cannot be realized on the scale that would then be required, or can only be achieved by causing severe land competition and high negative concomitant effects, people in the future will be forced to choose between the evil of more drastic climate impacts and the dramatic concomitant effects of CO_2-removal methods that can lead in a similar way e.g. to food shortages or biodiversity loss (Minx et al., 2018; Lenzi, 2018).
- In the WBGU's view, CO_2-removal methods should be considered and established as a third, complementary approach in climate policy alongside mitigation and adaptation. This can help to ensure that, in the design of a future necessary governance of CO_2 removal, research and development policy does not set false incentives for CO_2-removal methods that crowd out options for avoiding emissions that are already available today. For on the one hand, as described, rapid global decarbonization remains necessary even with large-scale future CO_2 removal, in order to achieve the climate-protection goals of the Paris Agreement. On the other, methods of removing CO_2 from the atmosphere are fraught with their own risks to climate protection and sustainable development, especially also with a view to possible competition as outlined in the land-use trilemma. However, the fundamental qualitative difference that argues in favour of a clear distinction between CO_2 removal and avoiding CO_2 emissions is based on the permanence of their climate impact: the removal and storage of CO_2 is subject to a reversibility risk, especially in the longer term, and this risk is often beyond human control. Its long-term climate impact is thus more uncertain than avoiding emissions (Hurlbert et al., 2019:686). Eliminating disincentives that crowd out emissions avoidance is also key because of the fundamental uncertainty that exists regarding potential geophysical limits to the use of CO_2-removal methods to mitigate climate change (Fuss et al., 2018:3). For example, it is scientifically disputed whether and to what extent warming can be stabilized again in the longer term with the help of CO_2 removal at a lower temperature level after a temperature limit, in particular the 2°C guard rail, has been exceeded (Steffen et al., 2018); irreversible climate impacts will persist even if a 1.5°C temperature overshoot is reversed in the future (IPCC, 2018).
- The inclusion of local population groups in decision-making and processes to create new CO_2 sinks via land-use changes must be assured. Since such changes in land stewardship are often accompanied by risks for the land users – and they are often among the most vulnerable groups, especially in the case of subsistence farmers and indigenous groups – their voluntary, prior and well-informed consent and participation is indispensable. The long-term success of the measures and strategies is also highly uncertain without local acceptance.
- When creating new sinks, the focus should be on measures and strategies that exploit numerous co-benefits and minimize risks rather than on maximum climate-change mitigation. At the same time, this overarching concept of risk minimization (in the sense of consistent consideration of the precautionary principle in the design of climate-policy strategies) brings to the fore those climate-change-mitigation scenarios and framework conditions that limit the use of CO_2-removal methods as far as possible, even

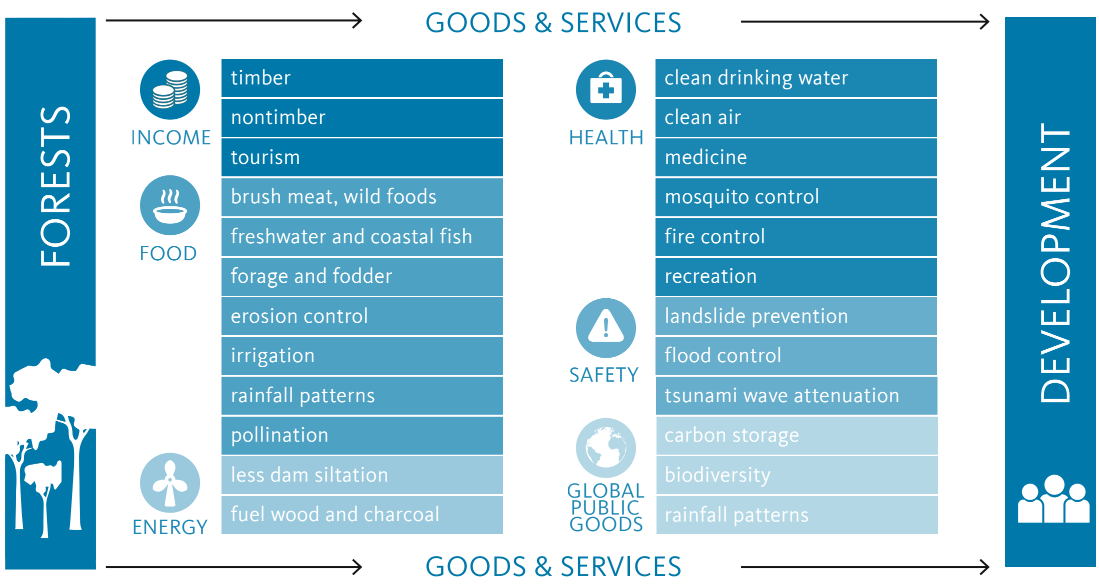


Figure 3.1-3
Contributions of forests to development and human well-being.
Source: Hanson et al., 2019

though the rapid decarbonization of the global economy required by this within the next few decades will undoubtedly involve its own major challenges (Rickels et al., 2019:149f.). Positive co-benefits and/or considerable ecological and social multiple benefits can be found particularly in approaches to creating land- or ecosystem-based sinks (Field and Mach, 2017; Griscom et al., 2017). In addition to a contribution to climate-change-mitigation that should not be neglected, these can also result in real multiple benefits in terms of the land-use trilemma. Higher carbon sequestration in soils, for example, can be a key contribution of ecological agricultural practices (Section 3.3). Better management of degraded protected-area systems (Section 3.2) or the ecological restoration of degraded areas (Section 3.1.3) regenerate lost natural carbon reservoirs, and bioeconomic approaches such as timber-based construction can replace emissions-intensive materials such as concrete and steel (Section 3.5).

› The broadest possible portfolio of approaches to removing CO_2 from the atmosphere should be pursued in research and development, and the competition and synergies within such a portfolio should be identified and exploited accordingly. Since, not least, many risks and negative concomitant effects depend on the scale of the individual method of CO_2 removal, the WBGU sees great potential in such a multi-pronged approach, which combines diverse measures and scales while strengthening ecological and cultural diversity.

Strategies of climate policy that take these principles into account recognize that the goals of the Paris Agreement are unlikely to be achieved without removing CO_2 from the atmosphere. At the same time, however, these strategies limit the risks of climate change, should it prove impossible to achieve CO_2 removal on a sufficient scale in the future. They also make it possible to circumvent the risks and negative side-effects of comprehensive CO_2 removal that relies on just a small number of methods, or at least to reduce them to an extent that accentuates the positive side-effects of the various approaches to CO_2 removal and thus the multiple benefits apart from climate protection. In this sense, near-nature, ecosystem-based methods that can be implemented directly are already available today. If implemented prudently with low risks, these methods not only contribute to protecting the climate but also promise substantial multiple benefits. In the following section, the WBGU takes a more in-depth look at such a value-added strategy: the restoration of degraded terrestrial ecosystems.

3.1.3 Multi-benefit strategy: restoration of degraded terrestrial ecosystems

Among the various approaches to removing CO_2 from the atmosphere, some of which are still under development, the restoration of degraded ecosystems such as forests, grasslands or peatlands is not only already

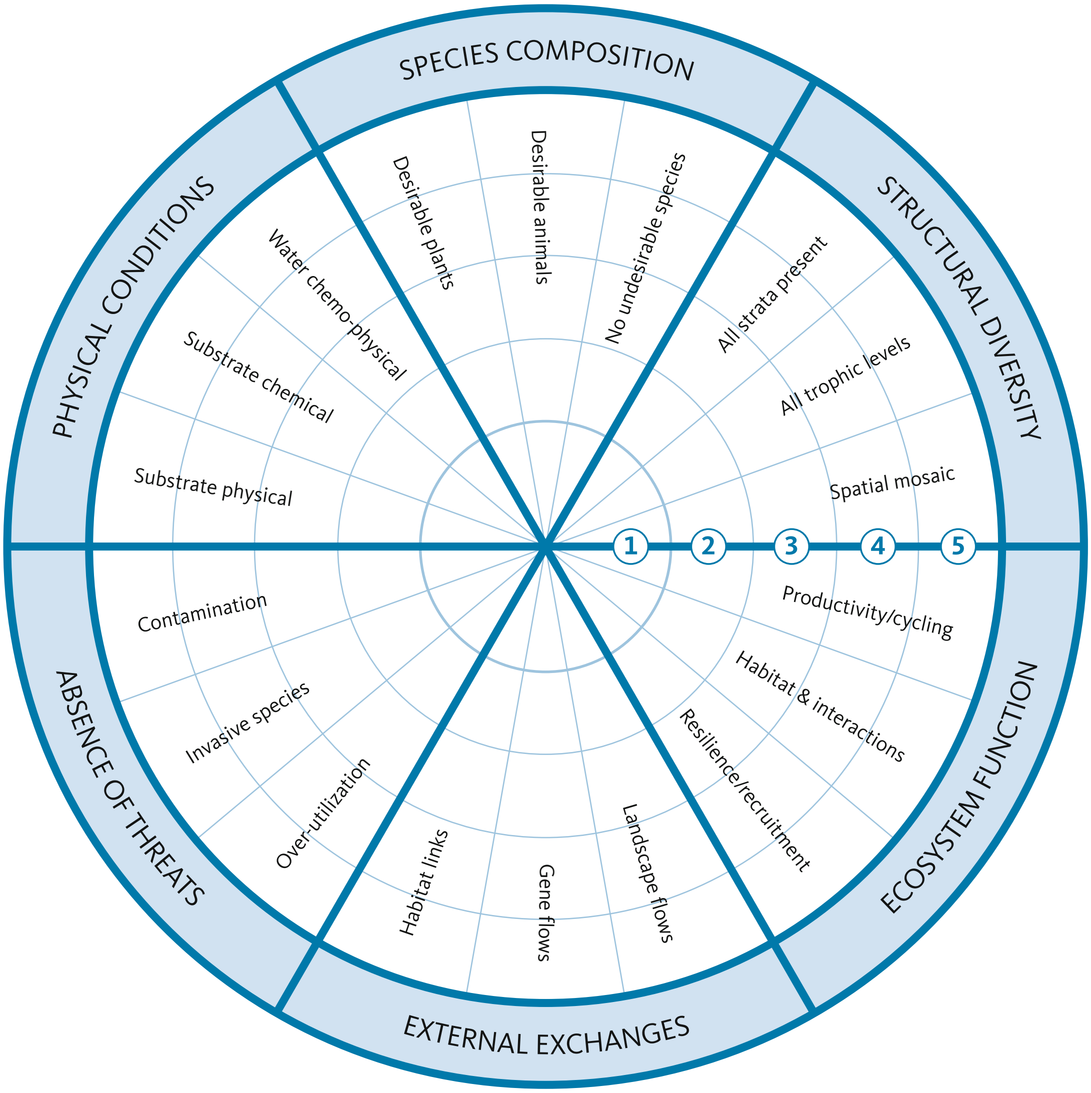


Figure 3.1-4
Template for determining the degree of recovery reached by an ecosystem.
Exchange between landscapes: exchange that occurs on a level larger than individual ecosystems or sites and includes flows of energy, water, fire and genes. The exchange is facilitated by habitat linkages. Productivity: the rate of biomass production from the growth and reproduction of plants and animals. Offspring of species: production of a subsequent generation of organisms. Layer, layers: vegetation layer or layers in an ecosystem; often refers to vertical layering involving e.g. trees, shrubs and perennial layers. Trophic levels: stages in food webs (e.g. producers, herbivores, predators and decomposers). Overuse: any form of harvesting or use of an ecosystem that goes beyond its capacity to regenerate those resources (e.g. overgrazing). Substrate: the soil, sand, rock, shells, rubble or other medium on which organisms grow and ecosystems develop. 1–5 = degree of target achievement.
Source: Gann et al., 2019

available and tested today, it is also a comparatively low-risk and relatively low-cost strategy, especially in the context of the land-use trilemma. Furthermore, restoration looks not only at the creation of sinks for CO_2 but rather at their limitations. Restoration cannot achieve the kind of large-scale CO_2 removal from the atmosphere that is called for in some climate-change-mitigation scenarios and would be necessary particularly if the reduction of global CO_2 emissions were further delayed (Section 3.1.1). Rather, restoration is *a priori* oriented towards a bundle of multiple benefits in the sense of rehabilitation or strengthening ecosystem services (Chapter 2), of which CO_2 removal from the atmosphere represents only one part. The WBGU therefore proposes restoration as an ecosystem-based approach which is made especially convincing by its multiple benefits and low risks. However, these possible multiple benefits of restoration can only be realized if increased restoration efforts are backed up by a considerable increase in efforts to cut global CO_2 emissions.

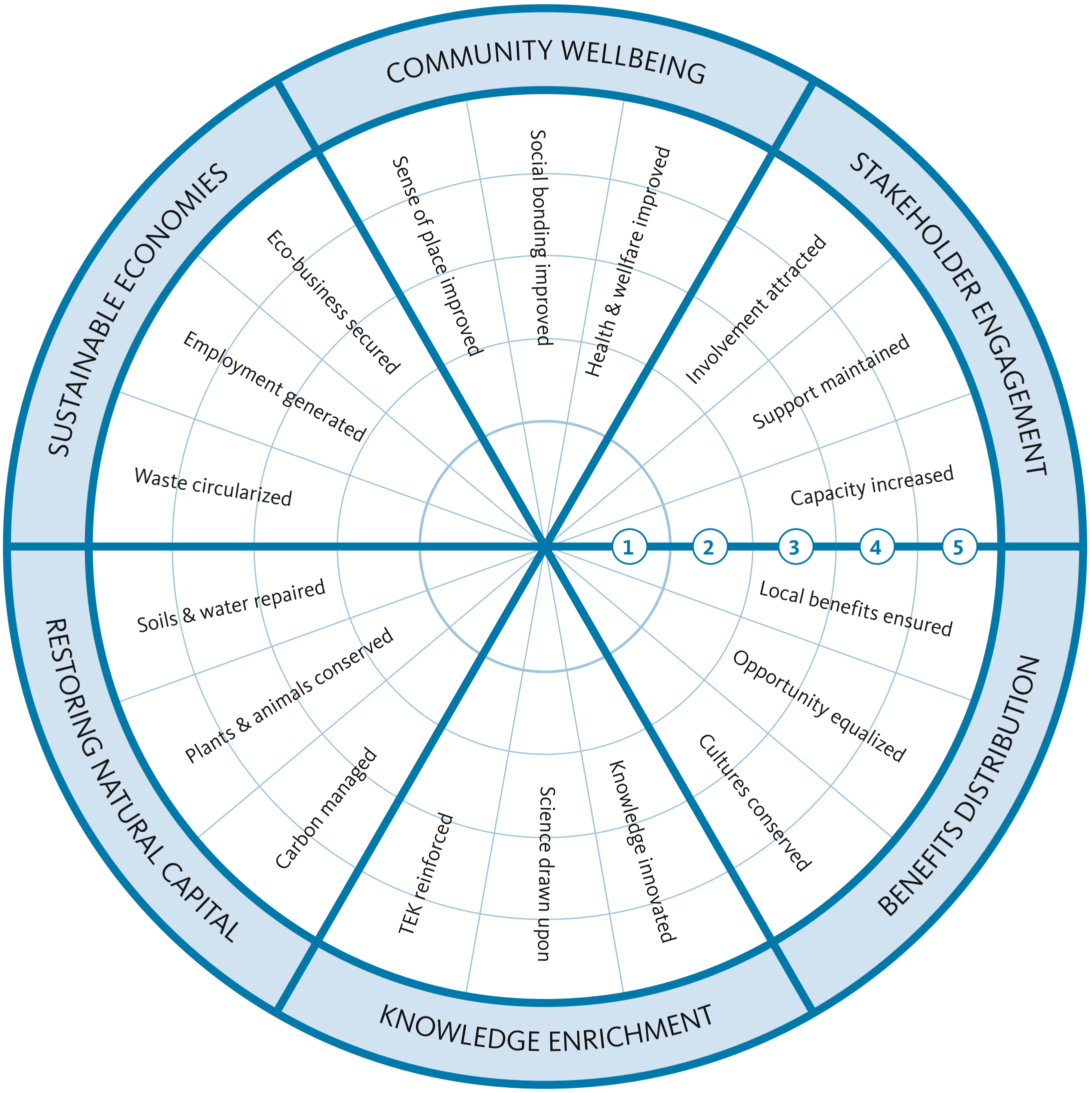


Figure 3.1-5
Template for surveying socio-economic concomitant benefits from restoration measures.
Source: Gann et al., 2019

The synergistic potential of restoration measures is of outstanding importance for the protection of humanity's natural life-support systems – a fact that is reflected in the UN Decade (2021–2030) on this topic. The restoration of degraded ecosystems is furthermore an elementary component of the CBD's Aichi Targets 14 and 15; it is also an integral concept in the UNCCD, the UNFCCC, the Ramsar Convention and the SDGs (goals 15 on ecosystems, 15.3 on land degradation neutrality, and the goals on poverty, food security, health, water and sanitation infrastructure).

3.1.3.1
Restoration as a strategy for revitalizing ecosystem functions

Restoration is a measure aimed at enabling the substantial recovery or rehabilitation of a once existing ecosystem that has been degraded or destroyed (Gann et al., 2019). However, restoration does not mean returning to a kind of original or ideal state. Rather, it is about sensibly designing the management of terrestrial ecosystems and keeping it within sustainable limits, while at the same time making a contribution to climate-change mitigation and adaptation (IPBES, 2019a). The restoration of degraded ecosystems can

- revitalize and enhance ecosystem services for people and nature (Figure 3.1-3; Section 2.2),
- strengthen the multifunctionality of cultural land-

scapes,
- contribute to achieving many SDGs,
- promote cooperation and a shared cultural identity (*Eigenart*) among local residents because it usually extends across administrative and sometimes even national borders.

When planning restoration measures, reference models are used that are based on ecosystems resembling the desired 'original state' (Gann et al., 2019: 15). Restoration measures can comprise one or several aims that identify the ecosystem to be restored (according to the reference model) as well as the desired degree of rehabilitation. A distinction is made between full and partial recovery. Full recovery is the condition where, after restoration, all key ecosystem attributes are very similar to those of the reference model (Gann et al., 2019: 16; e.g. biodiversity, ecosystem functions) and the ecosystem is capable of self-organization.

Alongside approaches to restoration aimed at producing a specific ecosystem state, restoration is also carried out to protect beneficial ecological processes (Higgs et al., 2018). One strategy for doing this is called 'rewilding', which aims to restore self-sustaining and complex ecosystems with interacting and mutually supporting ecological processes. Care must be taken to ensure that e.g. invasive species are also taken into account as drivers of biodiversity loss (Section 2.2.2). Thus, rewilding aims to directly restore functioning ecosystems, including the ecosystem services they provide, without committing to a target state for the ecosystem (Perino et al., 2019). Natural restoration processes are more successful than designed restoration, especially in tropical forests (Crouzeilles et al., 2017).

By contrast to restoration measures, the aim of rehabilitation measures (in the sense of partial restoration) is to restore only individual ecosystem functions (Gann et al., 2019:52). This may include, for example, the remediation of contaminated soils or the rehabilitation of overused or degraded agricultural soils.

Restoration measures must be closely interlinked with the usage claims of the local population, so that benefits for both the ecosystem and the socio-economic system are always considered together in the sense of a multifunctional landscape. The wide range of criteria that need to be considered when measuring the success of restoration measures is illustrated in Figures 3.1-4 and 3.1-5 (Gann et al., 2019:20; 100). The economic design of restoration projects, i.e. income generation through certain measures, can also help achieve social goals such as poverty reduction. The Society for Ecological Restoration has developed eight principles for the design of restoration measures. They include drawing on many types of knowledge, a restoration practice informed by native reference ecosystems while considering environmental change, and seeking the highest level of ecosystem recovery possible (Gann, 2019:18ff.).

The following sections discuss reforestation (Section 3.1.3.2), the restoration of grassland ecosystems (Section 3.1.3.3) and the restoration of peatlands (Section 3.1.3.4) as key fields of action for restoration measures. The following boxes deal with improved forest management (Box 3.1-4) and afforestation (Box 3.1-3), since they are often mentioned in the context of restoration measures, although, strictly speaking, they do not constitute restoration.

3.1.3.2 Reforestation

Reforestation, i.e. the conversion to woodland of an area of land that was formerly forested, aims to restore large contiguous areas of degraded or fragmented woodland in order to revitalize the ecological functions of the original forested landscape (IPBES, 2018a:155). Restoring woodlands by reforestation (Figure 3.1-6) can increase terrestrial carbon stocks in deforested or degraded forest landscapes and provide many other benefits, such as increased resilience of the forests to climate change, improved connectivity between patches of woodland, and the conservation of biodiversity hotspots (Smith et al., 2019b:570). A recently published study concludes that protecting forests and mangroves would reduce economic losses from the climate crisis and other forms of damage by between US$170 billion and US$534 billion per year by 2050 (Waldron et al., 2020).

Forests as carbon reservoirs

Forest ecosystems have three main carbon reservoirs: (1) living biomass (above and below ground), (2) dead wood trees, and (3) soil organic matter, including surface litter, humus and mineral soil layers. These forest carbon reservoirs react over time to interventions such as timber harvesting, management, and anthropogenic and natural disturbances (e.g. weather extremes, forest fires) – over years or decades. Harvested wood products can serve as longer-term carbon reservoirs, for example when used as building material. In this context, they also substitute building materials whose production releases considerable amounts of CO_2 emissions, such as reinforced concrete (Section 3.5.3). In addition, wood and wood waste can be used to generate bioenergy.

The restoration of natural or semi-natural forests is the most effective way to sequester carbon. This is especially true in the tropics and subtropics because trees grow relatively quickly near the equator (Lewis et al., 2019). Compared to the restoration of natural forests, however, plantations (Figure 3.1-7) store only marginally more carbon than the previously cleared area – quite apart from their much poorer biodiversity. In the long term, therefore, restoring degraded woodland through reforestation and turning it into a near-natural forest stores much more carbon than, for example, agroforestry or plantations (Lewis et al., 2019).

Reforestation (and likewise afforestation, Box 3.1-3) can change the physical properties of the land surface, especially the surface albedo (reflectivity that determines whether solar radiation is absorbed). For example, (re-)afforestation in the boreal zone (cold-temperate climate zone of the northern hemisphere) can have a warming effect that exceeds the cooling effect of greenhouse-gas reduction. In the tropics, by contrast, the opposite effects are observed. In the temperate zone, the effects vary from one area to another, depending on the type of vegetation, the timing of snow cover and other factors (National Academies of Sciences, Engineering, Medicine, 2019:113).

Ecosystem services of restored woodlands

As a rule, the restoration of degraded or cleared forests helps to reduce or stop soil erosion and to improve soil fertility and water-storage capacity. Forests also have a central function for the microclimate. These effects can be greatly enhanced by connecting woodland areas and creating biodiversity corridors (Smith et al., 2019a: 591). Forests are coming under mounting pressure from climate change. Their resilience to changes in the climate is therefore becoming increasingly important in restoration measures. This applies e.g. to drought resistance, susceptibility to pests and to storm resistance. In the Black Forest, for example, there is a discussion on replacing drought-sensitive spruce with silver fir. Furthermore, intact forests such as mangroves can help protect coastal areas and shorelines and contribute to water and flood regulation.

Forests also play an important role in providing food (e.g. mushrooms, berries, fruits, herbs, game) for the rural population; in combination with agricultural use, they can also be an essential pillar for the livelihoods of farming communities (e.g. agroforestry) and indigenous groups (Figure 3.1-2). The International Union for Conservation of Nature has developed a set of guiding principles for forest restoration (IUCN, 2020). The focus is on the landscape level (Box 2.3-3) with the different land uses that interact there. These guiding principles form the framework within which multiple benefits can be designed and generated in restoration projects, for example by combining restoration with food production, income generation and climate adaptation.

Potential for afforestation and reforestation

Since the scientific literature often does not distinguish clearly between the potential for afforestation and reforestation, this section covers both of these forestry-management methods. Global estimates of the amount of land potentially available for (re-)afforestation up to the end of the century can be as high as 25.8 million km^2 (equivalent to the area of Russia and Brazil combined), depending on a wide variety of assumptions about socio-economic developments and climate policies (Griscom et al., 2017; Kreidenweis et al., 2016; Popp et al., 2017). Estimates of the potential for removing carbon from the atmosphere through afforestation and reforestation range from 0.5 to 17.9 Gt CO_2 annually. Looking at the two methods separately, the IPCC sees the potential of afforestation in a range between 0.5 and 8.9 Gt CO_2 per year and of reforestation at 1.5–10.1 Gt CO_2 per year (Smith et al., 2019b:585; Section 3.1.1.2). These ranges result from different assumptions and modelling approaches, price differences and assumptions about incentives. A study conducted by the Royal Society (The Royal Society, 2018:105) puts the potential amount of CO_2 that can be removed from the atmosphere by afforestation at 80-300 Gt CO_2 (cumulated over 25 years; equivalent to 3.2–12 Gt CO_2 per year). Fuss et al. (2018) estimate the sequestration potential that can be sustainably realized by (re-)afforestation at 0.5–3.6 Gt CO_2 per year (Table 3.1-1).

3.1.3.3 Restoration of grassland ecosystems

When it comes to afforestation, grassland ecosystems are frequently also discussed as possible areas, yet this would usually threaten the biodiversity and soil carbon stocks of this tree-free or relatively treeless biome. Strictly speaking, afforestation in grassland ecosystems is not restoration since this would mean greatly altering an intact, non-degraded ecosystem and have negative consequences.

Grassland ecosystems are extensive, open landscapes and contain some of the largest soil carbon stocks of all the ecosystems used by humans (Chapter 2). Examples of grassland ecosystems include the prairies of North America, the dry savannas of the tropical belt, the pampas of South America, the Eurasian Steppe and the grassland tundra in Arctic regions. Grassland ecosystems are often grazing pastures for wildlife or livestock herds. They are predominantly found in regions that receive less than 400 mm of average annual rainfall; there is therefore no natural succession towards scrubland and forest: 69% of the world's arid regions are used for cattle grazing (IPBES, 2018a:145) and 26% of its global ice-free area is pastureland (Smith et al., 2019b:560). The type of grazing (time and duration of

Box 3.1-3

Afforestation

Afforestation is the conversion into forest of an area of land that was not previously wooded; strictly speaking, it is not restoration because it does not seek to restore or recover a 'natural' or near-natural forest condition. The IPCC uses the term 'afforestation' when an area has not supported woodlands for at least 50 years (Table 3.1-1). However, the question as to the 'original' state of a landscape is not easy to answer. For example, due to the geo-ecological conditions, central Europe was predominantly woodlands, which have been greatly shaped by humans since the end of the last ice age. However, there are also grassland ecosystems in central Europe in which wooded and open vegetation types have alternated. The decisive question is what impact afforestation has on intact ecosystems and their soil carbon stocks and biodiversity. In this respect, it is important to distinguish between afforestation and the reforestation of degraded ecosystems, although the boundaries can be blurred.

Afforestation can increase terrestrial carbon stocks, but it can also decrease them. For example, a reforestation project in Fort McMurray planted spruce in stands that were much too dense. As a result, the peat was drained, encouraging devastating forest fires in 2016 and causing high CO_2 emissions (Elbein, 2019). The climate impact of afforestation measures depends particularly on the previous vegetation. This is especially true of grassland ecosystems with their high soil carbon stocks, as well as to wetlands and peatlands.

Afforestation can also help reduce soil erosion on degraded land, improve water storage and support groundwater recharge. Furthermore, it can improve adaptation to climate change, reduce the vulnerability of ecosystems, and generate economic benefits. Possible adverse effects of afforestation include a potential reduction in food security if an increase in global forest area leads to a loss of agricultural land, resulting in land scarcity and thus to higher food prices. Other negative side-effects can occur when afforestation is based on non-native species, especially when the risks associated with the spread of exotic, fast-growing tree species are involved. For example, invasive exotic species can displace native species and disrupt the balance of an ecosystem or alter the water balance, with negative impacts on water availability, especially in arid regions (Smith et al., 2019b:572).

The estimates of the potential of afforestation are discussed together with reforestation in Section 3.1.3-2, as the two are often insufficiently separated in the literature.

grazing, amount of biomass eaten) also determines the development of carbon storage in the soils. Since overgrazing lowers the soils' carbon uptake as well as their carbon stocks, reducing livestock numbers and grazing intensity can allow the vegetation to recover and carbon stocks to increase. Perennial grasses, which are prevalent on most pastureland, store a substantial portion of their photosynthetically sequestered carbon below ground, making a major contribution to soil carbon stocks (National Academies of Sciences, Engineering, and Medicine, 2019: 101).

Pastureland degradation and species loss are mainly caused by overstocking and grazing cycles that are too close together. Therefore, on these areas, grazing management is the key control variable to avoid overexploitation. With the rising demand for animal products over the last few decades, the pressure on pastureland has also increased. An estimated 73% of the world's 3.4 billion hectares of pasture land are affected by soil and vegetation degradation (IPBES, 2018a: 454).

Figure 3.1-6
Reforestation of a previously cleared forest area.
Source: iStock photograph

Figure 3.1-7
Timber plantation in Sengon (Indonesia).
Source: Simeon Max

Figure 3.1-8
Mongolian steppe.
Source: iStock photograph

Strategies and instruments for the restoration of degraded grassland ecosystems

There are many strategies for preventing land degradation and restoring degraded pastureland (IPBES, 2018a: 454):

- monitoring of land use using data archives and remote sensing to observe vegetation cover, land degradation and land use (Box 3.1-2);
- assessments of the current and potential carrying capacity and of the condition of land areas using field surveys when databases are inadequate. Carrying capacity refers to the state of natural equilibrium of the ecosystem without progressive degradation;
- description of land areas and land use, e.g. grazing and pasture-development parameters, land type, fencing, waterholes, wetland management, biodiversity conservation measures, legislative responsibility, management of tree/grass balance, wildfire prevention and fire-fighting;
- grazing-pressure management to control stocking density, control of livestock growth, herd sizes, grazing-management zones and maintenance of a more consistent pressure on pastureland;
- weed and pest control by means of monitoring, management and control of invasive plants, insects and other pests. Incorporating traditional knowledge of indigenous people and pastureland-management practices provide additional approaches to effective weed and pest control.

In (arid) grass-, shrub-, and pastureland, degradation can be reversed by reduced soil compaction, fencing, and the removal of livestock, but there are no global estimates of the potential for CO_2 sequestration (Smith et al., 2019b:600).

3.1.3.4
Restoration of peatlands

Peatlands make up about 3–4% of the Earth's terrestrial surface and are an important carbon reservoir. Even the small-scale destruction of peatlands as ecosystems can have a tangible impact on the global carbon balance (IPBES, 2018a:248; Olsson et al., 2019:397). In addition to their function as a CO_2 sink, peatlands offer other valuable ecosystem services such as flood control or water purification and are a biodiversity-rich habitat for many endangered plants and animals, as well as for endemic species.

Peatlands can be found all over the world, but most are at high latitudes. They cover large areas of Russia, Alaska and Canada, but are also found in some regions of Scandinavia (e.g. Finland, Sweden) and the Baltic states (e.g. Estonia). In Germany, peat bogs can be found mainly in the north and north-east, as well as in the Bavarian pre-Alps (Schopp-Guth, 1999). Tropical peatlands (mainly peat swamp forests) are found in Indonesia, the Congo Basin, the Okavango inland delta and the Amazon Basin. In Africa and South America, peatlands are generally less important by comparison in terms of area (Grootjans et al., 2012).

Intact peatlands, especially those in the boreal tundra, bind 1,300 t C per ha worldwide and 550 Gt C in total – making them the most important natural carbon reservoir on Earth, binding as much carbon as all other terrestrial biomes combined. There are concerns (UNEP, 2019) that there might be a sudden release of greenhouse gases from peatlands in boreal areas as a result of temperature increases due to climate change (UNCCD, 2017b:171; UNEP, 2019).

Although degraded peatlands represent only 0.3% of the terrestrial land surface, they are responsible for 5% of global anthropogenic CO_2 emissions, equivalent to a release of 0.9-3 Gt CO_2 per year (Olsson et al., 2019:397). In addition, peat fires can release very large quantities of greenhouse gases: one year's peat fires in Southeast Asia alone released carbon equivalent to 40% of the global emissions generated by fossil fuel use in the same year (IPBES, 2018a:248). The degradation of peatlands also has an impact on a region's water cycle, as peat often also fulfils a water-storage function and restores the necessary balance in times of drought and flooding.

Worldwide, about 12% of peatlands are affected by degradation. There are regional hotspots of peatland degradation: in Europe, for example, 10% are already regarded as lost, and 48% of remaining peatlands are affected by degradation (IPBES, 2018a:248). It is globally estimated that the area of peatlands being restored is only about one fifth of the area affected by ongoing degradation processes. The Earth's peatlands have thus

Box 3.1-4

Improved forest management

Another forestry-related option for climate-change mitigation is the removal of CO_2 from the atmosphere by improved forest management. In tropical rainforests, for example, great potential lies in establishing selective timber harvesting as a successful management method. With regard to climate-change mitigation, improved forest management focuses on increasing the carbon stocks in biomass as well as in dead organic matter and soils. In addition, the use of wood in materials management (e.g. as a building material, Section 3.5.3.) and for generating energy can reduce emissions in other sectors (e.g. by replacing reinforced concrete). Better forest management can also improve resilience to the impacts of climate change, contribute to biodiversity conservation, increase water-storage capacity, improve the sustainable economic use of forests, and protect against soil erosion and flooding (e.g. mangrove forests). Overall, this can also improve the living conditions of the people who live off and with the forest. However, forest-management strategies that aim to increase biomass stocks can also have negative side effects, such as reducing the structural complexity of a stand and of biodiversity, as well as resilience to natural disasters (Smith et al., 2019b:570).

Improved forest management serves climate-change mitigation and the conservation of biodiversity in equal measure and involves:

- accelerating the recovery of forests in areas where major disturbances have occurred, e.g. speeding up the recovery of 'nonstocked forest land,' i.e. woodlands that have been damaged by logging, forest fires, windthrow or other disturbances (e.g. pests) and whose stocks are currently less than 10% of normal.
- restoring woodlands that have been converted to unsustainable forest areas. This includes both increasing carbon stocks by returning a forest to its original vegetation type and reducing tree-population density to avoid forest fires. It can also include enriching woodland with tree species of the natural forest ecosystem, e.g. in Germany converting spruce forests at low altitudes into mixed forests.
- adjusting harvest cycles to reduce emissions caused by too-frequent harvesting, while optimizing CO2 uptake by trees and biodiversity. Saturation of CO2 uptake capacity occurs at different times, depending on the tree species. Although fast-growing tree species (which are often used for plantations) have the highest CO2 uptake capacity, improved forest management always targets several ecosystem services, not just climate-change mitigation.
- introducing minimum harvest diameters for each tree species. This can help ensure the reproduction of the species in question and guarantee structural diversity in the forest.
- applying technologies for more careful logging, e.g. creating and maintaining logging trails or planning logging with the help of geo-information systems.
- forest certification and related forest-management practices: numerous indicators and criteria for sustainable timber harvesting have already been developed, such as the ITTO manual on reduced-impact timber harvesting in tropical forests. Such criteria and indicators are in turn used for forest certification. The two most important global certification systems for forests are those of the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC). The two organizations together reported 510 million hectares of certified forest in 2018; after accounting for double certifications, the net certified forest area was 424m ha, or about one-tenth of the global forest area (UNECE, 2019). The majority of certified forests are located in the northern hemisphere.
- creating conditions that make it difficult for pests to spread.
- thinning (i.e. reducing stand density) and other silvicultural measures that promote higher overall stand growth compared to untreated conditions (National Academies of Sciences, Engineering, and Medicine 2019:93).

Potential for improved forest management

In managed forests, biomass productivity and wood-substitution effects are the most effective carbon sequestration strategies (Smith et al., 2019b:584). However, the political focus on carbon storage can be problematic if it ignores other aspects of forest ecosystems, such as biodiversity – and especially the fauna (Panfil and Harvey, 2016; Peres et al., 2016; Hinsley et al., 2015). Timber extraction from the world's forests averages about 3 billion m3 per year, or 0.65% of the growing stock, of which about half is used for wood products and half for fuel (National Academies of Sciences, Engineering, and Medicine, 2019:94).

According to one study (Griscom et al., 2017), a change in forest-management practices could store an additional 0.2 to 1.2 t C per ha per year worldwide for several decades. This estimate includes changes in biomass and soil carbon, but excludes changes in stock caused by logging. The IPCC speaks of a range of roughly 0.4–2.1 Gt CO_2 per year (Smith et al., 2019b:585). The potential for removing CO_2 from the atmosphere by means of improved forest management is reported to be 30 Gt CO_2 cumulatively over 50 years (equivalent to 0.6 Gt CO_2 per year; The Royal Society, 2018:105).

been transformed from a CO_2 sink to a source of CO_2 (Grootjans et al., 2012: 207).

The causes are (or have been) drainage for agriculture and forestry, peat extraction, fires and, more recently, settlement construction and use for tourism. The thawing of permafrost soils in the tundra is putting increasing pressure on large areas of intact peatlands, which would release very large amounts of greenhouse gases in a very short time (Natali et al., 2019; UNEP, 2019). About half of the carbon stored in soils worldwide is found in the Arctic permafrost. Peatlands in the tundra are subject to a seasonal rhythm. In spring, the upper soil-layer thaws, allowing methane and CO_2 to escape. During the summer growth phase, the mosses and ferns absorb CO_2 from the atmosphere, while methane is released by wet soils. The longer and deeper the thaw continues in the tundra during the summer, the more likely therefore is an increase especially in methane emissions. Overall, the amount of CO_2 and methane released by microorganisms also increases because of

Figure 3.1-9
Peat bog in the Sudetes (Polish part).
Source: iStock photograph

the improved supply of water and nutrients (UBA, 2006).

There is little experience with the restoration of peatlands in the tropics (Olsson et al., 2019:398). Experience has shown that the restoration of severely degraded peatlands in northern latitudes is not possible due to fundamental changes in the hydrological conditions. As a rule, the rewetting of peatlands involves interventions across an entire water catchment area (e.g. after a rise in the groundwater level or a reduction of nitrate or sulphate contamination of the water) and requires the consideration of the several different user interests. Politically, this growing attention to peatlands, motivated especially by their outstanding importance for climate-change mitigation, was articulated in 2016 in the founding of the Global Peatland Initiative (in the context of a Conference of the Parties (COP) to the UNFCCC). The initiative aims to save the peatlands and bogs as the world's largest terrestrial organic carbon reservoirs in order to prevent the stored carbon stocks from being released into the atmosphere. Furthermore, the 13th COP to the Ramsar Convention on Wetlands of International Importance in 2018 adopted two resolutions highlighting the importance of peatlands and bogs in the context of climate policy. It recommends pursuing the sustainable management and restoration of peatlands within the framework of a landscape approach (Box 2.3-3), taking into account both innovative and traditional, non-destructive forms of peatland use. Finally, it also points to the need for more accurate global mapping and recommends more precise monitoring of change dynamics (in near real-time; Crump et al., 2017; Box 3.1-2). To date, the Global Peatland Initiative has been active with or in developing countries in Africa, Southeast Asia and South America (Indonesia, Peru, the Democratic Republic of Congo and the Republic of Congo).

3.1.3.5
Ecosystem restoration in the focus of international sustainability policy

According to the assessment of IPBES (2018a: XLII), there is an urgent need for a fundamental change in policy to prevent an irreversible degradation of land and soil and the progressive loss of biodiversity, and to accelerate restoration measures – also as a contribution to climate-change mitigation. Such measures can make essential contributions to achieving the goals of the three Rio Conventions: for example by restoring areas where protected wildlife and plants live (CBD), protecting soils and water resources by means of forest cover (UNCCD), and creating carbon sinks with forests and by restoring wetlands (UNFCCC; Besseau et al., 2018). One of the most important international knowledge platforms in this field is the Global Landscapes Forum (GLF), founded in 2013 at COP 19 to the UNFCCC. The GLF is managed by the Center for International Forestry Research (CIFOR) and supported by UNEP, the World Bank and the German Federal Ministries for the environment and economic cooperation / development (BMU and BMZ).

In recent years, governments around the world have committed to numerous and extensive measures to restore degraded land areas; some even speak of the world having entered an "era of global ecological restoration" (Gann et al., 2019:77), establishing a new set of goals for sustainability policy. The most significant international areas of political progress on the restoration of degraded landscapes and forests are the Bonn Challenge, launched in 2011 by the IUCN and Germany and later expanded by the New York Declaration on Forests (often referred to as the expanded Bonn Challenge), and the United Nations Strategic Plan for Forests adopted in 2017. The Bonn Challenge (Figure 3.1-10) is a global initiative to restore 150m ha (roughly the size of Mongolia) of the world's deforested and degraded land by 2020 and 350m ha by 2030 (www.bonnchallenge.org). The Bonn Challenge's original target was confirmed, expanded and extended to 2030 by the New York Declaration on Forests. The Bonn Challenge's aims are being given a significant boost by the Global Partnership on Forest and Landscape Restoration (GPFLR). The GPFLR is supported by a large number of international organizations and by some countries, and provides an overarching framework within which numerous partnerships are launched. Up to 2018, 58 countries and organizations had made pledges to the Bonn Challenge via their own regional groupings: e.g. the 20x20 Initiative (20m ha by 2020, cooperation of Latin

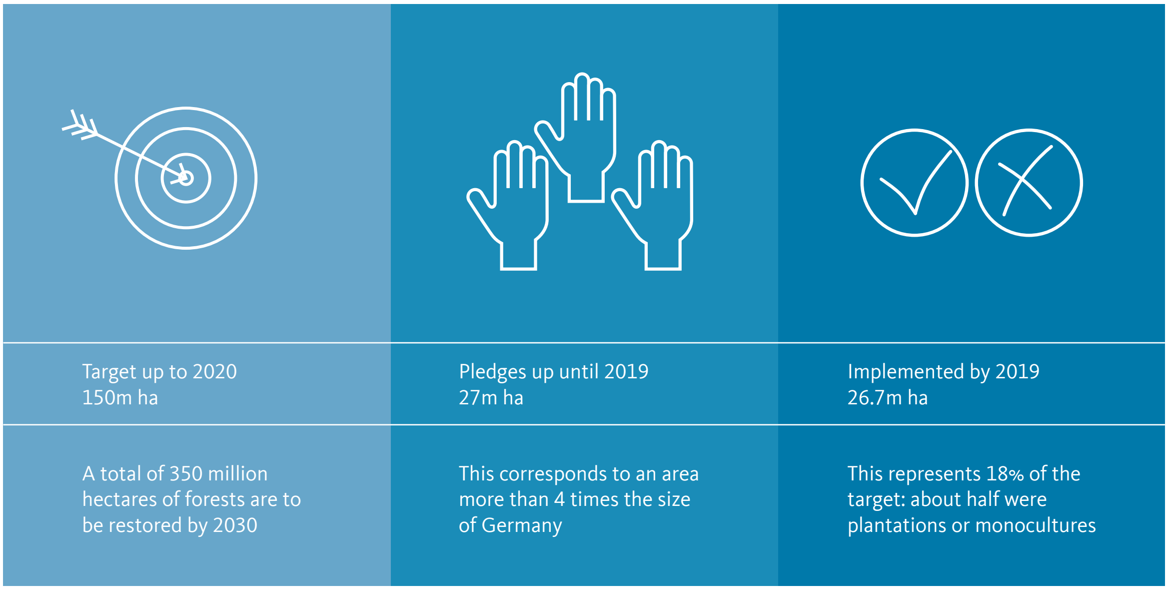


Figure 3.1-10
Restoration of forest landscapes in the context of the Bonn Challenge: difference between pledges and implementation and quality problems.
Source: NYDF Assessment Partners (2019) and BMU (2020a, as of July 2019). Own diagram.

American and Caribbean countries with the WRI, IUCN and others), the African Forest Landscape Restoration Initiative (AFR100), the Agadir Commitment (European and Maghreb countries plus Turkey, 2017) and the Astana Resolution (Caucasus and Central Asia, 2018; Besseau et al., 2018). Most of these pledges related to tropical and subtropical forests, where such actions can be most effective in mitigating climate change (Lewis et al., 2019). They cover a total area of over 170m ha (as of July 2019; Besseau et al., 2018; Figure 3.1-10). In the political sphere, forest restoration is also often incorrectly interpreted as the establishment of a plantation or monoculture (Lewis et al., 2019). Measures aimed at achieving the Bonn Challenge goals have therefore been criticized (Lewis and Wheeler, 2019) because nearly half of all pledges – contrary to the goal of this landscape-based restoration approach – consisted of creating new tree plantations (monocultures) instead of restoring degraded areas. The latter has much greater potential for CO_2 removal than plantations and also contributes to biodiversity conservation. About a fifth of the pledges related to agroforestry measures. Furthermore, cases of land-use competition between reforestation measures and crop cultivation have been reported (Lewis and Wheeler, 2019). Up to 2019, only 18% of the Bonn Challenge's 2020 target had actually been implemented (NYDF Assessment Partners, 2019).

The Global Environmental Facility (GEF) also aligns its work with the Bonn Challenge and the Global Partnership and promotes restoration projects all over the world. In 2018, the IUCN, UN Environment and the FAO launched The Restoration Initiative funded by GEF and others, which includes 11 national projects in 10 Asian and African countries. Seconding the Global Partnership, the United Nations Strategic Plan for Forests (2017–2030) aims to more closely integrate the international activities for forests. Its objective is to restore sustainable management and long-term conservation of the world's forests in order to contribute to climate-change mitigation.

Beyond the Global Partnership there are global multi-actor networks working to restore degraded landscapes. For example, Commonland (www.commonland.com, founded in 2013 as a collaborative project between an ecologist and an entrepreneur) is a network in which local stakeholders, governments, businesspeople, ecologists and scientists work together (including McKinsey & Company, the Dutch Red Cross, the Nature Conservancy, the Rainforest Alliance, Wageningen University, World Business Council for Sustainable Development, World Resources Institute, WWF). Commonland also sees itself as a contribution to the UN Decade on Landscape and Ecosystem Restoration and carries out large-scale restoration projects worldwide (one example of a project in South Africa covers 500,000 ha and has one million beneficiaries).

Another example of a multi-actor network is Nature4climate (an initiative of UNDP, UNREDD, UNEP, CBD, IUCN, TNC, CI, WCS, WBCSD, WIR and WWF), which aims to promote investment in 'nature-based solutions' in support of the Paris Agreement. On the private-sector side, the World Business Council for Sustainable Development (WBCSD) is an important player under the heading of 'natural climate solutions', which addresses restoration measures in the service of climate-change mitigation as a business model (www.wbcsd.org).

At the World Economic Forum in Davos 2020, the multi-stakeholder platform '1t.org – a platform for the trillion tree community' was also founded to promote accelerated action on the science-based reforestation, restoration and conservation of forests. In this way, 1t.org aims to support important international processes such as the UN Decade on Ecosystem Restoration.

What all measures and initiatives have in common is that, in addition to biodiversity conservation and climate protection, they generally focus on conserving and strengthening ecosystem services and on the SDGs, and that they need the involvement of a wide range of stakeholders when designing restoration measures. This participation relates not only to technical experts and administrations but also to local actors (Table 3.1, 2; Box 3.1-5). The lasting success of restoration efforts depends on an understanding of local conditions and on the coordinated interaction of private and public actors (Roe et al., 2019). Passing on (some) responsibility to the local level, while keeping in mind the subsidiarity principle, is an important condition for success here. The decisive factor is how diverging interests and power relations are dealt with (who benefits? who determines the rules?). Indigenous Peoples and Local Communities, who together use or inhabit at least half of the world's forests, play a particularly important role. However, they only have legal rights to about 10% of this land (Hanson et al., 2019). Overall, at least a quarter of the global land area is managed in a traditional way by indigenous peoples (IPBES, 2019a). Some countries, e.g. Indonesia with its Social Forestry Initiative, have programmes to transfer land-use rights from the state to local communities. There are numerous examples of how local communities manage their forests sustainably, often contrasting with the unsustainable way in which many (international) companies use land as monocultures.

3.1.3.6 Implementation of restoration measures

Restoration as part of integrated landscape and/or spatial planning

Restoration measures often involve more than e.g. simply restoring a previously forested area. Transposed to a landscape, they can also be a combination of a protected forest and monoculture-based short-rotation forestry or agroforestry. The economic viability of restoration measures is crucial for lasting success (OroVerde and GNF, 2019). When local actors see the economic advantages and the potential of restoration measures for improving their own living conditions, they are more willing to change their present forms of use and to take risks. Thus many measures integrate agroforestry, which offers numerous opportunities for income generation (Section 3.3).

The implementation of restoration measures within the framework of a form of landscape and spatial planning that is geared to a landscape's multifunctionality (Section 4.2.3) can bundle synergies, promote sustainable regional development and help sustain the natural life-support systems in line with a multiple-benefit strategy. Moreover, the planning units under the landscape approach (Box 2.3-3) consist of large-scale physical areas with overlapping ecological, social and economic activities. These encompass many different functions ('multifunctionality', Section 2.2) and services, including food, biodiversity, water, housing and socio-economic prosperity. Land-use policies frequently pursue the needs of individual sectors: for example soil quality and access to water in the case of agriculture; access through open landscapes in the case of pastureland management; the designation of building land and development in the case of settlement and infrastructure expansion; the sink potential of reforestation in the case of climate-change mitigation; biodiversity conservation, soil protection and near-natural landscapes in the case of nature conservation; changes in tree species where there is a need to adapt to climate change; or recreational value and attractive landscapes in the case of tourism. Ultimately, each of these policies has its own selective perspective on designing a landscape. Sustainable land management must bring these interests together in participatory processes and find integrated responses that preserve the multifunctionality of a landscape and its ecosystem services. Using scenarios and models can be helpful here. Integrated landscape planning over larger areas can bring together the demands of the different land uses and protection needs in a joint design process that is adapted to local conditions. It is indispensable for the development of rural areas. By contrast to the concentration of land uses by further intensification, there is a growing discussion of extensive approaches geared towards sharing the use of a landscape (e.g. wildlife-friendly agriculture; Collas et al., 2017; Mertz and Mertens, 2017; Phalan et al., 2011).

Integrated landscape planning can correct the deficits of sectoral approaches by taking into account all claims to land use, for example balancing those of the

Table 3.1-2
Actors involved in restoration measures: examples
Source: WBGU

Actors in afforestation, reforestation and the restoration of degraded pastureland		
	Examples of actors: afforestation and reforestation	**Examples of actors: restoration of degraded pastureland**
Global	Global Partnership on Forest and Landscape Restoration, United Nations Strategic Plan for Forests (2017-2030), Nature4Climate (N4C), UN Forum on Forests, development banks, donor organizations (e.g. GIZ: German Agency for International Cooperation), sponsors (foundations, networks, e.g. WBCSD). Private sector, timber industry	Global Partnership on Forest and Landscape Restoration, FAO: pastoralist knowledge hub and regional networks, multilateral development banks, donor organizations (e.g. GIZ), League for Pastoral Peoples and Endogenous Livestock Development (LPP), sponsors (foundations, networks, e.g. WBCSD)
National	Forestry/environmental authorities, forest owners, nature-conservation/environmental authorities, foundations, spatial planners, private sector, timber industry, mining (compensation areas)	Nature-conservation/environmental authorities, spatial planners, foundations
Regional	Spatial planners, national park authorities, tourism industry, private sector, timber industry	Spatial planners, national park authorities, tourism industry
Local	Land users/indigenous people, community-based organizations (CBOs), foresters, NGOs, private sector, timber industry	Mobile livestock farmers/indigenous people, community-based organizations (CBOs), rangers, NGOs, pastoralists
Landscape	Possibly bordering countries, indigenous forest users (e.g. in Amazonia), national park, Private sector, timber industry possibly farmers, mobile livestock keepers, incl. indigenous peoples	Possibly bordering countries, pastoralists, e.g. Saami Council, International Centre for Reindeer Husbandry (ICR), possibly farmers, mobile livestock keepers, including indigenous peoples

rural poor against nature conservation or land requirements for plantations. Extensive approaches also help to take into consideration encroaching effects on neighbouring areas (indirect land-use effects, such as a negative impact on water availability or the interests of neighbouring regions in the upper and lower reaches of rivers, or changes in local climates). In addition, integrated landscape approaches can also take cultural values into account and help protect them (e.g. the local identities of a cultural landscape, sacred places, cross-border mobile pastoralism). There are important global platforms that document good-practice examples of sustainable land use, for example the World Overview of Conservation Approaches and Technologies (WOCAT) and the Society for Ecological Restoration and Conservation Evidence.

In contrast to the traditional level-oriented (local, national, etc.) approach, the large-area planning and implementation of restoration projects at the landscape level (scaling up) require cooperation across administrative boundaries, possibly even across national borders, which also requires corresponding governance innovations (such as new forms of cooperation) – a challenge especially for formal institutions (IPBES, 2018a; Mansourian, 2017). There are already approaches where local groups, NGOs, the private sector and public administration work together and equal representation of all actors is assured (IPBES, 2018a:496).

Barriers to the implementation of restoration measures

Forest management often involves multiple authorities and institutions, and this can lead to a fragmentation of interests, priorities and actions along horizontal (e.g. forestry vs environment ministries vs investor) and vertical (e.g. national vs local government) lines. Furthermore, the equitable distribution of benefits and burdens, for example between investors and smallholders, is often seen as the biggest challenge when designing restoration projects (IPBES, 2018a). Local communities and (small) farmers often bear the biggest risk in restoration projects, as they have to adopt new forms of use and may be forced to accept temporary losses of income (OroVerde and GNF, 2019). Precisely because forests are often seen as an obstacle to economic development from a short-term perspective, leading to their clearance to obtain arable land (Hanson et al., 2019), it

Box 3.1-5

From degradation to restoration thanks to change agents

Change agents can be important actors in combatting land degradation as they operate strategically across all social strata and areas of activity and are instrumental in spreading new technologies and ideas (Rogers, 2003; Grin et al., 2010; Kristof, 2010). Initially, they act as niche actors outside of established practices and models, but as they become increasingly networked and initial ideas are implemented, they can win allies and develop a transformative impact, for example by "changing routines and framework conditions and by forming new institutions" (Kristof, 2010), which then lead to a paradigm shift.

A wide range of different niche actors have been campaigning for restoration measures for decades. Back in 2011, the WBGU wrote about the biologist Wangari Maathai and her key contribution to the restoration of watersheds. In 1977, she founded the Green Belt Movement under the auspices of the National Council of Women of Kenya (NCWK). It began with a women-led community reforestation project aimed at halting deforestation and soil erosion in order to ensure supplies of food, firewood and especially water. The movement has already planted over 51 million trees across Africa and uses political and educational work to advocate for women's rights and more democratic space in Kenya and beyond. Maathai and the movement developed from a niche player into an international trendsetter; in the meantime the organization is active in 13 African countries, implementing its original mission statement and strengthening regional climate-change mitigation and the protection of the Congolese rainforest along the way. As early as 1984, Wangari Maathai received the Right Livelihood Award for her work with the Green Belt Movement. Exactly 20 years later, she became the first African woman to be awarded the Nobel Peace Prize for her commitment to 'sustainable development, peace and democracy'; the Green Belt Movement is a key partner of the United Nations Environment Programme (UNEP) in the Trillion Tree Campaign.

People have been practising restoration for quite some time, yet many practices have been forgotten and only recently rediscovered by change agents, such as in Niger in 1983. Deforestation in Niger's Sahel region took a dramatic upturn in 1935 when the French colonial rulers centralized the management of natural resources. In the 1950s, the post-war export boom exacerbated this trend, and after Niger's independence in 1960, droughts and the ensuing food and energy shortages intensified deforestation and land degradation in the region (Birch et al., 2016). In 1983, Tony Rinaudo popularized a method of restoration in Niger called the 'Farmer Managed Natural Regeneration' approach (FMNR; Birch et al., 2016; Rinaudo, 2001); the method was probably known as far back as prehistoric times. Only 12 farmers initially participated in the initiative of the evangelical NGO 'Serving in Mission', which uses traditional methods to promote growth in naturally existing tree stumps, roots and seeds, thus resurrecting a locally adapted 'underground forest' (Rinaudo, 2001; Tougiani et al., 2008). A few years of successful intercropping trials and the waning political – often corrupt – control by colonial and national authorities (due to the economic slump and the political vacuum) allowed farming communities to make more independent decisions about tree cover and cultivation and to develop the formalized method of FMNR.

Change agents such as Tony Rinaudo, local farmers, the NGO Serving in Mission, and the International Fund for Agricultural Development (IFAD) made the broad success of this restoration approach possible (Birch et al., 2016). Today, FMNR is practised in Niger, Chad, Burkina Faso, Ethiopia and Mali. The Global Evergreening Alliance is also preparing to roll out the approach in eight East African countries. A total of 60,000 square kilometres of tree cover returned between 1983 and 2015. FMNR is not only cost-effective, it also addresses many problems at the same time: land degradation, soil infertility and erosion, biodiversity loss, shortages of food, firewood, building timber, fodder, and the problem of dysfunctional water cycles. FMNR is thus an effective method for reducing poverty and hunger among subsistence farmers while boosting resilience to climate extremes (Birch et al., 2016). In 2018, Tony Rinaudo was awarded the Alternative Nobel Prize for (re-)discovering and disseminating the principle, and FMNR is cited as an official 'best practice' for achieving a total of 12 of 17 Sustainable Development Goals (Partnerships for SDGs Platform, 2020).

is even more important to keep a close eye on the long-term economic viability of restoration projects. Another challenge is that many of the ecosystem services that are promoted or restored by restoration measures are commons and therefore not (or only partially) remunerated via markets; the business advantages therefore lag behind the societal and/or macroeconomic benefits of the restoration measures. The result is a lack of private incentives to implement or finance restoration measures.

Particularly in developing countries and emerging economies, corruption, weak institutions and a lack of legal clarity are supportive factors for deforestation and important obstacles to attempts at promoting restoration measures. Overcoming such institutional deficits is therefore key to the success of restoration projects. Private-sector investment also needs reliable framework conditions that ensure the long-term economic viability of projects, as well as incentives for the sustainable production of timber, other forest products (e.g. from wild collection) and agroforestry products (OroVerde and GNF, 2019).

Very common barriers include uncertainties in land tenure and rights of use. While many national forest legislations recognize traditional land-use rights, as a rule they are subordinate to national legislation. Especially in developing countries and emerging economies, it is often unclear who owns a piece of land, and the actual users are excluded from decisions or exposed to arbitrary actions, which may even extend to eviction.

Box 3.1-6

Forest conservation and afforestation programme under the Framework Convention on Climate Change: REDD+

REDD+ is the forest conservation and reforestation programme under the United Nations Framework Convention on Climate Change (UNFCCC) and stands for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries. The programme was established in 2005 and has since been further developed in a comprehensive regulatory regime. The Paris Agreement explicitly mentions REDD+ as an instrument for climate-friendly land use (Art. 5 para. 2 of the Paris Agreement). In the meantime, numerous REDD+ projects have been initiated and implemented with a large number of stakeholders.

Phase model for the implementation of REDD+

The regulatory regime for REDD+ imposes extensive technical and institutional requirements on developing countries. The phase model adopted in 2010 defines three phases during which developing countries must meet certain conditions for receiving performance-based payments for forest-related reductions in emissions (UNFCCC, 2010: paragraph 73).

In the *first phase* national Strategy or Action Plans are developed and national capacities and institutions are expanded with financial support from donor countries and institutions. A National Forest Monitoring System must also be established to measure the success of emissions-reduction measures. The countries are also to take the Safeguards (see below) into account in their national strategies. The implementation of the national strategies begins in the *second phase:* the countries carry out voluntary demonstration projects before receiving results-based payments (RBPs) in the final phase for documented and verified reductions in emissions under the conditions set out in the Warsaw Framework (UNFCCC Decisions 9 to 15/CP.19; especially Decision 9/CP.19, paragraph 3). After a lengthy institutionalization process, the first developing countries entered the final third phase in 2019 and received RBPs; they included Brazil, DR Congo and Mozambique.

Safeguards

Furthermore, the REDD+ regulatory regime defines seven *Safeguards* (UNFCCC Decision 1/CP.16, Appendix I paragraph 2), which are designed to ensure that not only the reduction of greenhouse gases is taken into account but also overall ecological and socio-economic factors. The participation of stakeholders and respect for the rights of indigenous communities are of socio-economic importance. In ecological terms, the aim is to ensure the long-term irreversibility of emissions reductions ('permanence') and to prevent 'leakage' effects caused by emissions-intensive forestry measures being relocated to a forest area not covered by REDD+. Wherever possible, information is to be communicated regularly to the UNFCCC showing how the Safeguards are being taken into account in connection with REDD+ projects during all phases of REDD+ implementation (UNFCCC Decision 12/CP.17).

Current developments

Despite very broad political support from the outset, the international community faces some challenges in implementing REDD+.

The main problem is the provision of and access to RBPs. The reach and impact of the programme have so far been limited due to existing funding deficits. Contrary to what was initially envisaged, no international carbon markets have emerged in parallel that could have tapped private sources of finance for REDD+ projects on a large scale. Instead, up to now public funds have been provided mainly by multilateral institutions (e.g. World Bank, FAO, UNDP), regional development banks (e.g. KfW) and by Germany, Norway and the United Kingdom via bilateral agreements. However, dependence on a generally rather small group of donor countries means considerable (political) uncertainty about the longer-term funding of the programme (Duchelle et al., 2019:7).

Financial uncertainty means actors in developing countries have little flexibility in implementing further REDD+ projects, while at times unsatisfactory experience with pilot projects discourages both state and private donors from investing more extensively (Fischer et al., 2016:55). International carbon markets as a future source of financing and opportunities to leverage private funds for REDD+ are still under discussion. Initial steps in this direction already exist in the form of voluntary, private-sector carbon markets, e.g. for offsetting aviation emissions. The International Civil Aviation Organization's CORSIA system could create considerable demand for project certificates in this context (Hein et al., 2018:8; Golub et al., 2018:2). However, REDD+ encompasses both avoiding the threat of emissions as a result of deforestation and creating natural sinks by restoring and reforesting woodlands. In the case of the latter at least, the WBGU believes that offsetting natural sinks against emissions-reduction measures – an aspect or risk that might accompany such carbon markets – should be viewed critically and, wherever possible, ruled out (Section 3.1.4). In this context, there is also a need for clarification on details of the implementation of the Paris Agreement, especially Article 6. A related problem is the fact that, for example, setting up precise and consequently costly MRV (measurement, reporting and verification) systems requires a level of financial investment of developing countries that may exceed the promised performance-based payments (Köhl et al., 2019:2). Access to RBPs under REDD+ is also made considerably more difficult by the large number of different (institutional) requirements specified by the various donor institutions for projects.

The implementation of the Safeguards is also a prominent point of criticism. In this respect, reference is made to de facto existing power and information asymmetries that work in favour of (donor) states and major investors and to the disadvantage of the civilian and, in particular, the indigenous population (Rodríguez de Francisco and Boelenz, 2014:2; Haywood et al., 2015:134; Maniatis et al., 2019:386). The legal structures are unclear because the regulatory regime for REDD+ interacts with numerous national and regional laws and with contracts involving private individuals. A related issue is the fact that the ecological integrity required by the Safeguards is not guaranteed. Non-permanence and leakages are risks that can only be addressed by targeting the underlying drivers of deforestation and forest degradation (Maniatis et al., 2019:377).

Finally, deficits can be seen in the systematic fight against the drivers of deforestation and forest degradation, such as livestock farming and palm-oil and soybean production (Hein et al., 2018:10). There are difficulties here, particularly in identifying both indirect and site-specific causes of deforestation and forest degradation (Maniatis et al., 2019:379).

Apart from cutting emissions, REDD+ is intended to bring about non-carbon benefits of socio-economic factors and biodiversity. With regard to biodiversity, it is positively emphasized that REDD+ creates synergies between the UNFCCC and the Biodiversity Convention in that, for example, donor countries and institutions stipulate a high level of biodiversity monitoring (Latham, 2014:3). However, the already lengthy and difficult implementation of REDD+ hinders the additional integration of biodiversity targets into existing and future REDD+ programmes (Fischer et al., 2016:55).

Positive effects are also observed in relation to land tenure because ownership must be clarified at the local and regional level for the successful implementation of REDD+ projects. By contrast, when it comes to potential land-tenure reforms at the national level, it is questionable whether REDD+ can prevail over other forms of land use (Fischer et al., 2016:55).

Given the REDD+ implementation status outlined here, there is a need for improvements in order to successfully implement forest-related measures of climate-change mitigation. For REDD+ to have a long-term positive impact, a transformative change must be achieved that has hitherto been hindered by the above-mentioned shortcomings (Maniatis et al., 2019:380; Fischer et al., 2016:55f.). However, the potential of REDD+ becomes evident not least from the key role for climate-change mitigation that the international community has accorded to REDD+ by its inclusion in Article 5 paragraph 2 of the Paris Agreement (Maniatis et al., 2019:373).

Compliance with Safeguards and combatting the drivers of deforestation are particularly important for the leasing solution presented in Section 4.3.3.

This problem is also reflected in the SDGs, where some sub-targets also include land rights (SDG 1.4; SDG 2.3; SDG 5.a). Unclear or uncertain land rights also make it difficult, for example, to design payment systems for ecosystem services, which could make restoration measures more attractive in economic terms.

In view of the deficits in funding, the existing capacities for implementation, and the lack of policy making and enforcement, there is currently still a very large gap between the targets set for restoration and target achievement (IPBES, 2019a). Especially in developing countries and emerging economies, there is a need for a marked increase in funding and capacities for restoration and nature conservation, both inside and outside protected areas. The (specialist) spatial planning required for this should not only be participatory in structure, it should also cover an entire landscape (IPBES, 2019a; Section 4.2.3). The cost of inaction is estimated globally (across all biomes) to be ten times the (societal) cost of avoiding degradation (IPBES, 2018a: XXXV).

3.1.3.7
Conclusions on restoration

- Only when a forest landscape is already degraded is restoration the method of choice: forest-restoration measures have the greatest concomitant benefit when they involve either areas that used to be forested and are now degraded, or degraded areas for which no other use is envisaged and where there is accordingly no competition for use of the land (Royal Society, 2018). Conversely, this means that afforestation on land that was not previously forested must be reviewed very critically from a sustainability perspective. This applies particularly to non-forested biomes such as grassland ecosystems.
- Restoration is currently high on the international political agenda. However, restoration is often misinterpreted in the political arena and, accordingly, many measures go in the wrong direction: behind many measures declared as restoration lies the establishment of plantations or monocultures (Lewis et al., 2019). Nevertheless, the currently high level of political attention paid to this issue provides a window of opportunity that should be used to build new coalitions and partnerships.
- The reforestation of degraded and cleared forests and the restoration of peatlands or grasslands can contribute significantly to the creation or revitalization of landscape multifunctionality. Restoration is therefore a multiple-benefit strategy whose concomitant benefits extend beyond the land-use trilemma of climate-change mitigation, biodiversity and food security.
- When implementing restoration measures, it is essential to observe the principle of subsidiarity, to comprehensively involve stakeholders, and to take into account the (long-term) impact beyond the landscape level.
- Although principles for designing restoration measures can be formulated, there are no universally valid solutions because of the great variations in geographical, ecological and cultural conditions. Restoration measures must therefore always be precisely tailored to the context of a specific landscape.

3.1.4
Recommendations for action

In the following, the WBGU first develops overarching recommendations for removing CO_2 from the atmosphere as an independent approach to climate policy. Section 3.1.4.2 provides specific recommendations on the restoration of forests and other ecosystems as a low-risk and multifunctional strategy for CO_2 removal.

3.1.4.1
Recommendations for CO_2 removal

With the Paris Agreement the international community has committed itself to limiting global warming to well below 2°C. To achieve this goal, climate-change mitigation must focus on the early, substantial reduction of global CO_2 emissions. Climate-protection scenarios also show, however, that the Paris goals can hardly be achieved without CO_2 removal from the atmosphere, especially if a risky temporary overshoot of the 2°C guard rail is to be avoided. The reason is that mitigation efforts have been too slow in the past. Therefore, in addition to reducing global CO_2 emissions, it is necessary to ambitiously develop and carefully expand methods to remove CO_2 from the atmosphere, while also considering sustainability criteria beyond climate-change mitigation. The guiding principle of these efforts should be to take precautions against climate-change risks rather than hoping to buy time for climate policy, let alone to get by without emissions-avoidance measures completely. The avoidance of CO_2 emissions should be the first choice because the climate impact of avoidance is immediate and long-term, whereas approaches to removing CO_2 from the atmosphere after it has been emitted only have a retrospective effect and entail long-term risks such as a lack of permanence, possible leakages, and technical or political uncertainties. Furthermore, given the state of development of many approaches and technologies, as well as the great and uncertain sustainability risks of their large-scale deployment, relying today on the future availability of CO_2 removal is not compatible with the precautionary principle.

Ambitiously and rapidly cutting global CO_2 emissions reduces not only the risks of climate change but also the sustainability risks of using methods to remove CO_2 from the atmosphere. In this respect, early climate protection by avoiding emissions has, in many ways, a high 'insurance value' against a wide range of future risks (Pindyck, 2020). It also makes it possible to sustainably pursue primarily ecosystem-based and/or land-based approaches to CO_2 removal which, despite their rather limited potential, offer numerous additional benefits that go beyond the climate-protection aspect, and which can be combined with other strategies for the multifunctional use of land and ecosystems presented in this report, such as the ecological transformation of industrial agriculture or using timber in construction.

Clearly separate climate-policy targets for avoiding and removing CO_2

Climate-policy targets, schedules and crediting structures for CO_2 removal from the atmosphere should be kept clearly separate from those aimed at avoiding CO_2 emissions (McLaren et al., 2019; Jeffery et al., 2020). Parties under the Paris Agreement should also implement this separation in their Nationally Determined Contributions (NDCs). This separation prevents disincentives that can deter early investment in emissions reductions and development of the respective technologies and can encourage a risky degree of reliance on the future feasibility of CO_2 removal. It also takes account of the differences between avoiding CO_2 emissions and CO_2 removal when it comes to the permanence and reliability of their mitigating effect on climate change, and makes it possible to take a differentiated view of other effects on sustainability. Therefore, when formulating net-zero targets and especially the goal of climate neutrality, clear information should always be provided on the assumed contributions to be made by CO_2 avoidance and removal.

Strategically plan the application of approaches to CO_2 removal and limit their sustainability risks

At the European level and together with the parties to the Paris Agreement, Germany's Federal Government should, in good time, explore and strategically plan the goals and sustainable implementation options of the different approaches to global CO_2 removal from the atmosphere, before any broader funding mechanisms for approaches to CO_2 removal that go beyond research and development are established. Climate impacts especially on ecosystem-based approaches and the interplay of different approaches to CO_2 removal should be part of these plans, as should different geographical conditions and the global distribution of responsibility. The strategies should take into account in detail any imminent sustainability risks of CO_2 removal; they should also be embedded in the necessary, overarching strategic coordination of future uses and the sustainable availability of biomass and ecosystems (Section 3.5). In this context, in order to effectively address sustainability risks, consideration should also be given to limiting or excluding the use of individual CO_2-removal methods in certain countries. In addition, the international scheme for accounting of CO_2 removal – e.g. using BECCS – could be tied to strict sustainability criteria, as is currently envisaged for the process of determining eligibility for bioenergy funding in the EU under the revised Directive on the Promotion of the Use of Energy from Renewable Sources ('RED II'; EU, 2018a; Section 4.2). Essential factors for successful strategic planning here are substantial progress in research (Section 3.1.5.1); strong governance mechanisms for financing and promoting scientific expertise for risk and potential assessments, boundary demarcation and effective monitoring; and enabling the robust development, adaptation and implementation of the strategies.

Implement ecosystem-based approaches to CO_2 removal at an early stage with a view to multiple benefits

National regulations and international support programmes should rapidly make the most of the potential offered by methods such as restoration and soil-carbon sequestration, since they represent proven, low-risk and cost-effective options for removing CO_2 from the atmosphere. Although the volume potential for CO_2 removal and the permanence of storage are limited, these approaches deliver multiple co-benefits such as improved soil quality and biodiversity conservation. In this way, they help mitigate the land-use trilemma between climate protection, biodiversity conservation and food security. Furthermore, they are elements and/or the basis of many of the multiple-benefit strategies discussed in this report, such as effective protected-area systems, ecological agriculture and timber-based construction as a bioeconomic alternative to cement and steel. In line with the recommendation to separate CO_2 avoidance from CO_2 removal, the Federal Government should not list the promotion of ecosystem-based CO_2 removal on the territory of other countries as a contribution towards its own national reduction targets (Jeffery et al., 2020).

Create multilateral financing systems for sustainable CO_2 removal

At the multilateral level, the Federal Government should encourage the development of new, independent mechanisms for financing sustainable CO_2 removal from the atmosphere. International transfer payments according to the polluter-pays principle are a suitable and justified instrument given internationally different natural conditions, economic capabilities and historical responsibility for climate change (Pozo, 2020). In the longer term, a separate international market for CO_2 removal in the spirit of Article 6 of the Paris Agreement would also be conceivable. Both instruments would need to be aligned with approaches to reduce emissions, broader sustainability goals such as biodiversity conservation and food security, and social justice components beyond the polluter-pays principle, and the specific benefits and risks of the very different approaches would need to be taken into account. In the short term, the financial resources required can be raised by pricing CO_2 emissions (Barbier, 2020); however, additional resources will be needed in the medium term (Bednar, 2019:76).

Create state financing systems for sustainable CO_2 removal

At the national level, government payments should be made for CO_2 removal; these would ultimately finance the provision of a public asset (commons) in the form of the contribution made to climate protection. In the case of ecosystem-based methods of CO_2 removal and sustainable biological-technical approaches, this could take place within the framework of a broader system of payments for ecosystem services (Section 4.2). Such a system should be implemented much more consistently and systematically than has been the case to date, not only with a view to potential CO_2 removal but also in general with regard to ecosystem services that can be defined as commons. This approach should also guide the reform of the EU's Common Agricultural Policy (Sections 3.3, 4.3). It would also be conceivable to implement the separately identified targets for CO_2 removal via auction mechanisms. Here, too, the different benefits and risks of individual approaches to CO_2 removal should be taken into account through individual quantity restrictions and sustainability requirements, for example in the form of strict certification obligations for (re-)afforested woodlands or biomass used in BECCS.

3.1.4.2 Recommendations for the restoration of degraded ecosystems

Under certain conditions, the restoration of degraded terrestrial ecosystems to create additional sinks for greenhouse gases can generate numerous additional benefits for humans and nature, e.g. for climate-change mitigation, biodiversity conservation and food production, and thus contribute to defusing the trilemma of land use (Chapter 2). With regard to the climate impact, the institutions responsible for landscape planning (e.g. forestry and environmental authorities) should bear in mind that in the long term the restoration of degraded forests by reforestation, culminating in a largely natural forest, stores considerably more carbon than agroforestry or plantations. Plantations often store even less carbon than the land before afforestation. In particular, replacing grasslands, with their high soil carbon stocks, by a process of afforestation can lead to a considerable loss of biodiversity and soil carbon. With its various functions for humans and nature at the landscape level, restoration is a suitable multiple-benefit strategy for resolving the land-use trilemma. For this purpose, regionally specific solutions must always be sought and negotiated among the actors and interest groups, taking into account the climate changes that are taking place. In this context, the economic efficiency of the measures and income generation via restoration are also key success factors affecting permanence. When decisions that affect terrestrial ecosystems are made by planning authorities, land managers or private investors, all the main costs and benefits – monetary and non-monetary

– for the region affected and the people living there should be taken into consideration. In addition to the economic factors mentioned above, the permanence of restoration also depends on measures being implemented in a socially responsible way. This includes taking into account the rights and needs of the local population, avoiding competition for land from other uses, especially food production, and enabling local people to benefit from the social, economic and ecological added value generated by restoration.

There is a need for an intensified, routine collection and assessment of information on the state of terrestrial ecosystems by means of data capture on the ground, but also using remote sensing. New and efficient methods and tools are needed for cost-effective and broad-based data capture. Reliable and up-to-date information is a prerequisite for effective decision-making and the efficient and scalable implementation of restoration measures. There is also a need for an open exchange of standardized data and knowledge on best practices for the conservation and restoration of terrestrial ecosystems. Successful restoration at the landscape level requires institutions collaborating closely at several levels both with each other and with policy-makers and spatial planners, in order to develop standards for systematic monitoring and facilitate access to data and instruments (Willemen et al., 2020). In addition, standards for sustainable restoration practice must be developed, established, communicated and implemented by these institutions and actors in order to ensure that the above-mentioned benefits are generated for all reference groups in the long term.

Massively increase and push ecosystem-restoration measures worldwide

The global importance of restoration measures for climate-change mitigation, biodiversity conservation and food production is also reflected in the significant increase in the amount of political attention being paid to this topic. As demonstrated by the Decade on Ecosystem Restoration (2021-2030) proclaimed by the United Nations, the restoration of forests and landscapes is now a globally recognized approach to combatting the degradation of terrestrial ecosystems. The momentum generated by this Decade should be exploited in the coming years. Achieving the international goal set by the Bonn Challenge to restore 350 million hectares of global terrestrial ecosystems by 2030 (Figure 3.1-10) requires a massive increase in and acceleration of restoration measures. The focus should be on restoring degraded forests rather than on creating plantations (Lewis et al., 2019). 350m ha represents only about 2% of the terrestrial surface.

Significantly expand the area target for restoration

The area target formulated in the Bonn Challenge should be significantly expanded and focus not only on reforestation but also on wetlands and grasslands – especially since the goal of designating 30% of the Earth's surface as protected areas also has to be backed up by restoration measures.

Greatly expand the Global Partnership on Forest and Landscape Restoration

The number of states (currently approx. 60) that have committed themselves to carrying out restoration measures within the framework of the Global Partnership on Forest and Landscape Restoration (GPFLR) in the context of the Bonn Challenge should be massively expanded – on condition that plantations and monocultures are excluded. This would equally contribute to the goal of expanding global protected-area systems to cover 30% of the Earth's surface. To this end, Germany should form coalitions with other EU countries to provide financial and logistical support for the implementation of restoration measures, especially to developing countries. The EU Biodiversity Strategy for 2030 is exemplary in this respect. Existing financing mechanisms, such as the GEF or the development banks, should be more strongly geared to this task and financially strengthened as a support measure. UN-Environment and the FAO are already making important conceptual contributions here.

Increase support for NGOs and civil-society initiatives

It is necessary to set up support programmes specifically for civil-society initiatives and NGOs that implement restoration. They require more financial support, for example in the form of start-up funding or to cover their personnel costs. At the same time, there is great potential for harmonizing existing funding instruments and establishing a uniform funding line. The different funding programmes of state institutions (e.g. the German Federal Ministry for the Environment, the promotional bank KfW) should therefore be better coordinated and interlinked.

Combine COVID-19 recovery programmes for developing countries with sustainable land use

Many Least Developed Countries (LDCs) have valuable terrestrial ecosystems that are affected by degradation. At the same time, these countries are particularly exposed to the economic consequences of the COVID-19 pandemic. They urgently need support from economic stimulus packages, whose design should be linked to multi-benefit strategies involving sustainable land-use practices and the conservation of terrestrial ecosystems, combined with income-generating measures. The IMF, World Bank and regional development banks are particularly called upon here. The G20 could set the political framework for this, especially as land degradation was on the agenda of the Saudi Arabian G20 presidency in 2020.

Design financing mechanisms with sustainability in mind

In order to promote ecosystem-restoration measures, it is necessary to take into account the complexity of the topic and the long-term horizon of implementation. Accordingly, funding programmes should be designed for the long term and not only initiate the process of restoration but also accompany it for its entire duration. In addition, the financing of restoration measures should be designed systemically and include all ecological, social and economic perspectives.

3.1.5 Research recommendations:

3.1.5.1 Research recommendations: CO_2 removal

The WBGU sees significant and risky deficits up to now in the public and political perception of methods for removing CO_2 from the atmosphere and in the status of research and development. Against this background, the WBGU welcomes the BMBF's newly issued funding guideline for projects dealing with 'Methods of Atmospheric Carbon Dioxide Removal', whose thematic focus already comprehensively addresses these deficits. Because of the central role of CO_2-removal methods for climate-change mitigation, and not only in the short term, this funding should be continued in the long term and on an appropriate financial scale to address the research questions listed here. There is a considerable need for research and development, both with regard to individual technologies and approaches to CO_2 removal and on how a portfolio of promising measures can make a resilient, sustainable contribution to climate protection; examples include strengthening resilience to climatic changes and ensuring that concomitant effects on other priorities, such as biodiversity conservation and food security, are positive or at least not seriously negative. The same applies to the structures and mechanisms needed at the international, national and organization-based governance levels to integrate CO_2 removal alongside CO_2 avoidance into the climate-protection architecture and to finance these structures.

Examine sustainable methods and potential for the removal of CO_2 from the atmosphere

In order to achieve net-negative emissions world-wide in the second half of the century, more precise assessments are needed of the extent to which CO_2 removal is sustainably possible, i.e. technically, economically and politically possible without causing land-use conflicts as outlined in the land-use trilemma or jeopardizing sustainable development goals in a broader sense. There is a need for research in this area at the national, regional and international level. These findings are also essential for formulating independent climate-policy targets for CO_2 removal at all these levels. The technical and ecological characteristics of the respective approaches and geographical differences between countries or regions must be taken into account here with regard both to country-specific prerequisites for the implementation of CO_2 removal and to country-specific sustainability risks. Furthermore, a deeper understanding is also necessary of how dependent sustainable potential is on socio-economic developments that go beyond the realm of land use. Finally, it is important to develop a more precise understanding of trade-offs and synergies between different methods of CO_2 removal, in order not to overestimate aggregated potential and, with the help of suitable combinations of different CO_2-removal methods, to avoid a greater scaling of a single approach and the risks this would entail.

Develop suitable structures for governance and financing

There should be detailed scrutiny of the interplay between existing climate-policy structures and new mechanisms yet to be created, following the guidelines outlined in the recommendations for the sustainable expansion of CO_2-removal options. The same applies to suitable regulatory frameworks and to financing instruments for a rapid but prudent expansion of a portfolio of measures. It is also important to develop suitable and effective 'safeguards' based on a more precise understanding of the sustainability risks associated with the application of (land-based) CO_2-removal approaches, to ensure that CO_2 removal is embedded in global, sustainable land stewardship and land-based ecosystems and that technology impact assessments are taken seriously. Suitable monitoring, reporting and scrutiny of the desired CO_2 removal are important components.

Use government funding to research and develop a broad portfolio of methods and accelerate their market readiness

The majority of CO_2-removal methods are neither technically nor commercially mature, but are currently still being researched, developed or tested in demonstration plants. Known uncertainties, risks and potential multiple benefits are considerable, including for all dimensions of the trilemma: climate protection, biodiversity and food security. However, climate-change-mitigation scenarios show that considerable amounts of atmospheric CO_2 would already have to be removed by the middle of the century, especially to limit global warming to 1.5°C. Key research questions therefore focus on which incentive structures enable the further development and rapid, yet sustainable expansion of a portfolio of approaches; which funding models, political framework conditions and private business models are suitable for this; and how a prudent combination of diverse market-ready approaches can be realized in such a short time. Ethical issues such as global, intra- and intergenerational justice must also be taken into account. In science and in the communication of scientific results, transparent distinctions should therefore be made between the possible contributions to the climate-policy goals of emissions reductions on the one hand and CO_2 removal on the other.

3.1.5.2
Research recommendations: ecosystem restoration

Assess more precisely the sustainable potential of restoration measures

- *Reforestation:* thinking beyond the area targets of the Bonn Challenge, the question arises as to the globally sustainable potential of measures to reforest woodlands, rewet wetlands and restore grassland ecosystems. Further research is needed to better assess the extent of suitable (sustainable) land area potential, taking into account competing uses and conservation requirements.
- *Grassland ecosystems:* in arid grasslands, shrublands and pastureland, degradation can be reversed by reduced soil compaction, fencing and the removal of livestock, but there are no global estimates of potential (Smith et al., 2019b:600). There is a need for research in this field.

Boost the development of indicators and increase monitoring capacity

National, regional and global networks for monitoring terrestrial degradation processes and restoration measures should be strengthened and new networks established wherever none exist. Monitoring by field observation should be complemented by remote sensing methods. Many of the existing indicators are inadequate; they need to be refined and new ones developed. In particular, there is a need for more accurate global mapping and more precise monitoring of the change dynamics (in near real-time) of peatlands (Crump et al., 2017).

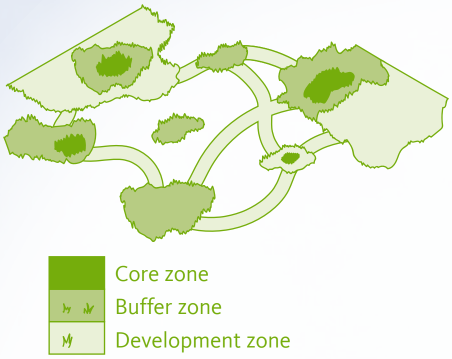
Quality criteria for upgrading protected-area systems. They should be:

1 — Effectively and equitably managed

2 — Ecologically representative

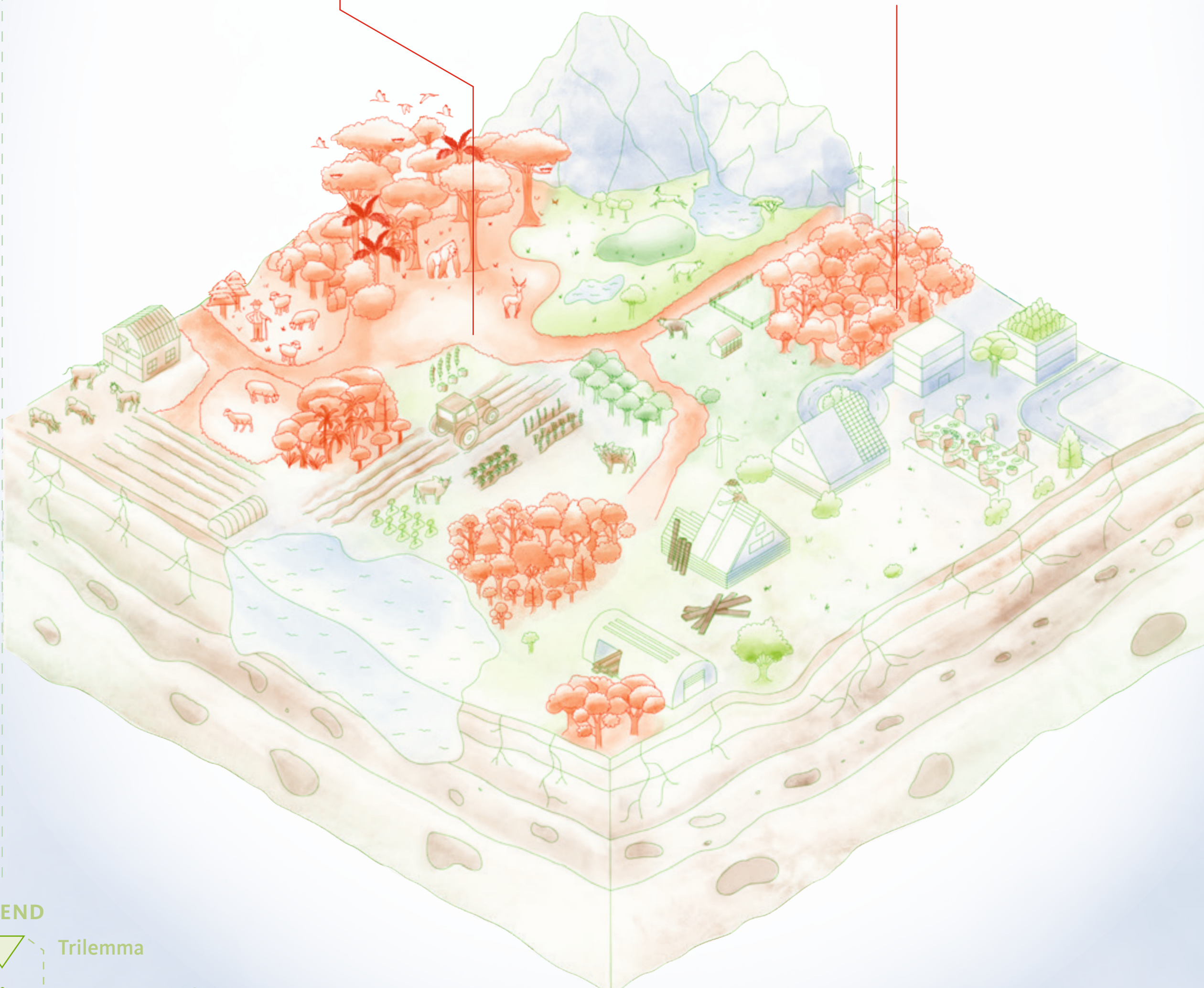
3 — Well connected

4 — Integrated into the landscape



Well connected by means of corridors and **zoning of** protected areas: the zones are shown schematically using the example of biosphere reserves.

15% of land is currently protected. The aim is to expand **protected-area systems to cover 30%.**



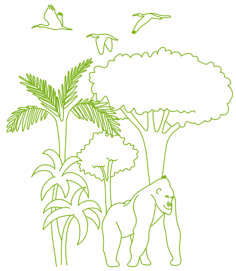
LEGEND

Trilemma

Multiple-benefit strategies

Governance

3.2
Expand and upgrade protected-area systems



Effective, well connected systems of protected areas form the backbone of ecosystem conservation and are indispensable for stopping the global biodiversity crisis. Preventing further destruction of ecosystems, especially in areas inhabited by Indigenous Peoples and Local Communities, also benefits climate-change mitigation. Furthermore, multiple benefits for food security can be realized. The WBGU recommends expanding terrestrial protected-area systems to cover 30% of the global land surface and consistently applying internationally agreed quality criteria.

3.2.1
Ecosystem conservation: problems and multiple benefits

Biodiversity and ecosystem services are of critical importance to people, society and the transformation towards sustainability. Yet the world is currently experiencing a biodiversity crisis (Section 2.2.3), which is powerfully illustrated in the Assessment Reports of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2018a, 2019a). Land-use changes – i.e. the destruction and fragmentation of intact ecosystems primarily for the purposes of agriculture, forestry and the construction of civilizational infrastructure (e.g. cities, transport and energy infrastructure, mining) – are a major direct driver of this crisis. This applies equally to terrestrial and freshwater ecosystems. The main focus of current ecosystem destruction is in the tropics, where most biodiversity is located. For example, natural forests lost 290 million ha to deforestation between 1990 and 2015 (for comparison, the area of the EU is approx. 413 million ha), while timber plantations, which host only a fraction of biodiversity, increased by 110 million ha (IPBES, 2019b: 28). Natural wetlands and grasslands have also been increasingly converted for agriculture. The extraction of mineral resources has risen considerably in parallel. Here, major causes for concern are not only the destruction of directly affected natural areas, but also the pollution of soils and water with toxic substances, with all the consequences for humans and biodiversity. One example is gold mining (e.g. in forested areas of the Amazon basin), which involves increasing levels of forest clearance and degradation, mercury poisoning of humans and the environment, and reduced carbon sequestration on the land in question (Bebbington et al., 2018; Kalamandeen et al., 2020). Other major immediate drivers of the biological depletion of ecosystems include the direct overexploitation of wild-animal populations and plant stocks (by harvesting, hunting and fishing), colonization by invasive alien species, of which anthropogenic trade flows between continents are a major driver, and – of rapidly growing significance – climate change (IPBES, 2019b:28; Section 2.2.1). With reference to protected areas, the WBGU limits itself in this report to terrestrial ecosystems and the freshwater ecosystems embedded in them (inland waters).

Humanity's destructive approach to nature is driven by demographic and economic factors with short-term economic calculations being the primary cause, while the costs of destroying nature are generally externalized. Moreover, government subsidies frequently exacerbate damage to ecosystems (OECD, 2019). Although spending on ecosystem conservation is rising, it is still considerably lower than the subsidies that contribute to ecosystem degradation or destruction (IPBES, 2019b:30; Section 3.2.3.7). One fundamental problem is that ecosystem services are commons and as such are hardly taken into consideration in national economic accounts and private-sector calculations (IPBES, 2019b:14; Box 4.2-4). For example, the value of crop pollination as an ecosystem service is not taken into account, despite the fact that globally more than three quarters of the most important food crops depend on animal pollination for their fruits to develop (IPBES, 2016).

The aim must be to reverse this momentum of loss (Leclère et al., 2020). Maintaining biodiversity and ecosystem services is increasingly becoming a challenge for the whole of humankind, as many of the SDGs will become unachievable if the current loss continues (IPBES, 2019b:14). The conservation of the remaining natural and near-natural ecosystems is essential for meeting this challenge, as is the maintenance of traditional sustainable land use in old cultural landscapes. We need to find ways of protecting ecosystems that not only enable the long-term conservation of biodiversity and ecosystem services, but also reveal synergies with the other dimensions of the trilemma (climate change and food security; Section 2.2; WWF International, 2020a):

- *Ecosystem conservation and the biodiversity crisis:* The conservation of intact ecosystems is the decisive approach to solving the biodiversity crisis (IPBES, 2019b; CBD, 2010a; Section 2.2.3) and has therefore been firmly embedded in science and governance for a long time (WBGU, 2001:126ff.). This is by no means only a matter of primary ecosystems, which up to now have hardly been exposed to human influence. Attention must also be paid to cultural landscapes which, in Europe for example, have developed over very long periods of time in co-evolution with sustainable use, are rich in biodiversity and can only be preserved by maintaining sustainable use (or corresponding landscape management). Furthermore, the conservation of ecosystems is very closely linked to their restoration, which is another indispensable strategy for solving the biodiversity crisis (Section 3.1; IPBES, 2018a:353; Sanderson et al., 2018). Stopping further land conversions and with them the destruction of intact ecosystems is already a fixed feature of the multilateral canon of goals (CBD, 2010a). This objective goes far beyond formal protected-area systems made up of individual protected areas; it also includes wilderness and the areas protected *de facto* by Indigenous Peoples and Local Communities (IPLCs), and should be regarded as a general task in the design and use of landscape (Section 3.2.3). Current scenarios show that increased efforts for ecosystem conservation and restoration have a significant positive impact on the future of biodiversity (Leclère et al., 2020).

- *Ecosystem conservation and the climate crisis:* Addressing the parallel biodiversity and climate crises simultaneously is a major challenge (Dinerstein et al., 2020; Barbier et al., 2020). Decisive interactions are involved here (Melillo et al., 2016): on the one hand, the uptake of CO_2 from the atmosphere (CO_2 sink function) and its conversion into biomass is an ecosystem service (IPBES, 2019b:23) and the conservation of natural carbon stocks and sinks is of great importance for climate-change mitigation (Section 2.2.1). The destruction of intact ecosystems for agriculture also means the release of additional climate-damaging CO_2 emissions. Therefore, alongside the phase-out of fossil fuels, sustainable land stewardship is seen as critical to achieving the temperature goal of the Paris Agreement (Section 2.3; Griscom et al., 2017). On the other hand, anthropogenic climate change is an important and increasingly powerful driver of the biodiversity crisis and a threat to ecosystems (IPBES, 2019b:13,16). Even regions where temperatures have hitherto been stable – which are often also hotspots for biodiversity (e.g. the Philippines or Madagascar, Mittermeier et al., 1999:53) – are increasingly being threatened by climate change (Brown et al., 2020). Anthropogenic climate change could cause the extinction of a sixth of all species (Urban, 2015). At the same time, not only populations of wild species but also global patterns of agricultural management systems are shifting polewards and upwards, thus causing additional challenges for protected-area systems and new threats to biodiversity and ecosystems (Loarie et al., 2009; Hannah et al., 2020). Thus, mitigating the climate crisis is simultaneously a decisive factor in addressing the biodiversity crisis.
- *Ecosystem conservation and the food crisis:* Increased food production causes and exacerbates the biodiversity crisis as a result of the industrial use of agricultural land and the conversion of natural ecosystems into agricultural land, as well as the resulting increase in competition for land use (Section 2.2.2). In addition, the supply of freshwater is a very relevant service in the food context provided by (often protected) ecosystems; one third of the world's 100 largest cities depend significantly on forested protected areas for their supplies of drinking water (Dudley and Stolton, 2003; Dudley and Hamilton, 2010). Near-natural ecosystems also provide positive, in some cases indispensable ecosystem services for agriculture in the surrounding landscape (e.g. pollination; IPBES, 2016; Section 3.3). The conservation of those wild species that are closely related to cultivated plants is of crucial importance for the resilience and further breeding of such plants (Section 3.2.3.2). Protecting them in their natural habitats therefore makes a further contribution to long-term food security. Finally, the protection of areas inhabited and used by IPLCs in traditional ways contributes directly to their food security and food sovereignty and is key to safeguarding their lifestyles (Section 3.2.3.5; Pimbert and Borrini-Feyerabend, 2019).

Protected-area systems are not only highly effective instruments for protecting ecosystems and thus for conserving biodiversity and ecosystem services, they also offer strategic multiple benefits for climate protection and food security, which are a major focus of attention in this report (trilemma of land use, Section 2.2). Section 3.2.3 therefore examines protected-area systems as a multi-benefit strategy.

3.2.2 International goals for ecosystem conservation

The topic of ecosystem conservation fits well with the WBGU's normative compass (Box 2.3-1; concept and examples in WBGU, 2016a:127ff.; WBGU, 2019b:35ff.). It can be broken down into its three categories as summarized here:

- *Sustaining the natural life-support systems:* In line with multilateral goals (Section 3.2.2), the WBGU has proposed halting the loss of biodiversity and

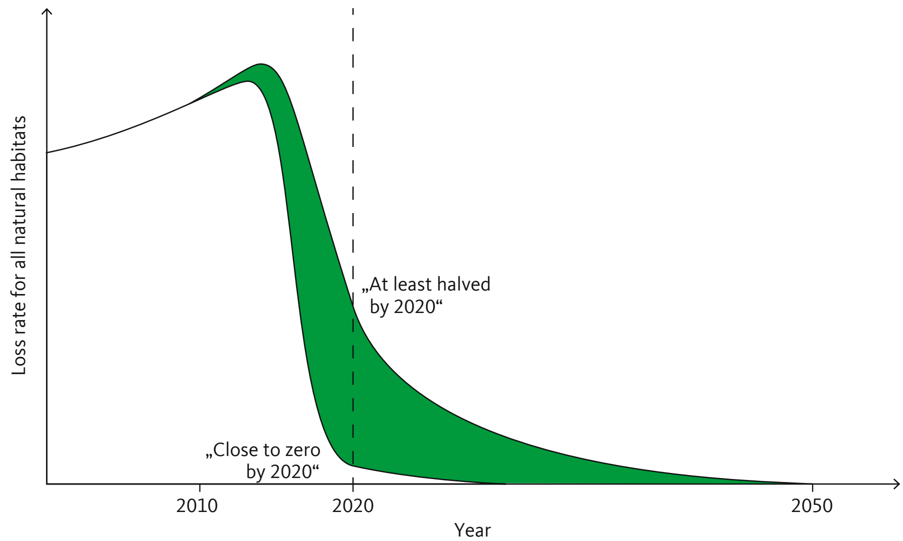


Figure 3.2-1
Schematic diagram showing global development paths of the rate of loss of natural habitats. This figure elucidates the great challenge of Aichi Target 5 at the time when the CBD's Aichi Targets were agreed in 2010. Target 5 states that the rate of loss of all natural habitats should be 'at least halved' – and, where feasible, brought 'close to zero' – by 2020. Up to 2010 the diagram outlines the observed rate of loss. The area shaded green is the area within which the path should have moved after 2010 to achieve Aichi Target 5. There should have been a drastic trend reversal within a few years. However, the trajectory of the rate of loss observable to date shows that this necessary trend reversal has not been achieved. Aichi Target 5 has therefore been missed by a significant margin (SCBD, 2020:52).
Source: WBGU, 2014:31; text of figure caption partly adopted word for word

ecosystem services as a planetary guard rail. The aim should be to stop the direct anthropogenic drivers of biodiversity loss by 2050 at the latest (WBGU, 2014:4).

- *Inclusion:* One aspect of the realization of societal and political inclusion for everyone is enabling them to get involved in the management and shaping of their natural environment. For IPLCs, economic inclusion in ecosystem services is also of great importance; they should therefore be able to participate in ecosystem conservation in general and in the management of protected areas in particular (e.g. Section 3.2.3.5)
- *Eigenart:* Socio-cultural diversity is a core element of *Eigenart* (a German word meaning character), and for many people – especially IPLCs – it is closely linked to biodiversity, ecosystems and their services both in natural ecosystems and in cultural landscapes (UNEP, 1999). When they are destroyed, traditional knowledge about nature is also lost – knowledge which is valuable, among other things for climate adaptation and for the conservation and study of cultivated and medicinal plants (Nakashima et al., 2012; Cámara-Leret et al., 2019).

The multilateral canon of goals for overall ecosystem conservation is explained below; target achievement is discussed in Section 3.2.3.3 specifically for protected-area systems.

'Living in Harmony with Nature' is both the title and the vision of the Strategic Plan for Biodiversity 2011-2020 (CBD, 2010a). Together with the 'mission' of taking effective and urgent action to halt the loss of biodiversity, and the plan's specific targets (currently the 'Aichi Biodiversity Targets', from 2021 the corresponding post-2020 targets; CBD, 2020), it can be regarded as an overarching, multilaterally recognized set of goals for interacting with nature. Three of the 20 Aichi Targets that are either specifically related to ecosystem conservation or to financing (CBD, 2010a) are mentioned here as examples:

- *Aichi Target 5* refers to reducing the drivers of habitat loss: "By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced." Achieving this target was a major challenge, as illustrated by Figure 3.2-1, and it was missed by a large margin (SCBD, 2020:52ff.). This makes it all the more important to look at the barriers and actors that play a role in containing the drivers (Section 3.2.3.4).

Box 3.2-1

Definition and categories of protected areas

Definition

The IUCN defines a protected area as follows: "a protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values."

Categories

The definition is extended by *six management categories* (one with a subdivision), which are summarized below. German nature-conservation legislation is also based on these categories.

Ia Strict Nature Reserve: Strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphical features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.

Ib Wilderness Area: Usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

II National Park: Large natural or near-natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.

III Natural Monument or Feature: Protected areas set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.

IV Habitat/Species Management Area: These protected areas aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.

V Protected Landscape/Seascape: A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

VI Protected area with sustainable use of natural resources: These protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

The priority objective should apply to at least three quarters of the protected area – the 75% rule.

Types of governance for protected areas

The IUCN distinguishes four governance types (a description of who holds authority and responsibility) for protected areas, to each of which any management objectives can be assigned:

- *Governance by government:* federal or national ministry/agency in charge, sub-national ministry/agency in charge, government-delegated management (e.g. to NGO);
- *Shared governance:* collaborative management (various degrees of influence), joint management (pluralist management board), transboundary management (various levels across international borders);
- *Private governance:* by individual owners, by non-profit organizations (NGOs, universities, cooperatives), by for-profit organizations (individuals or corporate);
- *Governance by Indigenous Peoples and Local Communities: (1) areas and territories declared and governed by indigenous people; (2) protected areas and territories declared and governed by local communities.*

Source: IUCN, 2008

- *Aichi Target 11* refers to protected-area systems and specifies both quantity targets (concrete area targets) and quality criteria: "By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes." Target achievement for protected-area systems and the need to raise the targets are considered separately in Section 3.2.3.3.
- *Aichi Target 20* includes the agreement to substantially increase the mobilization of financial resources by 2020. The plan emphasizes that implementation in developing countries depends on financial contributions from industrialized countries and requests the Global Environment Facility (GEF), the CBD's financial mechanism, to provide adequate, timely and predictable financial support. The target was only partially achieved; the expansion of conservation funding continues to be offset by considerable subsidies that harm biodiversity (SCBD, 2020:44, 120).

The *United Nations 2030 Agenda* (UNGA, 2015) also builds on the work of the CBD in formulating its goals.

SDG 15 is particularly relevant for the conservation of terrestrial ecosystems: "Protect, restore and promote the sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, halt and reverse land degradation, and halt biodiversity loss". The 2030 Agenda also has a funding target: "15.a: Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems."

The overall conclusion is that the global goals for ecosystem and biodiversity conservation are differentiated and appropriate, but that achievement of the goals remains highly unsatisfactory. The targets of the first Strategic Plan for Biodiversity (2002-2010; CBD, 2002) were already missed. And regarding the implementation of the last Strategic Plan (2010-2020; CBD, 2010a), none of the 20 targets were fully achieved at the global level, and only six were partially achieved (SCBD, 2020; Section 3.2.3.3). The trends remain negative for biodiversity and the great majority of ecosystem services despite the action that has been taken up to now (IPBES, 2019a: Ch. 2.3.6; IPBES, 2019b:14). The targets cannot be met in business-as-usual scenarios, and further scenario analyses show that nature and its contributions to people will degrade drastically if there is no transformative change of course (Díaz et al., 2019). The proclamation of a 'UN Decade on Ecosystem Restoration' (2021-2030; Section 3.1) directly following the 'UN Decade on Biological Diversity' (2011-2020) points out that much greater efforts are needed to realize the CBD's vision of Living in Harmony with Nature. The current discussion on an 'apex target' for the CBD is taken up in Box 4.4-3.

3.2.3
The expansion and upgrading of protected-area systems as a multiple-benefit strategy

Protected-area systems can contribute to all three dimensions of the trilemma (Section 2.2), and are therefore treated as a multi-benefit strategy in this Section 3.2; they are subsequently focused on *three priority topics* as examples: IPLCs' services for ecosystem conservation (Section 3.2.3.5), the integration of protected-area systems into the landscape (Section 3.2.3.6) and the financing of protected-area systems (Section 3.2.3.7).

This multiple-benefit strategy is embedded in the larger context of a transformation towards sustainability (WBGU, 2011). The term 'transformative change' is therefore playing an increasingly important role in scientific and policy discourses on ecosystems and biodiversity (Díaz et al., 2019; IPBES, 2019b:14; SCBD, 2020). However, the societal, economic and political points of departure for this transformative change that affect ecosystem conservation lie to a large extent outside the protected areas. Such points of departure include, for example, the drivers that lead to ecosystem degradation inside and outside protected areas via telecouplings, the design of framework conditions for appreciating ecosystems and their services (Box 4.2-4), and the support options for private actors and by industrialized countries in international cooperation alliances (Section 4.5).

3.2.3.1
Protected-area systems as instruments of ecosystem and biodiversity conservation

Many of the drivers of the biodiversity crisis mentioned in sections 2.2.3 and 3.2.1 can be countered by designating and upgrading protected areas in which biodiversity conservation is a priority. It is widely recognized in science and governance that protected-area systems are indispensable and effective tools for conserving ecosystems, their services and biodiversity (IPBES, 2018a:488, 2019a:Ch. 2.1; IUCN, 2014; CBD, 2004; UNEP-WCMC, 2018; Leclère et al., 2020; Jones et al., 2018; Gaston et al., 2008).

On the one hand, *protected areas* are formally designated areas under national or international nature-conservation law, where effective ecosystem and biodiversity conservation is the priority objective. They are defined by the IUCN as follows: "A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (IUCN, 2008; Box 3.2-1). On the other hand, there are also "other effective area-based conservation measures" which are not formally designated protected areas, but are "governed and managed in ways that achieve positive and sustained long-term outcomes for the *in situ* conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio-economic, and other locally relevant values" (OECMs: CBD, 2018d; Woodley et al., 2019). In addition to e.g. private protected areas, these include in particular areas used and conserved by IPLCs in the context of their traditional lifestyles (Section 3.2.3.5; CBD, 2018b; UNEP-WCMC, 2016a; IUCN, 2017).

Contrary to frequent misunderstandings, protected areas are by no means about excluding any use other than nature conservation, but merely about giving *priority* to nature conservation. This can often be reconciled with sustainable use, and in some cases is even synergistically dependent on it, e.g. in the conservation of extensive pasture farming or with regard to arable

Box 3.2-2

Digitalization for monitoring ecosystems and biological diversity

The massive increase in the degree of networking, data storage and computing power is leading to increased discussion, research and application of digital or digitally supported methods (WBGU, 2019b:200ff.). Corresponding technologies open up promising prospects especially in the regulation and management of protected areas, although attention must be paid to safeguarding human privacy in observed regions – as is the case with all such digital applications (WBGU, 2019b:78f.).

Remote sensing (Box 3.1-2) based on digital photography, acoustic recorders or GPS sensors for wildlife tracking is already in widespread use (Fig. 3.2-2; WBGU, 2019b:201ff.). Furthermore, the specific monitoring, e.g. of the habitats of endangered species (Brooks et al., 2019) can be supported by the use of digital technologies such as drones (Lipsett, 2019). The evaluation of images from photo traps using artificial intelligence (WBGU, 2019b:71ff.) also offers options for combating poaching. Citizen science (CS) has great potential for collecting better and more up-to-date knowledge (Fig. 3.2-3).

CS is a productive resource in the field of biodiversity and the CBD, especially with regard to Aichi Target 18 on integrating indigenous and local knowledge. Although different knowledge systems regarding evidence and validation can be methodologically challenging (Danielsen et al., 2018), this problem can be addressed beyond digital methods with approaches from qualitative social research and mixed methods. These include focus groups (targeted, moderated group discussions on a topic) and triangulation (using different perspectives to gain a multi-layered understanding of the research subject; Diaz-Bone and Weischer, 2015:140, 414).

Digitalization can support existing CS projects, e.g. with online platforms or apps, and open up new participatory potential. Of course, this cannot be 'decreed' from the top down, but can only emerge on a voluntary basis from a local perspective via corresponding motivation and participation (Chandler et al., 2017; Pocock et al., 2018a). The international ICARUS initiative (2019), for example, uses satellite-based mini-transmitters to systematically observe the lives of various small animals. Not only behavioural science but also species conservation, the spread of infectious diseases and early-warning systems for ecological changes and natural disasters can be better researched in this way. Moreover, ICARUS provides an 'animal tracker app' offering the worldwide communication and use of observations by hobby animal observers, including the real-time tracking of wild animals. Such virtual observation opportunities promote more detailed knowledge of animal habits and make it possible to get much closer to the animals under observation. An app called *Naturblick* also offers an approach that increases awareness; it was developed by Berlin's *Museum für Naturkunde* (Natural History Museum) with funding from the BMU (MfN, 2020). It enables the user to digitally identify species of animals and plants on the basis of video and audio recordings and to map biodiversity at natural sites. Initially limited to Berlin, the pilot project is being expanded to the whole of Germany after more than 130,000 downloads (as of 2019); at the same time, it offers users a chance to support research by making their own recordings, e.g. of a nightingale singing. Furthermore, there are already other popular apps with a narrower focus, such as *Flora Incognita* from the Technical University of Ilmenau and the Max Planck Institute for Biogeochemistry Jena (Flora Incognita, 2019), Pl@ntNet (2020) and BirdNet, an app developed at the TU Chemnitz for the AI-supported recognition of bird calls (TU Chemnitz, 2019). When correctly used, the latest version of the latter is already better than human observation (Darras et al., 2019a) and could produce even better results by combining audio recordings with image data from camera traps. The European and eventually global further development, dissemination and use of such apps in an interoperable open-data ecosystem would promise great potential for an improved data pool, while raising awareness

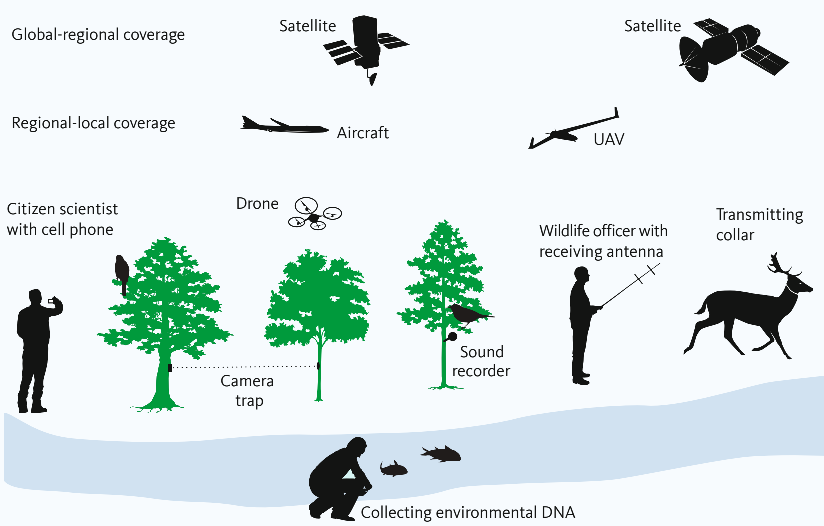


Figure 3.2-2
Overview of digitally enhanced techniques for monitoring ecosystems and biodiversity.
Source: modified according to P. Huey/Science from W. Turner, Science 346:301 (2014). Reproduced with the permission of the AAAS

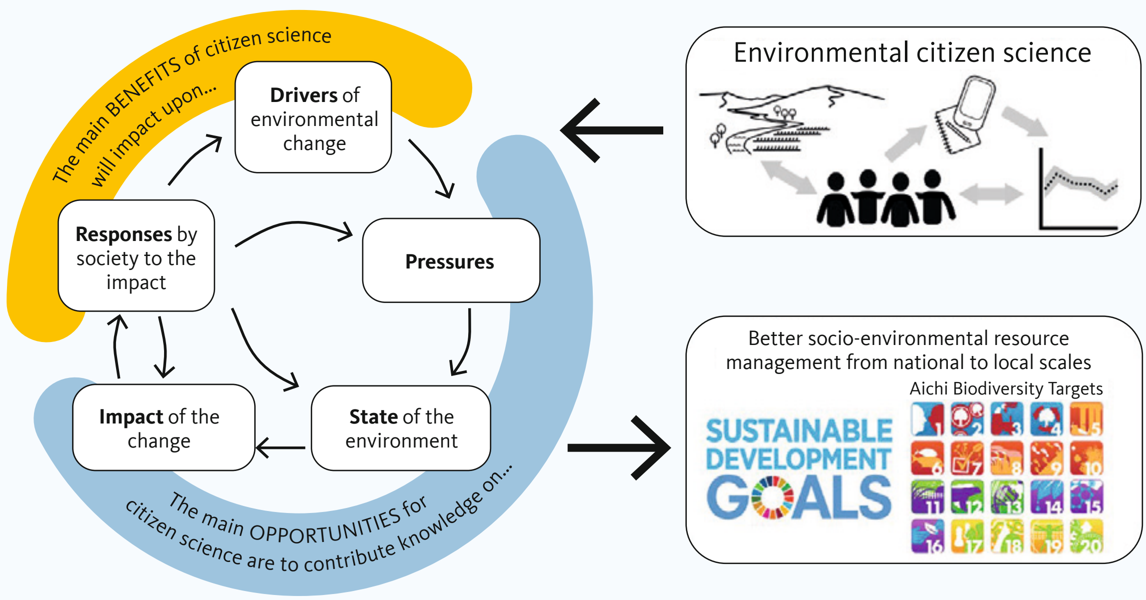


Figure 3.2-3
Citizen science for environmental protection and SDGs, and in particular for monitoring biodiversity in local and global contexts.
Sources: Pocock et al, 2018b (CC BY 4.0)

of the environment and nature.

Some research infrastructures and data repositories can already be used for citizen science, e.g. the European Biodiversity Portal (EU BON, no date), an overarching directory of projects, tools and best practices, or the Global Biodiversity Information Facility (GBIF, 2020). In addition, the Citizen Science Global Partnership (Citizen Science Global Partnership, 2020) is an international CS networking platform explicitly focused on sustainability and the SDGs. Apart from participatory opportunities to improve scientific data quality, local knowledge and environmental awareness through digitally supported CS, the increasing amount of online data is also generating new research fields and visions. However, their feasibility is open to critical questions. For example, 'iEcology' (Jaric et al., 2020), i.e. 'internet ecology' in the context of ecological informatics, aims to bring together various online data sources and methods.

It aims to improve understanding of sustainability challenges by offering broader insights into temporal and spatial population distributions, interactions and dynamics of organisms and their environment in the context of human impacts. The initial phase, which, similar to the earlier field of digital humanities, was characterized by great optimism, is likely in practice to come up against the limits of big data and artificial intelligence (WBGU, 2019b), at least for the time being, if, for example, "the complete automation of all data-processing steps up to visualization" is predicted "for the near future" (Jaric et al., 2020:8). From today's perspective, it seems dubious to promote as continuously updated research a vision of a global digital real-time monitoring initiative based only on internet data, e.g. as an 'automatic' analysis and categorization of all uploaded YouTube videos.

Internet data are by no means exact representations of reality and, apart from data quality, the research field stands or falls with further research on validation and transparency in the field of artificial intelligence (WBGU, 2019b:71ff.; Marcus and Davis, 2019; Dignum, 2019). The high energy requirements for cloud infrastructure and computer centres (Bietti and Vatanparast, 2020), especially for training neural networks for machine learning, has not yet been considered in this vision. Whether in the context of biodiversity and protected areas or in sustainable land stewardship, it is a general rule that progress in monitoring via digitalization is rarely a case of 'low hanging fruits'. Rather, it must be achieved incrementally, and this requires both human and technical as well as temporal and financial resources. Furthermore, as in all application areas, the following statement applies: "Technology can help deliver a lot more knowledge, but governments still need to act" (Lipsett, 2019).

farming in cultivated landscapes. There is therefore a tiered system of conservation and sustainable use ranging from strict protection to allowing specific sustainable resource use, e.g. in the context of cultural landscapes. For this purpose, the IUCN (2008) has developed a differentiated classification of protected areas with six categories (Box 3.2-1). Three zones are defined in the UNESCO biosphere reserves (UNESCO-MAB, 2020; BfN, 2020):

- the *core area:* securely protected sites that allow no human use other than low-impact use (such as monitoring, research, education),
- the *buffer zone*, which surrounds or adjoins the core zone and serves to preserve and maintain ecosystems that have been created or are influenced by sustainable use; among other things, it can be used for environmental education, recreation, ecotourism and research, and
- the *transition area*, which surrounds the buffer zone, serves to implement sustainable development; among other things, it may allow sustainable use and may contain settlements.

A *protected-area system* composed of individual protected areas should meet the following criteria (CBD, 2010a; CBD, 2004; Section 3.2.3.3): (1) the system should be effective in terms of the conservation objectives; (2) it should be managed equitably – i.e. the planning and operation of the protected areas should be integrated into society (i.a. through stakeholder participation, including IPLCs, Section 3.2.3.5); (3) the system should be ecologically representative, i.e. it should cover genetic, species and ecosystem diversity in the best way possible; (4) the individual protected areas should be well connected (e.g. by corridors for population migration, including across national and bioregional boundaries); (5) the system should be integrated into the surrounding landscape, which is mostly shaped by agriculture, forestry or settlements according to an integrated landscape approach (Box 2.3-3; Section 3.2.3.6; Winter et al., 2018).

This last criterion of *landscape integration* is especially important. While biodiversity conservation is impossible without systems of protected areas, they are not enough on their own to halt biodiversity loss. For this reason, Section 3.2.3.6 focuses on the importance of protected-area systems in the landscape (see Box 2.3-3 on the integrated landscape approach).

3.2.3.2
Multiple benefits in protected-area systems

The priority objective of protected-area systems is initially to contribute to ecosystem and biodiversity conservation. In view of the systemic interdependencies and the increasing pressure of use (Chapter 2), it also makes sense to realize multiple benefits in the protected areas, as long as this can be reconciled with the priority objective of nature conservation (Stolton and Dudley, 2010). This section looks at how seemingly conflicting interests can be better reconciled with each other, both within the protected-area systems themselves and in connection with the surrounding landscape. Multiple benefits in the context of the land-use trilemma described in Section 2.2 are the main focus here; the many other positive effects (e.g. on the provision of water and genetic resources for the development of pharmaceuticals, the reduction in the risk of natural disasters, sustainable tourism; Stolton and Dudley, 2010) cannot be dealt with here.

Prevent multiple losses by expanding protected-area systems

Protected-area systems can be effective instruments for climate-change mitigation by conserving carbon stocks and sinks. Preserving intact ecosystems that are not only rich in biodiversity, but also store carbon, offer a win-win situation for biodiversity and climate-change mitigation (Field et al., 2020; Jantke et al., 2016). Protected areas currently account for 20% of carbon uptake by all terrestrial ecosystems (0.5 Pg C per year; Melillo et al., 2016). A strategic expansion of protected-area systems can thus address the parallel biodiversity and climate crises simultaneously. From a systemic perspective, however, this can only be effective if the shifts in land-use pressure caused by indirect land-use changes can be offset by flanking strategies (WBGU, 2009). This will help prevent the continuation of the current lose-lose situation of intolerable biodiversity losses and high GHG emissions caused by the conversion of the last remaining intact ecosystems.

Tropical forests and peatlands are among the main intact terrestrial ecosystems. For example, the Amazon is a biodiversity hotspot; protected areas and indigenous territories there store more than half of the region's above-ground carbon. At the same time, only 10% of net carbon loss has occurred there (Walker et al., 2020). Tropical protected areas have also brought about a reduction in deforestation, reducing the corresponding CO_2 emissions there by 29% between 2000 and 2012 (Bebber and Butt, 2017). Maintaining and strengthening natural ecosystem carbon sinks and reservoirs maintains and enhances the removal of CO_2 from the atmosphere (Section 3.1; Di Marco, 2016). In the Amazon, however, the trends are currently pointing in the wrong direction: carbon losses increased by 200% between 2012 and 2016. Not only large-scale deforestation is relevant here; forest degradation and disturbance also account for about half of the losses (Walker et al., 2020).

The areas where IPLCs exercise rights, thus protecting them from destruction, are of great importance for the realization of a win-win situation for biodiversity conservation and climate protection. Another benefit can be achieved by strengthening this protecting effect – the preservation of traditional lifestyles and identity as well as cultural diversity. This includes the indigenous peoples use of the intact ecosystems as a source of food and preserving valuable traditional knowledge about the species they use (e.g. medicinal plants) and about ecosystem interrelationships. For these reasons, IPLCs will be discussed separately (Section 3.2.3.5). Protected areas can also help to cushion negative climate impacts and reduce risks from natural disasters (IPBES, 2019a: Ch.3.2.1).

Finally, the COVID-19 pandemic has clearly revealed the links between the opening, fragmentation and destruction of natural ecosystems and the spread of zoonoses. Ecosystem conservation in protected-area systems can add further value here (Box 3.2-3).

Exploit synergies in ecosystem restoration

There are close links between ecosystem conservation and ecosystem restoration (which the IPBES refers to as 'twin processes'; IPBES, 2018a:353). Reconnecting fragmented near-natural areas, e.g. with corridors between protected areas to facilitate recolonization and climate-induced shifts in populations (Newmark et al., 2017), is one of the focal points of ecosystem restoration; increasing the size of protected areas by incorporating and restoring already degraded areas is another (Section 3.1). Case studies of successful restoration projects can be found all over the world (IPBES, 2018a). Skilfully planned restoration can contribute to climate-change mitigation through its sink effect, and generate gains for rebuilding biodiversity and ecosystem services. By serving as source sites, existing protected-area systems can make a strategic contribution to the recolonization and spread of rare or endangered species in restored ecosystems (Walston et al., 2010).

Provide agriculturally relevant ecosystem services via protected-area systems

Protected areas, natural and near-natural ecosystems also provide services outside their boundaries that are very important – and in some cases indispensable – for agriculture (Section 3.3.1). An important example is the provision of water, which is frequently linked to natural or near-natural ecosystems in protected areas (Harrison et al., 2016). The ecological depletion of landscapes has a negative impact on agriculturally relevant ecosystem services and ultimately on agricultural yields (Dainese et al., 2019). Biodiversity conservation in an agricultural landscape is therefore essential in order to maintain ecosystem services, including (among many others) erosion control, pest management by natural enemies and crop pollination by insects and other wildlife (Leopoldina, 2020; Dainese et al., 2019). The IPBES deliberately devoted its first special report to pollination (IPBES, 2016). By conserving biological diversity, protected-area systems that are planned and managed with an awareness of these interdependencies offer beneficial added value for agriculture and thus also for food security. Linking the two objectives in the landscape is the focus of Section 3.2.3.6 and should be considered in the context of the integrated landscape approach (Box 2.3-3).

Protection of the genetic diversity of crops and livestock: synergies between biodiversity and food security

Our food base is very narrow: only 12 crop species and five animal species provide about 75% of the world's food; this is only a tiny fraction of the 7,000 plant species cultivated for food in the course of human history (IPBES, 2019a: Ch.3.3.2.2). This makes it all the more important from a food security perspective to safeguard and broaden this narrow genetic base for plant breeding, among other things to promote resilience to environmental change, especially adaptation to climate change (FAO, 2010c). However, the great value of plant-genetic resources for food and agriculture is still underestimated.

These resources consist, on the one hand, of the diversity of traditional species, varieties and breeds (Box 3.3-7) and, on the other hand, of the wild species that are closely related to our crops (crop wild relatives, CWRs) or livestock. Although these two reservoirs of genetic diversity are of strategic importance for our food security, they are both at risk (Perrings, 2018; Hammer and Teklu, 2008). Since about the middle of the last century, the diversity of traditional varieties and breeds has been increasingly replaced in agricultural practice by ever fewer high-yielding varieties and breeds (van de Wouw et al., 2010; WBGU, 2000), while the related wild species of our crops and livestock are subject to conversion pressures in their locations, as are all natural ecosystems that can be exploited economically and are not under protection (Hunter et al., 2012).

The genetic characteristics of the related wild species of our crops and livestock are used for further breeding of varieties or breeds (e.g. resilience to diseases and pests and to environmental and climate change; FAO, 2010c; Maxted and Kell, 2009; Maxted et al., 2012; Perrings, 2018). Of the more than 50,000 CWR species worldwide, about 700 are regarded as gene pools for the most important crops and are therefore seen as a priority, yet they are insufficiently represented in protected areas (FAO, 2010c; Fig. 3.2-4). The global value of these genetic resources through higher harvests has been estimated by Pimentel et al. (1997) at US$ 115 billion per year. This potential for both biodiversity conservation and food security deserves increased attention (Hunter et al., 2012). Protected-area systems are already contributing to CWR conservation, yet despite growing recognition of their importance, the

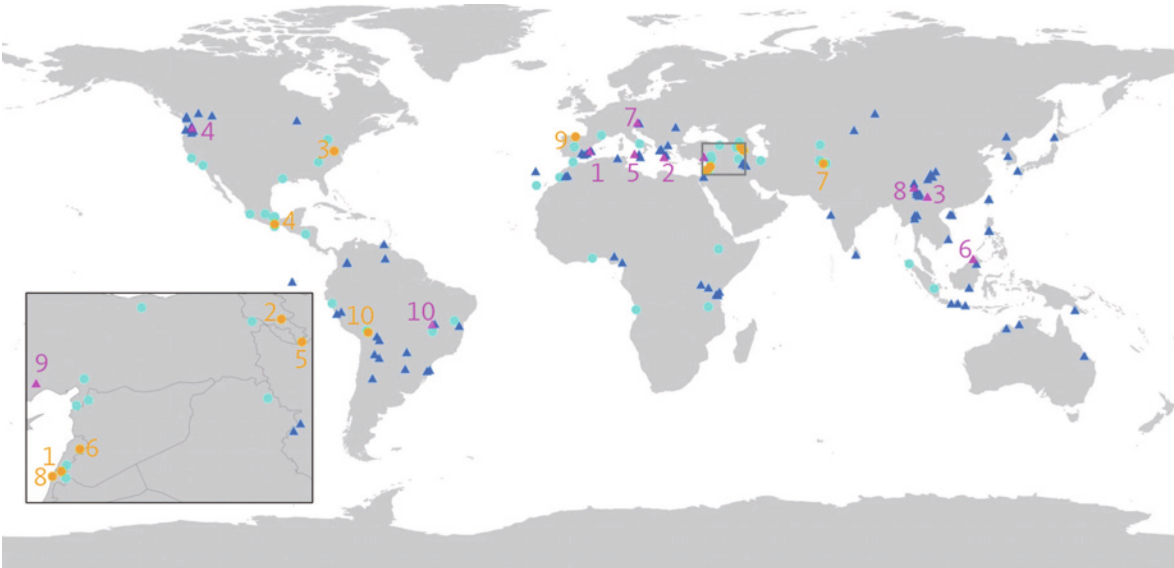


Figure 3.2-4
The 150 most important sites for the in situ conservation of wild species related to our crop plants (CWRs, crop wild relatives; with an enlargement of the 'fertile crescent' in the Middle East and the Caucasus). Magenta triangles: top 10 sites within existing protected areas; blue triangles: the remaining 90 priority sites within protected areas; yellow circles: top 10 sites outside of existing protected areas; turquoise circles: the remaining priority 40 sites outside of protected areas.
Source: Vincent et al, 2019

protection of CWRs remains inadequate (Hunter et al., 2012).

The conservation of traditional crop varieties is also indispensable for food security and for the stability of agricultural systems (Hammer and Teklu, 2008). Nevertheless, there have been significant losses of genetic diversity among crops, and their protection is at the focus of long-standing scientific and political efforts (e.g. FAO, CBD; Godfray et al., 2010). While *ex-situ* collections are very important for conserving this diversity (e.g. gene banks), conservation *in-situ*, i.e. in nature or on farm, remains indispensable and represents a task both of IUCN Category VI protected areas and of transition areas in biosphere reserves with corresponding conservation and management goals (Vincent et al., 2019; WBGU, 2001:72ff.). Protected-area systems can realize a strategic additional benefit here, because the sustainable cultivation of traditional varieties in small-scale agriculture adapted to the traditional cultural landscape can be implemented in protected areas (Stolton et al., 2006). For example, IUCN Category VI protected areas are suitable for safeguarding crop varieties in their natural habitats (Box 3.2-1; FAO, 2019g). Traditional grazing breeds are of great importance for the management of some biodiversity-rich grasslands in protected areas (IPBES, 2019a: Ch.3.2.4).

Agriculture in protected-area systems

As long as the purpose of conservation retains a clear priority, agricultural use can also be possible within protected-area systems if specific regulations are observed (IUCN Category VI, transition area of biosphere reserves). In some cases, the maintenance of traditional use, preferably combined with the use of old crop varieties or traditional livestock breeds, is actually necessary in order to preserve landscape biodiversity, which, has frequently established itself in cultural landscapes, particularly in Central Europe, in co-evolution with traditional forms of use (e.g. alpine farming, extensive pasture farming, heathland). Here, in addition to preserving biological diversity, protected areas make an additional contribution to food security through extensive agricultural food production and by simultaneously safeguarding the genetic diversity of farm animals and crops. The high quality of these agricultural products can certainly only partially compensate economically for the low yields per hectare; the task of safeguarding such genetic resources therefore remains a societal task to be supported financially (Box 3.3-7).

3.2.3.3
Target achievement and future goals

Global target achievement in ecosystem and biodiversity conservation is highly unsatisfactory (Section 3.2.2). None of the 20 Aichi targets have been fully met (SCBD, 2020).

Box 3.2-3

Protected areas: guardians of viruses

Over two-thirds of human infectious diseases are zoonoses (Karesh et al., 2012). A zoonosis is a disease that can be transmitted from an animal to humans and vice versa, but originally stems from an animal (Calisher et al., 2020). Increasing human encroachment into areas with natural ecosystems increases the exchange of viruses through the wildlife/human and wildlife/farm-animal/human transmission routes (Karesh et al., 2012; Johnson et al., 2020). This is in turn determined by two factors:

1. *Land-use changes and habitat loss:* The ongoing destruction of ecosystems leads to increased interactions across all three possible transmission interfaces (Evans et al., 2020). For example, primates and bats threatened by habitat loss have more viruses in common with humans than species that are threatened in other ways (Johnson et al., 2020). In their search for new habitats, they contribute to the spread of zoonotic viruses. The extinction of natural reservoirs (organisms infected with a virus without any symptoms of a disease) reduces the habitat of viruses and thus increases the evolutionary pressure on them. Ecosystem degradation, and specifically forest clearance, leads to an increased occurrence of generalists (e.g. rodents), which frequently act as new hosts and contribute to the spread of the virus due to their flexibility and population size (Johnson et al., 2020; Hong et al., 2020). Furthermore, viruses raise their effectiveness by specializing on one host (Kilpatrick and Randolph, 2012). The combination of evolutionary pressure on viruses and contact with new hosts (generalists) has been increasing the risk of emerging and widespread zoonoses for many years. The fragmentation of habitats could also be a driver of pathogens evolving in parallel (Box 2.2-2). At the same time, the fragmentation of the landscape can lead to more frequent overlaps between viruses and new potential hosts. For example, if cleared land is subsequently used for agriculture with crop cultivation or animal husbandry, the risk of a zoonosis increases, as local contact makes it easier for the virus to jump from animals to humans.
2. *Bushmeat:* Hunting for bushmeat has been a threat to biodiversity conservation for years. However, specifically in Africa and Asia bushmeat is a substantial source of income and food for several million people (Nielsen et al., 2018). Hunger crises and crop failures push the local population to buy, gather or hunt for alternative food sources. The COVID-19 pandemic is exacerbating the global hunger crisis by adding logistical and economic factors (Box 3.3-2). Moving into biodiversity-rich areas and consuming bushmeat increases the local population's contact with new pathogens and worsens the risk of infection. Gillespie and Leendertz (2020) warn of a possible transmission of COVID-19 virus to great apes – another coronavirus has been known in the past to jump from humans to great apes (Patrono et al., 2018). It is currently impossible to predict what consequences a transmission of the virus into natural ecosystems might have.

A zoonosis should be detected as early as possible so that it can be researched and its spread restricted (Box 2.2-2). The best time to do this would be the moment the virus jumps from animal to human (Grubber, 2017). Our knowledge of viruses living in the wild is still very limited (Carlson et al., 2019; Carlson, 2020) and the influence of biodiversity on disease pathogenesis has not been adequately researched as yet. Therefore, although hotspots of zoonotic disease are currently known (Jones et al., 2008; Allen et al., 2017), the virological evolution of a virus with respect to jumping to humans cannot be precisely predicted. The transmission routes of viruses should therefore be at the forefront of political action. Nevertheless, other factors influencing the development of zoonoses should be taken into account. For example, sufficiently large protected areas can reduce the evolutionary pressure on the viruses. Well connected protected-area systems can counter the trend towards global habitat fragmentation. The conservation and expansion of protected areas can help reduce the prevalence of zoonotic diseases and their intensity (Jones et al., 2008; Grubber, 2017; Keesing et al., 2010; Bonilla-Aldana et al., 2020). Setting up protected-area systems within the landscape, taking socio-economic factors into account, can make an important contribution to solving the multidimensional problems surrounding zoonoses.

The conservation and restoration of biodiversity and well-functioning ecosystems is crucial for preventing the emergence and spread of future diseases, and the interlinkages between human health and ecosystem health should be studied (European Commission, 2020c). Protected areas should therefore be planned holistically in line with the concept of 'planetary health' (Box 2.2-2). The risk of zoonoses should be taken into account when designating and connecting protected areas. Areas particularly at risk from zoonotic diseases (e.g. tropical areas with many mammalian species affected by land-use changes, Allen et al., 2017) should be monitored, especially for the benefit of people with frequent contact to wildlife (e.g. IPLCs). Protected areas can also be used for large-scale observations and field experiments to explore the influence of biodiversity and land-use changes (Box 2.2-2) on the threat of disease. The links between wildlife markets and the spread of zoonoses should be reviewed and researched.

Area targets

This disappointing assessment is true despite the fact that Aichi Target 11 on protected-area systems is one of the few areas where significant improvements have been made. The quantitative sub-target of protecting 17% of the land area and inland waters by 2020 may successfully be met or even exceeded in some cases (SCBD, 2020:82ff.; IPBES, 2019a: Ch.3). Between 1993 and 2009, the establishment of protected areas outpaced ecosystem destruction across all biomes and most ecoregions (Watson et al., 2016a). As of September 2020, about 15% of land areas were under protection (UNEP-WCMC et al., 2020; SCBD, 2020:82), when all IUCN protection categories and governance types (Box 3.2-1) are included but not the OECMs (Section 3.2.3.1; Figure 3.2-5). Fewer than half of these pro-

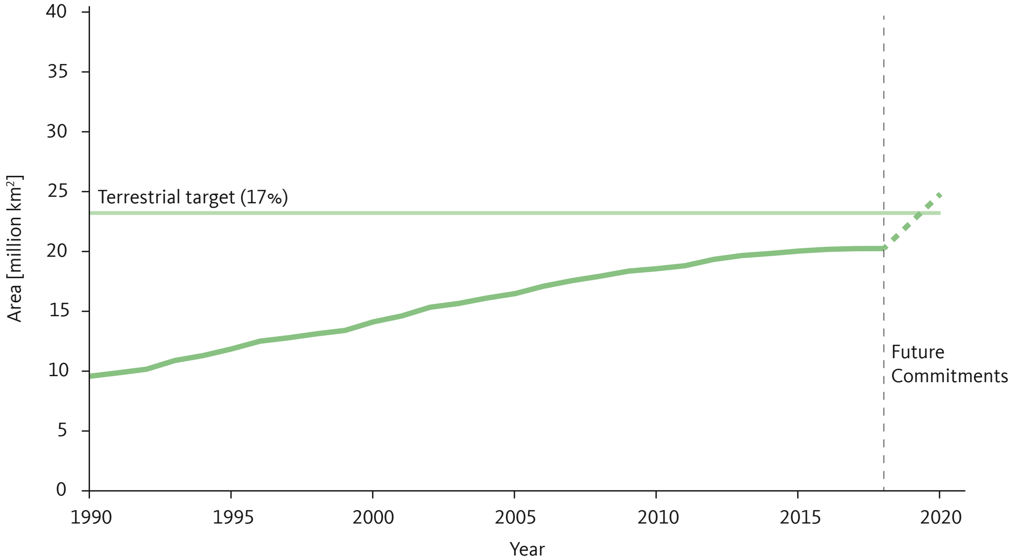


Figure 3.2-5
Development of terrestrial protected areas between 1990 and 2018.
Source: WBGU according to UNEP-WCMC et al., 2020

tected areas were rigorously protected, i.e. corresponded to the IUCN categories I-IV (Box 3.2-1; Kremen and Merenlender, 2018).

However, this positive development must be put into perspective. A scientific consensus is emerging stating that the 17% area target for terrestrial protected areas is much too low to safeguard biodiversity (Review in Woodley et al., 2019). There are serious scientific assessments that 50% or more would be needed to achieve the overarching goal of halting biodiversity loss (e.g. Dinerstein et al., 2020; Drenckhahn et al., 2020; Wilson, 2016; Mace et al., 2018; Dinerstein et al., 2017; Locke, 2013) and to mitigate the effects of climate change (Loarie et al., 2009). The Global Deal for Nature proposal calls for 30% of the Earth's surface to be protected by 2030 and 50% by 2050 (Dinerstein et al., 2019). This far-reaching 'half-earth target' has been criticized as scientifically unsound (Wiersma et al., 2017), unrealistic (Di Minin and Toivonen, 2015) or even counterproductive, as too many people would be directly negatively affected (Schleicher et al., 2019b). Others say it would be difficult to take social impacts into account (Büscher et al., 2017). In any case, selecting the right areas of land and effective management are said to be more important than designating the remaining wilderness areas (Pimm et al., 2018; Di Minin and Toivonen, 2015).

The target recommended by the WBGU several times in recent years of designating 10-20% of the world's terrestrial ecosystem areas (and 20-30% of marine areas) for a global, ecologically representative and effectively managed system of protected areas (WBGU, 2001, 2011, 2014) should be revised upwards by a considerable amount in the light of this current scientific debate. The draft Post-2020 Framework sets a target of 30% (CBD, 2020), which is also taken up in the EU Biodiversity Strategy (EU Commission, 2020c) and supported by the WBGU as a viable compromise. According to an estimate by Müller et al. (2020), the EU would have to expand 'Natura 2000', the European network of protected areas, by 6.6% in order to realize a 30% target that includes the ecological representativeness of ecoregions.

Quality targets

However, the effectiveness of protected-area systems does not depend on area sizes alone; a high level of quality is also vital (Barnes et al., 2018; Pimm et al., 2018; Coad et al., 2019; Woodley et al., 2019). Considerable efforts are still needed to also achieve the qualitative elements of the target (UNEP-WCMC, 2020). Aichi Target 11 of the Biodiversity Convention (Section 3.2.2) lists the following criteria for this: the areas should be managed effectively and equitably, be ecologically representative, well connected and integrated into the wider landscape (CBD, 2010a). There has been only moderate progress on these quality criteria (SCBD, 2020). The focus of goal achievement and goal development should therefore be extended from quantity to quality (Barnes et al., 2018; Pimm et al., 2018; Geldmann et al., 2019).

- *Effectiveness and equity:* The focus here is on an area's ability to withstand threats to ecosystems and biodiversity and to restore lost functions or species populations (e.g. the reintroduction of megafauna as part of ecosystem restoration, Svenning et al., 2016). This ability generally increases with the quality of management (albeit not everywhere significantly: Schleicher et al., 2019a). At present, it is difficult to assess management quality on a global scale because, although there are methods with which to assess the criterion of equitable management, only 9.4% of countries have conducted relevant research (UNEP-WCMC et al., 2018; SCBD, 2020:83). Moreover, designation as a protected area does not necessarily imply a permanent guarantee of protection; protected-area status can also be revoked (Protected Area Downgrading, Downsizing, and Degazettement, PADDD; IPBES, 2019a: Ch. 4.1.5; Section 3.2.3.4).

- *Ecological representativeness:* Protected areas are frequently designated not necessarily where threatened species are best protected, but where there is little conflict with agricultural or other uses (Venter et al., 2018). However, to achieve a strategic selection of areas for expanding and interconnecting protected-area systems, a representative range of regional ecosystems and threatened species should be included (Pimm et al., 2018). This does not happen frequently enough at present (Butchart et al., 2015); progress towards representativeness since 2010 is described as moderate (SCBD, 2020). The global protected-area system thus provides inadequate coverage of the most important areas for biodiversity (IPBES, 2019a: Ch. 3.2.2): only 47% of terrestrial key areas with significant importance for biodiversity conservation (Key Biodiversity Areas; IUCN, 2016b) and 43% of terrestrial biogeographic regions (ecoregions: Olson et al., 2001) are covered by protected areas. By contrast, almost 5% of biogeographical regions are assessed as highly threatened because the rates of loss due to land-use changes are very high and the areas under protection very small (Watson et al., 2016a). Grasslands are also inadequately protected. Only 4.6% of this ecosystem type, which can store large amounts of carbon in the soil (Section 3.1.3.3), is located in protected areas (Carbutt et al., 2017). Only 27% of amphibians, birds, terrestrial mammals and their ranges are adequately represented in protected areas (Hanson et al., 2020) and coverage of the ranges of endangered species is inadequate (UNEP-WCMC et al., 2018). As climate change advances, additional significant adaptation challenges for selecting and managing protected area will arise in the coming decades (Melillo et al., 2016; Loarie et al., 2009).
- *Interconnectedness:* To enable species migration and gene exchange between populations, connectivity between protected areas to form protected-area systems is necessary, e.g. by corridors and stepping-stone ecosystems (Section 3.2.3.6; Hilty et al., 2020). Currently, however, only about half of terrestrial protected areas are adequately connected (UNEP-WCMC et al., 2018) and just under a third of ecoregions have sufficiently connected protected-area systems (Saura et al., 2018). Although many regions have seen marked improvements in connectivity in protected-area systems, it nevertheless remained doubtful whether global connectivity targets would be met by 2020 (Saura et al., 2019).
- *Integration into the surrounding landscape:* Protected-area systems can only be effective if they are integrated into the surrounding landscape (or seascape) in such a way that use of this landscape also takes biodiversity into account. Section 3.2.3.6 deals with this issue. However, progress is difficult to measure, as very few of the CBD Parties have formulated specific strategies and spatial planning requirements to deliberately and/or systematically integrate their protected areas into the landscape (UNEP-WCMC et al., 2018).

3.2.3.4
Protected-area systems under pressure: drivers, needs for action, barriers and actors

The potential of protected areas for defusing the land-use trilemma cannot be fully exploited at present. This is largely due to the fact that the drivers of biodiversity loss (Section 2.2.3) remain effective and continuously exert great pressure on ecosystems, even within the protected-area systems themselves. One third of the world's protected areas are under intensive land-use pressure, and more than half of the protected areas consist entirely of land that is exposed to an intensive 'human footprint' (Jones et al., 2018). Human pressure on land areas (measured by the Temporal Human Pressure Index) has increased by 64% since the early 1990s, and this is also reflected in protected areas (Geldmann et al., 2014). This ongoing pressure is threatening to undermine the progress made by the CBD Parties in expanding and enhancing protected areas (Fig. 3.2-6; Jones et al., 2018).

The human-induced drivers that increase pressure on protected-area systems include demand for raw materials, the needs of the local population, trade in endangered species, climate change and invasion by alien species – these are the issues which both global and local actors must address (IPBES, 2019a: Ch.2.1; Geldmann et al., 2019; Jones et al., 2018; Geldmann et al., 2014; Worboys et al., 2006). These drivers are discussed in more detail below.

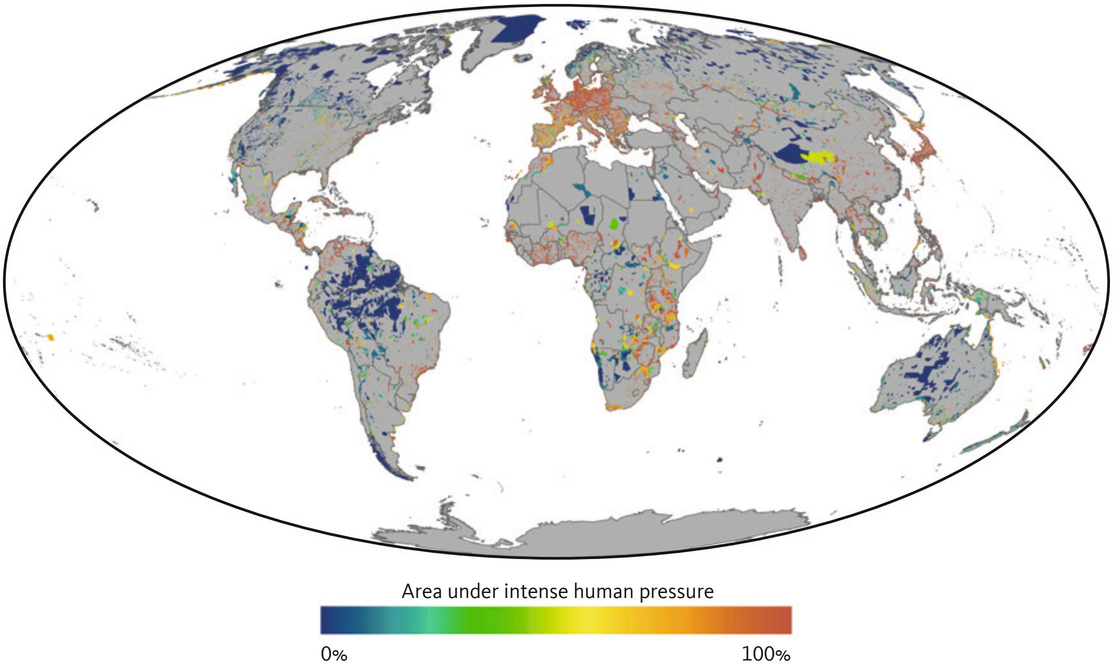


Figure 3.2-6
Human pressure in protected areas. The diagram shows the proportion of each protected area that is subject to intense human pressure, spanning from blue (low pressure) to orange (high pressure).
Source: Jones et al., 2018

Pressure of use generated by supraregional or international demand for raw materials

Incursions by commercial agriculture, forestry or mining into protected areas are frequently pursued by politically influential or even corrupt actors, sometimes using criminal methods. As a result, conservationists in some regions have faced death threats – and have been murdered (Nuwer, 2019). One major indirect driver of these often large-scale land-use changes and of ecosystem destruction is the global demand from industrialized countries and emerging economies for agricultural, forestry and mineral resources (telecouplings). Actors include major landowners, agribusinesses, food and timber companies, (bio)energy companies, and multinational mining corporations seeking to exploit the biological or mineral resources still present in protected areas (Stolton and Dudley, 2010:xxii). In industrialized countries, insufficient public and political attention is paid to ecosystem conservation and the telecouplings of these drivers; as a result, these issues play too insignificant a role in business decisions. In many developing countries and emerging economies, the overarching development paradigm is still based on resource extraction (Bebbington et al., 2018). For example, since the change of government in Brazil in late 2018, pressures on land use in the Amazon have increased significantly and indigenous territories are facing growing threats (Walker et al., 2020). In all countries, frameworks that do not take ecosystem services into account and the failure of appreciating and internalizing them encourage extractive and destructive uses (Kremen and Merenlender, 2018; Box 4.2-4) and represent a key barrier to nature conservation and sustainable use. Due to the increasing pressure on land use, there is a global trend among national governments towards PADDD, i.e. downgrading, downsizing and revoking protected status from protected areas (e.g. Mascia and Pailler, 2011; Mascia et al., 2014; Tesfaw et al., 2018). The environmental organization Conservation International cites over 3,000 cases of PADDD covering more than 130 million ha in nearly 70 countries (CI, 2020).

Pressure of use by the local population

The direct overexploitation of animal and plant populations by harvesting, hunting, fishing, firewood collection and logging is also an important driver of biodiversity loss (IPBES, 2019b:12). Lack of alternatives for food, income, employment and development for a growing population leads to increasing pressure by from local actors and thus to the conversion and degradation of ecosystems even in protected areas, sometimes in the context of subsistence agriculture. By contrast to IPLCs, these actors frequently do not have deep-seated ties with the region or ecosystems that have developed over a long period of time, nor do they have any knowledge of their fragility (Section 3.2.3.5). Unsustainable hunting for meat (bushmeat) is another commonly cited threat to biodiversity in protected areas (Schulze et al., 2018), leading to overexploitation and even population collapses among the hunted species (Wilkie et al., 2011). This is particularly true if hunting is not limited to the IPLCs' own needs and the meat is sent to local markets, which also increases the risk of zoonoses developing (Box 3.2-3). One promising approach here is co-management of protected areas by local communities and nature-conservation organizations (IPBES, 2019a: Ch.3).

Small-scale conversion of near-natural lands for agriculture or hunting and gathering by local populations has also increased greatly in many protected areas (Laurance et al., 2012) and is considered a major threat to biodiversity (IPBES, 2019a: Ch.3.3.2.2). Improved productivity in land use on the surrounding land can help reduce land-use pressure if it is ecologically sustainable (Nguyen et al., 2018). However, spatial proximity with agricultural areas generates additional conflicts with the local population, for example when wild animals ravage plantations outside protected areas (McGuinness and Taylor, 2014) or if, for example, there is an increase in life-threatening encounters with large predatory cats (Krafte Holland et al., 2018). For this reason, local actors are frequently opposed to the designation of protected areas because they are perceived as merely causing additional costs (IPBES, 2019a: Ch.2.1).

Today, tourism is already a major source of funding for many protected areas (and thus also an important sign of an appreciation for nature). Furthermore, it can have a positive impact on the local and regional economies (IPBES, 2019a:Ch. 2.1). However, too much or inappropriate tourism can certainly pose a threat to protected areas. For example, in industrialized countries, negative effects of recreational activities in protected areas (e.g., four-wheel-drive vehicles, outdoor sports) are a major factor in their degradation (Schulze et al., 2018).

Organized poaching and the trade in endangered species

There is also an urgent need for action to combat the activities of international criminal organizations targeting, for example, valuable ivory or rhinoceros horn for use in traditional Chinese medicine. This conflict, driven by the illegal wildlife trade, has resulted in the increasing militarization of protected areas in Africa, for example, where the local, often marginalized population finds itself caught in the crossfire between armed poachers and armed rangers. Increased patrols by rangers act as a deterrent against poachers and can be complemented by modern digital techniques (IPBES, 2019a: Ch. 6.2.3; Box 3.2-2). The illegal, international wildlife trade as a driver of the loss of endangered species is the target of multilateral agreements (above all the Convention on International Trade in Endangered Species, CITES). However, there is still a lack of implementation and enforcement at the national level (IPBES, 2019a: Ch. 6.3.2.3).

Climate change

Anthropogenic climate change could cause the extinction of a sixth of all species (Urban, 2015). Climate-change mitigation is therefore increasingly becoming an important prerequisite for ecosystem conservation. Climate change is also already being felt in protected areas, but the impact expected in the future may pose a significant threat to the effectiveness of such areas (Loarie et al., 2009; IPBES, 2019a: Ch.3.2.1). Even so, few protected areas have incorporated climate change into their goals or management (Poiani et al., 2011).

Adaptation to climate change is a big challenge, particularly at the level of protected-area systems (IPBES, 2019a: Ch.3.2.1). Fewer than 10% of the areas will still represent current climatic conditions in 100 years' time, making both the expansion of protected-area systems and the interconnection of areas for migratory movements increasingly important, also for reasons of climate adaptation (Kremen and Merenlender, 2018; Loarie et al., 2009). If rapid climate change coincides with major land-use changes, carbon uptake in protected areas could also drop to near zero by 2100, according to modelling by Melillo et al. (2016).

Invasive alien species

Invasion by alien species is also considered an important driver of biodiversity loss (IPBES, 2019b:13). It puts increasing pressure on protected-area systems because invasive alien species can displace native species and alter ecosystem structures. Invasive plant species pose the greatest threat in this context (Shackleton et al., 2020), while protected areas are better equipped against colonization by invasive animal species (Liu et al., 2020). Indirect drivers include the increasing transport of people and goods between regions and continents, from which protected areas are not isolated.

Three topics for discussion that require special attention can be derived from the analysis of the drivers: (1) In view of the complex interdependencies and impacts described above, the WBGU recommends encouraging the participation of the indigenous and local population in the planning and management of protected areas. Because these interrelationships are of such great importance for the functioning of protected areas, Section 3.2.3.5 focuses on the issue of *Indigenous Peoples and Local Communities*. (2) The *integration of protected areas in the landscape* is indispensable for successful ecosystem and biodiversity conservation, which is the reason why the WBGU devotes a further focus section to this topic (Section 3.2.3.6). (3) Any expansion and upgrading of protected-area systems on the scale described requires adequate *funding*; this issue is therefore dealt with in the third focus (Section 3.2.3.7).

3.2.3.5
Focus on Indigenous Peoples and Local Communities: guardians of the ecosystems

Generally speaking, the last large-scale, intact ecosystems are not simply nature devoid of humans, but are inhabited and used by people. The common term for such populations is 'Indigenous Peoples and Local Communities' (IPLCs), which has been used by the CBD and other conservation institutions for many years. This term applies to all local communities living in, with and from nature, and in particular to the land inhabited by indigenous peoples, which together comprises more than a quarter of the Earth's surface (Garnett et al., 2018; Figure 3.2-7). The importance of IPLCs for conservation has also long been explicitly recognized in the CBD (e.g. Aichi Targets 11, 14, 18; CBD, 2010a). They make important contributions to implementing the CBD's Strategic Plan (FFP, 2016).

Intact ecosystems (inside and outside protected areas) and their biological diversity represent these communities' cultural and spiritual home as well as "a kind of supermarket, hardware store, drugstore and pharmacy all rolled into one" (WBGU, 2005:76). More than a billion people, mainly in developing countries and emerging economies, depend on forests in protected areas for a significant proportion of their food and other supplies (UNEP-WCMC, 2018:13). "In addition to food, safe drinking water, wood and fibres, natural ecosystems also offer genetic resources of plants and animals, traditional medicines, as well as jewellery and sacred objects" (WBGU, 2014:12). The ecosystems inhabited and used by IPLCs thus also contribute directly to safeguarding their food security and food sovereignty (Pimbert and Borrini-Feyerabend, 2019). In addition to local communities, IPLCs explicitly refer to indigenous peoples, whose rights have been separately enshrined by the UN (UN, 2007). This UN Declaration on the Rights of Indigenous Peoples is considered a "milestone against the backdrop of years of efforts by indigenous peoples' representatives to raise awareness of the situation of indigenous peoples within the international community" (BMZ, 2020d).

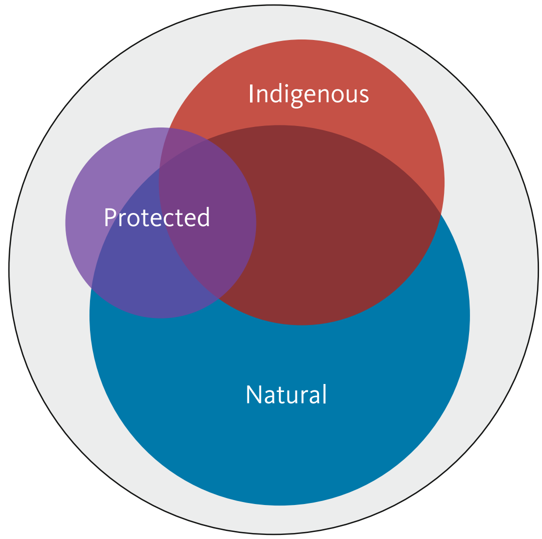


Figure 3.2-7
Regional variation in the conservation values of indigenous peoples' and other land. Overlaps between indigenous territories, protected areas and natural landscapes worldwide. Circles and intersections are proportional to the area, with the largest circle scaled to the land area of the Earth (135.2 million km^2 excluding Antarctica).
Source: Garnett et al., 2018

Earlier approaches to conservation involving the resettlement and displacement of people traditionally living in the respective areas have often lead to great injustice, suffering and human-rights violations (Tauli-Corpuz et al., 2018). These concepts are not acceptable. All conservation measures, including the establishment of new protected areas, their expansion or connectivity through corridors, must respect the rights of IPLCs and comply with corresponding standards (e.g. UN, 2007; Tauli-Corpuz, 2016; IUCN standards; CBD provisions).

The current scientific consensus in the IPBES goes a step further, calling the growing awareness in recent decades of the importance of IPLCs for conservation a "breakthrough in the conservation paradigm" (IPBES, 2019a: Ch. 6.3.2.3; Dinerstein et al., 2020). It is also widely recognized in political processes (e.g. CBD, IUCN) that IPLCs play a key role in both ecosystem conservation and restoration (CBD, 2018d; IUCN, 2016a; Edinburgh Process, 2020). This involves concepts such as co-management, community-based conservation areas and ICCAs, among others (IPBES, 2019a: Ch. 6.3.2.3).

Areas managed by IPLCs are referred to as ICCAs (Indigenous Peoples' and Community Conserved Territories and Areas; UNEP-WCMC, 2016a; IUCN, 2017). ICCAs are characterized by the following criteria (Borrini-Feyerabend et al., 2013:40; Farvar et al., 2018): (1)

the IPLCs living in them have a profound and usually long-lasting relationship with the territory and its ecosystems (i.e. they are not newly arrived or uprooted groups), (2) they have substantial decision-making power over the territory, (3) ICCA management contributes *de facto* to the conservation of biodiversity and ecosystem services in the territory. The ICCAs complement the network of mainly government-run 'formal protected areas' under national or international law, which are included in the databases of protected areas and are used to calculate areas for the Aichi Target 11. These ICCAs are of great importance for nature conservation because they are managed by local people in such a way that they have an effective conservation impact.

The IUCN therefore refers to "protected and conserved areas" (e.g. Woodley et al., 2019). Aichi Target 11 of the Biodiversity Convention also mentions not only formal protected-area systems but also "other effective area-based conservation measures" (OECMs, CBD, 2018d), which include ICCAs.

These areas contain a significant proportion of biodiversity (Dinerstein et al., 2020; UNDP, 2011; Nakashima et al., 2012). ICCAs overlap with 40% of all terrestrial protected areas and ecologically intact landscapes, although their designation as formal protected areas is not always and everywhere in the best interests of the indigenous people (Geldmann et al., 2019; Dudley et al., 2018). ICCAs are less vulnerable to deforestation (Blackman et al., 2017; Ricketts et al., 2010). The ongoing stewardship by IPLCs is considered crucial for the protection of Amazonian forests, with their biodiversity and carbon stocks, against competing claims of use, (IPBES, 2019a: Ch. 5) and may well be more effective and less costly than conventional protected areas (Walker et al., 2020). Last but not least, the traditional knowledge of IPLCs is highly valuable in the conservation and sustainable management of these territories, as well as for climate-change adaptation (Nakashima et al., 2012; Adger et al., 2014). Ecosystems of global importance are thus frequently to be found in the territories of IPLCs. By maintaining ICCAs, IPLCs provide globally relevant services that warrant increased support and funding (Walker et al., 2020). Accordingly, in the case of the 'conservation alliances for ecologically valuable landscapes' introduced in Section 4.5.3, it is of central importance to actively incorporate their rights and interests.

'Inclusive conservation' acknowledges the recognition of IPLCs as key actors (Farvar et al., 2018). The GEF uses this term in its current biodiversity strategy in the context of strengthening IPLCs as key actors for biodiversity conservation (GEF, 2018) and is already supporting a corresponding project (the Inclusive Conservation Initiative) that costs more than US$ 90 million, including co-financing (GEF, 2019).

The local-community-based approaches to co-management, as well as associated innovations, networks and social movements, are essential to the success of many of these areas and provide important opportunities for conservation and climate-change mitigation (Kremen and Merenlender, 2018; Berkes, 2010). At the same time, the custodians of ICCAs are not infrequently among the most marginalized groups in their countries (Perry et al., 2006). To ensure lasting success, IPLCs should experience not only the costs but also the benefits of conservation, which should work not only with them but also for them (Armitage et al., 2020; Emerton et al., 2006). Therefore, upholding and recognizing the rights of IPLCs is essential for the protection of these ecologically valuable landscapes and ecosystems (Garnett et al., 2018). Accordingly, the IUCN has decided to develop guidelines for the improved participation of indigenous peoples (IUCN, 2016a). There is widespread agreement that the rights and interests of IPLCs must be included in the regulation and management of protected areas in order to ensure success.

Co-management with local communities also faces various challenges. Above all, IPLCs in the Amazon region for example, are increasingly exposed to external threats. Legal protection is increasingly being eroded and legal and illegal forest clearing and land grabbing are on the rise, leading to existential threats to IPLCs and ICCAs (Walker et al., 2020). There are also internal factors: when local populations grow (albeit no faster than elsewhere: Joppa et al., 2009) and infrastructure development facilitates access to markets, their consumption expectations frequently increase. If invoices are paid with money earned by extracting biological resources from the ICCAs, then conservation goals risk falling by the wayside, especially since permanently sustainable extraction is hardly possible in tropical forests (Brazil/Amazon: Terborgh and Peres, 2017). In the Amazon region, for example, forest degradation and disturbance account for the most carbon losses within ICCAs, although losses outside have been much greater (Walker et al., 2020). Sustainable use of ICCAs should, wherever possible, be combined with monitoring and – particularly when it comes to extractive use – with appropriate enforcement of agreed rules to ensure that the areas are protected (Shafer, 2015).

It remains a major challenge to take these very dynamic and sometimes difficult-to-predict changes adequately into account locally in ecosystem conservation. There is a great need for long-term successful and simultaneously adaptive strategies for local populations. It is difficult to strike a balance between the rights and interests of IPLCs – not least the right to development – and the long-term safeguarding of areas worthy of protection from extraction and gradual degradation, let alone conversion. Solutions are highly dependent on local circumstances. In order to maintain the protective effect of ICCAs in the long term, the justified development needs of the local population should not be financed by unsustainable extraction from the areas themselves; rather, financial alternatives and development options must be opened up (Sections 3.2.3.7, 4.5.3).

3.2.3.6
Focus on landscape: interconnected protected-area systems in an integrated landscape approach

Biodiversity conservation is impossible without protected-area systems, but ecosystem conservation cannot be fully 'delegated' to a protected-area system because protected areas cannot function effectively as 'islands of biodiversity' in a landscape of biological depletion (IPBES, 2018a:165, 2019a: Ch. 6.2.3; Kremen and Merenlender, 2018). Furthermore, ecosystem services that are needed regionally or locally (e.g. by agriculture) cannot be provided exclusively by protected areas, and there are species of plants and animals that should be urgently conserved in the cultural landscape. At present, only 9.7% of the global terrestrial protected-area system is structurally connected by intact landscapes that lie in-between (Ward et al., 2020). Better integration of the protected areas into the surrounding landscape is therefore imperative (Aichi Target 11, Section 3.2.2; Sandwith and Lockwood, 2006). Guidelines on this have been developed under the aegis of the CBD (CBD, 2018d).

Within the protected-area systems, graduated zoning is helpful, allowing different intensities of use and combinations of conservation and sustainable use in the landscape context (Box 3.2-1; Figure 3.2-8). Moreover, as already explained in Section 3.2.3.3, the interconnectedness of protected areas is a crucial qualitative criterion in order to enable migration and gene exchange between populations and thus to move from individual protected areas to a well connected protected-area network (Hilty et al., 2020).

An important building block for connectivity can be large-scale corridor projects, which should also be conceived in transnational terms when planning interconnected protected-area systems; the Mesoamerican Biological Corridor is one example of this (Kremen and Merenlender, 2018). Cross-border protected areas not only make ecological sense, they can also serve as a means of international cooperation and détente ('Parks for Peace': Sandwith and Besançon, 2010).

Outside the protected-area systems, agriculture and forestry should take the concerns of nature conservation into greater account and be designed in the landscape context in such a way that they are also sustainable in terms of biodiversity conservation and generate added value in this respect (Fig. 3.2-9). This is particularly true for ecosystem restoration, which can be designed in a way that climate-change mitigation and biodiversity conservation complement each other (Section 3.1; IPBES, 2018a:21).

The CBD's Satoyama Initiative aims to integrate nature conservation with sustainable use also in the landscape outside protected-area systems (CBD, 2010b; Satoyama Initiative, 2020). Such a 'mainstreaming' of biodiversity conservation, i.e. including it in every area of land stewardship, was an overarching theme of the 14th COP to the CBD (2018e). Apart from agriculture and forestry, other sectors related to land use also have a responsibility for the mainstreaming of conservation functions; they include mining and infrastructure development (e.g. transport), but also sectors that can have a negative impact on biodiversity through their emissions (e.g. industry) or a positive impact through their design (e.g. cities; OECD, 2019). Without such mainstreaming, even the best protected-area systems will be unable to safeguard biodiversity, as shown e.g. by the collapse of insect populations in German protected areas (Leopoldina, 2020; SRU and WBBGR, 2018; Hallmann et al., 2017).

This is by no means only about large-scale, broadly interconnected protected-area systems; even small and scattered near-natural areas and biotopes in agricultural landscapes, although often not under conservation, are important for connectivity in the landscape and the provision of ecosystem services (Wintle et al., 2019; e.g. for pollination IPBES, 2016:365). In addition, there are ecosystems and species in old cultural landscapes that can only be preserved by maintaining traditional sustainable use (or corresponding landscape management; 'conservation through use', WBGU, 2001:12ff.).

The dichotomy between conservation and use must be overcome to make mainstreaming successful. To this end, actors both from nature conservation and from the various sectors of land use should listen to each other, approach each other and, if possible, work together to develop solutions that make the outlined multiple benefits feasible for both sides. The integrated landscape approach (Box 2.3-3) is a suitable framework of governance for this purpose. In an integrated landscape approach, the respective actors can bring together the goals of grading different combinations of conservation and sustainable use in protected areas and their buffer zones, interconnecting existing protected areas, mainstreaming biodiversity in sustainable agriculture and forestry, and restoring degraded land for climate-change mitigation and biodiversity conservation. Well-connected protected-area systems play a crucial role in this approach and, in a sense, form the ecological backbone of the landscape through their biodiversity and ecosystem services (Kremen and Merenlender, 2018; IPBES, 2019a: Ch.5). Together with the sometimes small-scale near-natural areas outside the formal protected-area systems, they form the 'ecological infrastructure' that is prioritized for ecosystem conservation and is a prerequisite for reconciling biodiversity conservation and ecosystem-service provision with sustainable use in the landscape (da Silva and Wheeler, 2017; Ervin et al., 2010:99ff.). Only through this integration of conservation and sustainable use in the landscape can the seemingly conflicting dimensions of the trilemma be overcome (Fig. 3.2-9).

3.2.3.7
Focus on financing protected-area systems

Although progress has been made in expanding the global protected-area network, protected areas still lack financial resources for effective biodiversity conservation (Coad et al., 2019). For example, in many cases funding is already inadequate for current protected-area systems, not to mention their need for expansion (Emerton et al., 2006). Insufficient funding hinders the implementation of the biodiversity targets (Barbier et al., 2020; Waldron et al., 2017; OECD, 2019). An increase in the funds available could mean a substantial improvement in the current situation – in terms of both the size of the protected areas and their effectiveness. Deferring investment can mean that future investment will have to be that much higher (CBD, 2014).

Estimates on expenditure and benefits from biodiversity conservation

Estimates of the current level of funding and the total resources required for biodiversity conservation and protected areas vary widely, as data availability is usually limited and the range of conservation activities included also varies. Moreover, past expenditures, financing requirements and benefits have not usually been reported specifically for protected areas but more generally for biodiversity conservation, nature conservation or meeting the Aichi Targets.

Public and private *spending* on biodiversity conservation is currently estimated at US$ 78–91bn per year worldwide; the EU spent approx. US$ 14.6bn in 2015–2017 (OECD, 2020a). Globally, more than 85% of the available funding was provided by public agencies, while private donors accounted for less than 15% (OECD, 2020a). The main sources of private funding were public and voluntary biodiversity-offset programmes, the certification and monitoring of sustainable goods production and NGOs. But philanthropic foundations and initiatives also contributed US$ 0.2-3.8bn in funding. A prominent example is Douglas Tompkins (founder of the companies Northface and Esprit) and Kris McDivitt Tompkins, who have purchased large areas in South America to restore them or protect them from further destruction (Tompkins Conservation, 2020). Initiatives such as LifeWeb, a CBD platform that organizations in developing countries can use to offer their projects for funding, also promote joint funding by public and private donors (CBD, no date).

Overall, much less private capital is mobilized in the biodiversity-conservation sector than in the field of climate financing (2017–2018: 56%, Buchner et al., 2014). Climate financing certainly offers many more investment opportunities that are attractive from an investor's point of view. However, voluntary offset programmes and private foundations show that investments in nature and biodiversity conservation do not have to be driven solely by commercial interests.

Estimates of *financing needs and funding gaps* are consistently within manageable ranges. For example, the 2012 CBD High-Level Panel estimated the total amount of financing required to reach the Aichi Targets at US$ 150–440bn per year (CBD, 2012), well below 1% of global GDP. With regard to ecosystem conservation and restoration in the context of terrestrial protected areas, McCarthy et al. (2012) estimate the funding gap to be around US$ 80bn per year; Credit Suisse et al. (2014) put the additional funding requirement for conservation purposes at US$ 200–350bn per year.

In terms of estimates of *global benefits from biodiversity conservation*, these consistently exceed the estimated costs many times over according to relevant studies (CBD, 2014; Barbier et al., 2018). Here, too, there is a wide range of estimates, as methodological challenges remain not only in measuring biodiversity but also in valuing ecosystem services that are not traded in markets (Box 4.2-4; Hanley and Perrings, 2019). Accordingly, in some cases no services at all or only selected services not traded on markets are included in the analysis.

Waldron et al. (2020) estimate that in 2050 the benefits will exceed the costs of implementing the 30% target for protected areas by US$ 64–454bn per year, even if the analysis is limited to a few economic sectors, and ecosystem services outside of markets are not included. Even the partial inclusion of the latter increases this amount considerably. Buckley et al. (2019) identify substantial mental-health benefits from visiting protected areas that far exceed associated commercial returns.

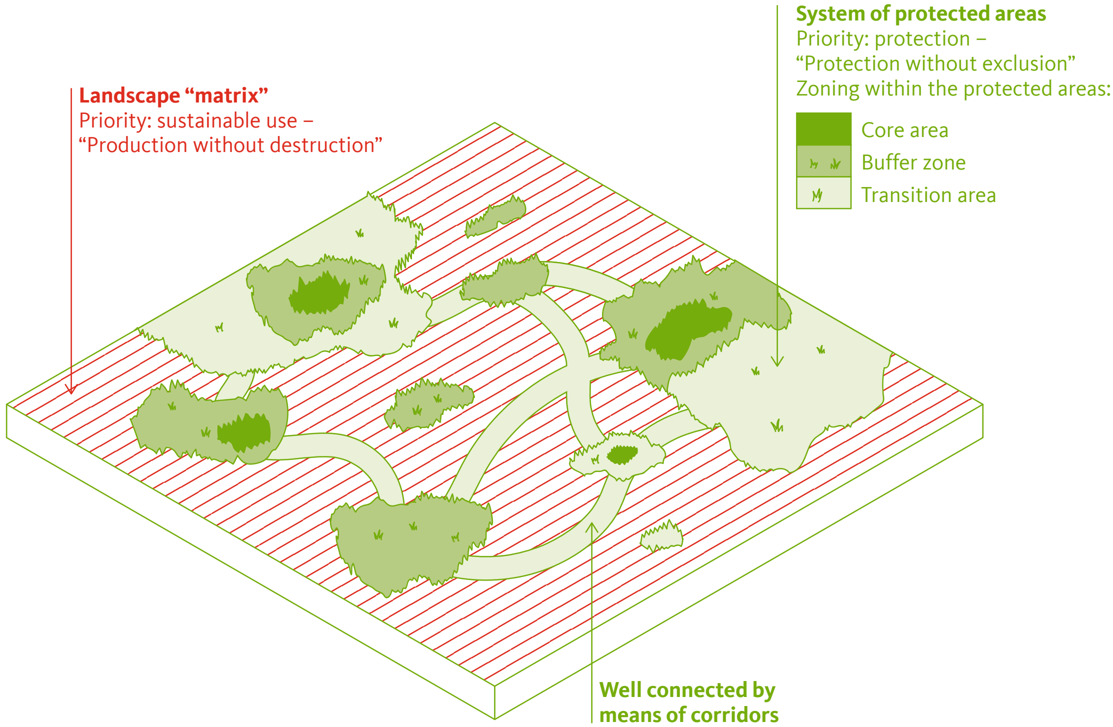
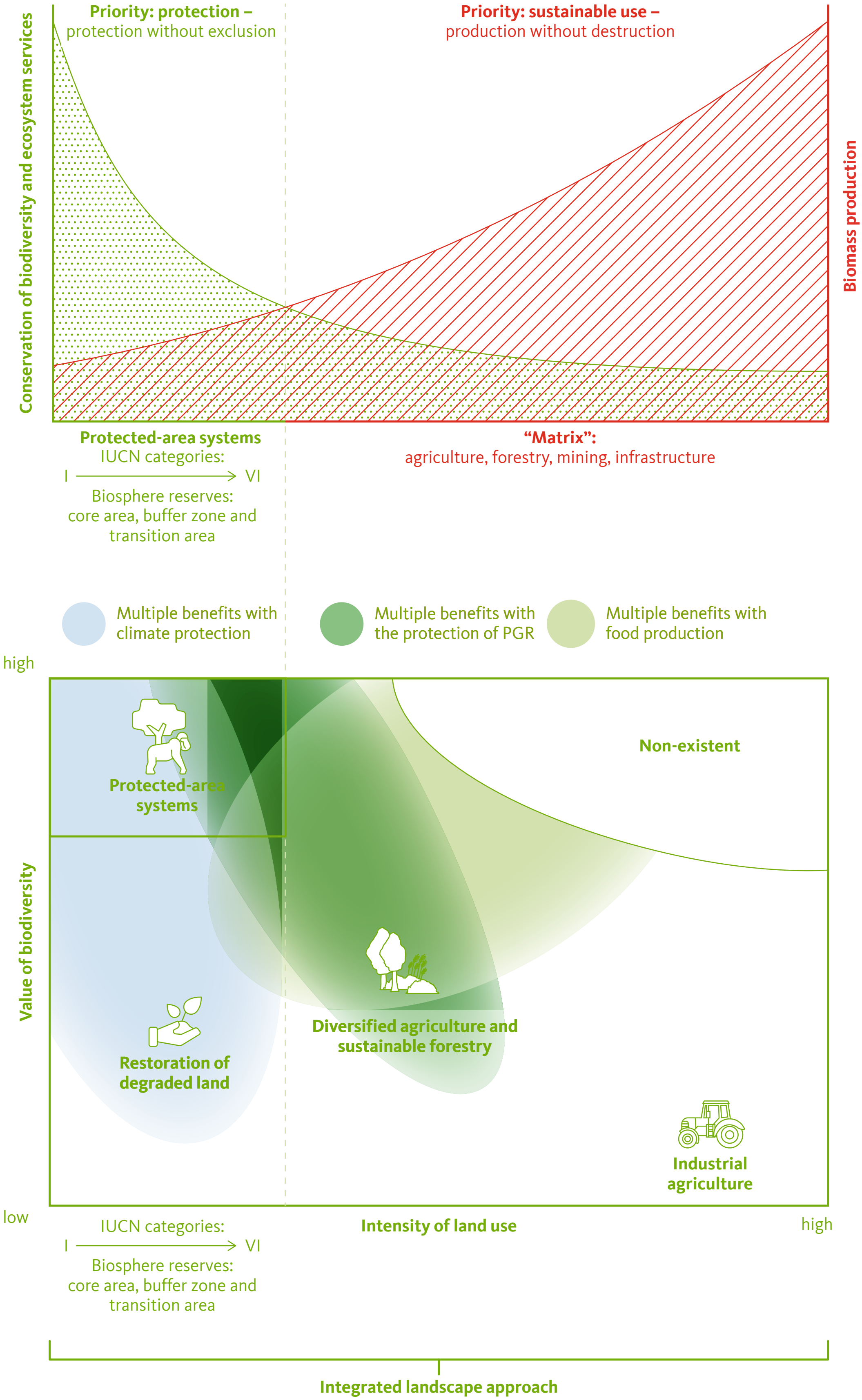


Figure 3.2-8
Zoning of protected-area systems and their integration into the surrounding landscape. By using ecosystem restoration to create corridors between intact ecosystems, biodiversity can be restored and a contribution made to climate-change mitigation. It is also important to maintain and expand the small-scale ecological infrastructure in the landscape, which is characterized by many near-natural sub-areas and margins, some of which are interconnected, others isolated; some smaller, others larger.
Source: WBGU, graphics: Ellery Studio

Figure 3.2-9 (right)
Ecosystem conservation and protected-area systems: relations between conservation on the one hand and land use and multiple benefits in the landscape on the other.
(above) Schematic gradation of conservation and use for protected areas (priority for biodiversity conservation and ecosystem services) and 'land-use areas' (priority for sustainable use with mainstreaming). Gradation from the far left: total conservation (scientific use only) to far right: e.g. sealed land, maize monoculture. The IUCN categories range from I: strict protection to VI: protection plus sustainable use (Box 3.2-1); UNESCO biosphere reserves only have a threefold division into core area, buffer zone and transition area (UNESCO-MAB, 2020). The division between protected-area systems and the matrix is at 30%; a proposal currently under discussion for a new post-2020 area target for protected areas. This is not a zero-sum game: the integration of conservation and land use in the sense of 'resolving the trilemma' (Section 2.2) and the multiple benefits across all three trilemma dimensions should be one objective of the integrated landscape approach.
(below) Schematic location of multiple benefits in the context of biodiversity and land use with examples. The area at the top right is not occupied, since combinations of very intensive use with a high biodiversity value can hardly be realized in practice. As in the upper chart, it is assumed that the protected-area systems will expand to cover 30% of the landscape area, i.e. the least intensively used areas of land with a simultaneously high biodiversity value. The area of the chart does not represent the area in the landscape; therefore, the green-framed rectangle of the protected areas does not correspond to 30% of the chart area. The potential for multiple benefits with food production is symbolized by the dark green area, multiple benefits with the conservation of plant genetic resources for food and agriculture (PGR) by the light green area. The blue area depicts possible multiple benefits with climate-change mitigation that can be realized by securing carbon stocks and sinks via ecosystem conservation.
Source: WBGU, graphics: Ellery Studio


Priority: protection –
protection without exclusion
Priority: sustainable use –
production without destruction
Conservation of biodiversity and ecosystem services
Biomass production
Protected-area systems
IUCN categories:
I → VI
Biosphere reserves:
core area, buffer zone and transition area
"Matrix":
agriculture, forestry, mining, infrastructure
Multiple benefits with climate protection
Multiple benefits with the protection of PGR
Multiple benefits with food production
high
low
Value of biodiversity
Protected-area systems
Non-existent
Diversified agriculture and sustainable forestry
Restoration of degraded land
Industrial agriculture
IUCN categories:
I → VI
Biosphere reserves:
core area, buffer zone and transition area
Intensity of land use
high
Integrated landscape approach

The European Commission (2020c) estimates that the costs of the EU protected-area network 'Natura 2000' of € 6bn per year are offset by benefits of € 200-300bn. Better resourced protected areas also tend to be of higher quality and more likely to meet the conservation targets (Geldmann et al., 2018), i.e. investment correlates with success (Waldron et al., 2017).

Especially serious funding deficits in developing countries and emerging economies

Funding deficits in the biodiversity hotspots of developing countries and emerging economies are a particular threat to the conservation of global biodiversity and protected-area systems. For example, the 40 most under-resourced countries host nearly a third of all mammalian biodiversity (Waldron et al., 2013). Some African countries with large protected-area networks and strong government prioritization for biodiversity have the biggest funding deficits in this regard (Lindsey et al., 2018). Africa and Latin America, both regions with very high shares of the world's biodiversity, have only a fraction of global funding available for biodiversity conservation (Parker et al., 2012:34).

Since the largest shares of the world's biodiversity are to be found in the poorest countries, it was already clear when the CBD was conceived that effective ecosystem conservation depends on financial flows from industrialized countries. Furthermore, industrialized countries, not least the EU, bear a large share of responsibility for the current biodiversity crisis (Drenckhahn et al., 2020; Section 2.2.3). Despite this, international financial flows currently account for only a small share of global public spending on biodiversity conservation (6–14%, OECD, 2020a). Funds from development cooperation (Miller et al., 2013), about 90% of which comes from bilateral development assistance (OECD, 2020a), are still the most important source of financial transfers for biodiversity conservation in developing countries.

Although the vast majority of public funding is used within the framework of national measures, underfunding is increasingly evident in developed countries too (Watson et al., 2014). For example, additional investments of at least € 20bn per year are recommended for the EU Biodiversity Strategy (European Commission, 2020c). In some states and governments, the willingness to invest in protected areas is actually declining (Watson et al., 2014).

Financing mechanisms and instruments

While the largest share of funding for biodiversity conservation still comes from public budgets, i.e. from general tax revenues or incentive taxes such as CO_2 taxes (e.g. in Costa Rica, Barbier et al., 2020), other funding mechanisms are also under discussion and in some cases are already being applied.

Mandatory and voluntary offset programmes are already established in the biodiversity context. However, they involve a wide range of conceptual and practical challenges (Gonçalves et al., 2015; Section 4.2.1), including the introduction of markets for tradable biodiversity offsets as discussed in the literature (Needham et al., 2019). Another financing instrument that is also not without controversy is debt-for-nature swaps (DNS), in which developing countries or emerging economies can have debts cancelled on the condition that they invest in nature conservation. DNS were used in particular in the 1990s (UNDP, 2017) to open up financing scope for nature conservation in developing countries and emerging economies. The empirical evidence on DNS regarding the actual provision of additional funding and its environmental impacts is mixed; however, experience with past programmes provides starting points for a more effective design of future programmes (Cassimon et al., 2011). Experience has also been gained in the past with funding from private foundations and philanthropists, although private conservation efforts, for example by purchasing land, are also controversially discussed in the context of 'land grabbing' and eco-colonialism (Holmes, 2015).

There are also other instruments although some aspects of their potential as a basis for the broader financing of protected areas is still under discussion. They include the use of green bonds, the establishment of biodiversity funds and even project finance for performance (Berghöfer et al., 2017; WWF International, 2015). Instruments like those proposed by the World Bank in the context of REDD+ (Box 3.1-6) could also be examined for the purpose of financing protected-area systems (World Bank, 2017a). However, Berghöfer et al. (2017) emphasize that the establishment of new instruments always involves costs. Accordingly, the focus should not only be on new instruments but also on improving the use of established financing mechanisms. Moreover, the economic development of neighbouring regions should also be taken into account in efforts to finance protected areas, especially in developing countries. The aim is to change the opportunity-cost calculations of local users by setting suitable framework conditions in such a way that the conservation of biological diversity and ecosystem services becomes worthwhile and alternative income opportunities are created (Section 4.2.1).

Preconditions and obstacles to effective governance

A survey of the World Heritage Convention's global network of protected areas finds that only 48% of protected areas have effective conservation and management, even though sustainable and reliable funding is cited as the most important criterion for this (Osipova et al., 2017). Due to a lack of financial resources, developing countries, emerging economies and ICCAs (Section 3.2.3.5) are also particularly affected here (Tran et al., 2019; Bovarnick et al., 2010).

Weak governance can, in turn, limit a country's capacity for absorbing additional funds (Berghöfer et al., 2017) and threaten the effective use of existing funds. This is especially critical as a lack of cost-effectiveness is in turn an important criterion for winning the acceptance and support of the public for conservation measures (Wätzold et al., 2010). The combination of a lack of financial resources and insufficient capacity thus impedes the implementation of biodiversity goals in general and protected-area goals in particular (Barbier et al., 2020; Waldron et al., 2017; Miller et al., 2013). Improving the financial basis for protected areas and efficient management must accordingly be considered together in terms of both expanding protected areas and improving the quality of existing protected areas.

Most Parties to the Biodiversity Convention also see the combined lack of financial, human and technical resources as a barrier to the implementation of the Strategic Plan (CBD, 2010a). Increasing financial resources for ecosystem conservation is therefore part of the canon of goals of both the CBD (Aichi Target 20) and the 2030 Agenda (SDG 15.a; Section 3.2.2), and, not least, of the new EU Biodiversity Strategy (European Commission, 2020c). The WBGU takes up these recommendations in Section 3.2.5.

3.2.4 Conclusions

The biodiversity crisis has not yet led to a sufficient change in societal structures and priorities in favour of ecosystem conservation. Although transformative change is beginning to emerge and is considered necessary by research and policy advisers (IPBES, 2019b; Díaz et al., 2019; SCBD, 2020; Leclère et al., 2020; FOLU, 2019), it is still far from being mainstream. The knowledge has been processed into the right form for policy-making (IPBES), the strategies have been formulated and are currently being revised (post-2020 CBD framework), the instruments have been developed and transformation pathways identified. However, awareness has not spread sufficiently, so that valuable elements of our Earth are still being irretrievably destroyed although they are very important and indeed, in some cases, indispensable.

Increased efforts for nature conservation and ecosystem restoration (Section 3.1), together with the transformation of the global food system (Sections 3.3, 3.4), are necessary and could reverse the negative trends of the loss of biodiversity and ecosystem services (Leclère et al., 2020). Even a relatively small increase in political attention could have a major impact, because the amount of money required to mitigate the biodiversity crisis – e.g. for establishing and expanding the global system of protected areas or for implementing mainstreaming in agricultural practice – is small in comparison to the climate crisis, for example. Nevertheless, the forces of inertia against the necessary transformation are powerful: (1) profound path dependencies in the relevant societal structures (visible, for example, in environmentally damaging subsidies); (2) inadequate valorization and internalization of biological diversity and ecosystem services; (3) for this reason, too, undiminished pressure by economic processes on the use of natural and near-natural ecosystems; (4) rising demand based on unchanged consumption patterns and resource-intensive lifestyles, which also act as important drivers of the biodiversity crisis via telecouplings. The populations in industrialized countries as well as the comparatively wealthy middle and upper classes of all countries have a particular responsibility for the last two points.

The conclusions for ecosystem conservation and the multiple-benefit strategy of protected-area systems are as follows:

- *Expand and upgrade protected-area systems:* Protected-area systems should be extended to cover 30% of the Earth's surface. This territorial extension should be complemented by upgrading the quality of protected areas, above all the selection, representativeness and connectivity of sites, as well as ensuring effective, participatory and equitable management, monitoring and enforcement of agreed regimes. The 'conservation alliances for ecologically valuable landscapes' presented in Section 4.5.3 can make an important contribution here.
- *Integration into the landscape and mainstreaming are crucial:* Protected-area systems should be appreciated as the ecological backbone of the landscape, and their interconnections should be expanded. Moreover, the mainstreaming of biodiversity concerns in all sectors (especially agriculture and forestry) is a key success factor. In the landscape, particular attention should be paid to achieving multiple benefits in the context of the land-use trilemma and to engaging the stakeholders in this objective. Humans should be regarded to a greater extent as part of ecosystems and protected areas. The 'regional alliances for the cross-border implementation of integrated landscape approaches' proposed by the WBGU in Section 4.5.1 offer an instrument for

stronger institutional cooperation between neighbouring regions.

- *Support IPLCs in their conservation efforts, safeguard ICCAs:* ICCAs generate considerable global benefits by conserving the biodiversity and carbon stocks they contain; the custodians of these areas, the IPLCs, are not nearly adequately compensated. This compensation should be organized by means of transfer payments, because otherwise the pressure of land use and therefore of destruction will grow not only from outside but also within the areas if the right to 'catch-up' development is financed by extractive use.
- *Invest more in protected-area systems:* Protected areas are worthwhile; a high level of co-benefits is achieved with comparatively low investment. However, these benefits are currently not reflected in standard economic indicators or integrated into prices and balance sheets.
- *Use the momentum of the CBD Summit* to achieve good targets in the post-2020 framework and to attract attention.

These conclusions are formulated more concretely as recommendations for action and research in the following two sections.

3.2.5 Recommendations for action

Ecosystem destruction and degradation as a result of land-use change – usually by conversion to agricultural land e.g. by forest clearance – are the most important drivers of the global biodiversity crisis. They are also important drivers of climate change, are themselves exacerbated by climate change, and contribute to food insecurity because of the loss of ecosystem services. For the thematic area of 'ecosystem conservation', the WBGU therefore believes the destruction and fragmentation of natural and near-natural terrestrial and freshwater ecosystems should be halted as soon as possible (by 2050 at the latest; Section 3.2.2; CBD, 2010a; WBGU, 2014:21).

Protected-area systems are characterized by the fact that their priority goal is the effective conservation of ecosystems and biodiversity. The following recommendations on protected-area systems are addressed to national policy-makers, to development-cooperation and international funding institutions (World Bank, development banks, GEF) as well as to private actors (e.g. NGOs in the field of nature conservation). Ambitious objectives and guidelines were already formulated by international actors (e.g. conventions, IUCN) ten years ago (Section 3.2.2). The aim now is to prevent the multilateral objectives on the development and management of protected-area systems from being diluted and to promote better implementation.

Implement the expansion and improved management of protected-area systems

National governments play a central role here and should therefore be assisted in developing countries, for example by helping to build robust and inclusive decision-making and management processes on protected-area systems (IPBES, 2019a: Ch. 6).

- Alongside the absolutely necessary expansion of protected areas to cover 30% of the Earth's surface (CBD, 2020), there is also considerable potential for improvement within the existing protected-area systems. This relates primarily to the consistent application of the quality criteria of Aichi Target 11 (Section 3.2.2; Barnes et al., 2018) by strengthening management, local participation and enforcement, and by the provision of resources (including financial resources; Pringle, 2017; IPBES, 2019a: Ch. 6.3.2.3). The effectiveness of implementation of existing and future multilateral objectives (Section 3.2.3.3) could be improved by means of clearer prioritization, for example by focusing efforts on protected areas that have unsatisfactory conservation status, as has been done under the EU Habitats Directive (IPBES, 2019a: Ch. 3.7).
- Effective climate-change mitigation is a prerequisite for the long-term performance of a global protected-area system (Section 3.2.3.4). Conversely, protected-area systems will also be required to provide adaptation services to meet the 2°C climate-protection guard rail. The long-term incorporation of climate change should be regarded as an integral part of the selection, strategic planning and management of protected-area systems (this is particularly important for mountain regions: e.g. Elsen et al., 2018).
- Further important prerequisites for protected-area systems are the monitoring both of biodiversity and ecosystem services and of rules on use and management, which should be developed in a participatory manner. Digitalization can provide valuable assistance with these tasks (Box 3.2-2). Also in the field of protected areas, digitally supported monitoring and digitalized spatial datasets should be increasingly used as a basis for land-use decisions and their implementation (OECD, 2020c:2). In addition, efforts should be made – wherever possible on a global scale – to develop early-warning systems for severe ecological changes, including natural disasters, as well as for the spread of infectious diseases.
- German and European development-cooperation projects should focus not only on expanding pro-

tected areas but also on exploiting the potential for improvement within existing protected-area systems in line with the CBD's quality criteria. Furthermore, the development and expansion of alternative sources of protein for the local and regional population could help reduce poaching for meat in protected areas and adjacent near-natural ecosystems.

Integrated landscape approach: incorporate and realize synergies

As part of the integrated landscape approach (Box 2.3-3), all dimensions of the land-use trilemma should be taken into account and possible synergies examined in the context of all land uses. This also applies to protected areas: certainly, all three categories of multiple benefits (i.e. including climate-change mitigation and food security) relating to the trilemma (Section 2.2) cannot be realized in every protected area (or on every hectare of the landscape); however, if protected areas are strategically interconnected both with each other and with the surrounding land areas, such multiple benefits *can* be achieved that permit a broader integration of conservation and land use than would be possible in individual areas (Section 3.2.3). An even more far-reaching 'resolution' of land-use competition functions especially at the landscape level; it thus explicitly becomes a task of the 'integrated landscape approach' (Box 2.3-3), whose ecological backbone is the protected-area systems. In order to strengthen the landscape's ecosystem diversity and improve the supply of locally relevant ecosystem services, integrated landscape planning should address areas of land both inside and outside protected areas.

- Planners and managers of protected areas should incorporate the synergies and possible multiple benefits mentioned into their thinking and integrate them more into the management plans of protected areas. In buffer zones (or Category VI protected areas), for example, the sink function should be strengthened and organic farming (including the preservation of old crop varieties) made possible, if this is compatible with the underlying purpose of conservation. The WBGU recommends an intensive exchange with regional developers, as well as agricultural, forestry and freshwater policy-makers, within the framework of the integrated landscape approach.
- Synergies between conservation and use in protected-area systems offer opportunities for overcoming sectoral 'silo thinking' and should be introduced with greater emphasis in the multilateral processes of, for example, the CBD, the International Union for Conservation of Nature (IUCN), the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and the UNDP, and implemented accordingly in development cooperation. The ITPGRFA of 2001 has a memorandum of understanding with the CBD, and the FAO a memorandum of cooperation with the CBD. These collaborations should be revitalized. They should also address much more emphatically the use of synergies and possible contributions of the global protected-area system to sustainable agriculture and the protection of plant genetic resources.

Internalize the benefits of ecosystem services and biological diversity

According to the World Economic Forum, more than half of the world's GDP is dependent on nature and its services and is therefore susceptible to the loss and degradation of ecosystems and their biodiversity (WEF and PwC, 2020). The fact that the costs of ecosystem-service and biodiversity loss are not internalized is an important driver here (Box 4.2-4). The following also applies to protected-area systems: many of their goods and services are widely available but do not carry a price tag, whereas the costs of ecosystem conservation, e.g. the management of protected areas, must be paid with real money (Emerton et al., 2006).

- The full extent of ecosystems' contributions for humans should be reflected in the countries' national accounts and company balance sheets – this also applies to agriculture and forestry. This transformation of the societal, economic and financial systems should begin without delay. On the one hand, it is a task for national governments and/or the EU; on the other hand, multilateral initiatives (at the G7, G20, UN level) should also be strengthened in this regard.
- National governments should review where regulatory law is sufficient for implementing the agreed objectives for protected-area systems, or where targeted financial incentives for specific actors should be added (e.g. via instruments such as Payments for Ecosystem Services: Box 4.2-1), and how high these would have to be in each case to achieve the desired effect (Section 4.2.1).

Improve the integration of the protected-area systems into the landscape

Guidelines for integrating protected areas into the landscape have been developed under the aegis of the CBD (CBD, 2018d). These approaches should be supported and further developed.

- *Interconnectedness:* Efforts to improve the connectivity of protected areas to ensure species migration and gene exchange between populations should be greatly strengthened and promoted by development cooperation and international funding institutions, also across national borders (Hilty et al., 2020).

- *Mainstreaming:* Landscape diversity and the protection of locally relevant ecosystem services (e.g. erosion control, soil-fertility conservation, water supply and water quality) should also be strengthened in the (future) 70% of land that is outside protected-area systems. The small and scattered near-natural areas of land and biotopes in the agricultural landscape should be conserved and better connected, as they are important for ecological connectivity and the provision of ecosystem services in the small-scale landscape context (Wintle et al., 2019; e.g. for pollination IPBES, 2016:365). To promote the mainstreaming of ecosystem-services and biodiversity conservation to this effect, the trend in industrial agriculture towards adapting the landscape to ever larger machines should be reversed; digitalization offers options in this context (Box 3.2-2; Section 3.3; WBGU, 2019b:195f.). Furthermore, biodiversity-damaging inputs (e.g. mineral fertilizers, liquid manure, pesticides) in agriculture should be greatly reduced and synthetic pesticides largely dispensed with (Section 3.3.2.2).
- *Integration in the landscape:* In this regard, the integrated landscape approach is an important concept, explicitly as an approach of governance to defuse conflicting interests in the specific context of the spatial structure (Box 2.3-3). The development of mechanisms for (local) conflict resolution (e.g. local farmers' interests versus the protection of wildlife, indigenous hunters versus poachers) should also be regarded as part of the implementation of the landscape approach. Large-scale, long-term, proactive (including cross-border) spatial and landscape planning is an important tool of the landscape approach for prioritizing land uses and leveraging synergies (IPBES, 2019a: Ch. 6; Ch. 4.2.3).
- *Framework conditions:* Beyond the landscape level, biodiversity-friendly national and international framework conditions that take into account, and seek to avoid, negative telecouplings on biodiversity are of great importance (Section 4.2; Box 4.2-4). Local opportunities for income and development that are not detrimental to ecosystems or are not land-based should be created.

Support Indigenous Peoples and Local Communities

The participation of local populations in the planning and management of protected areas is an essential factor for their success. Local stakeholders, especially IPLCs, have substantial decision-making power over the areas they manage (ICCAs), and as a rule their management contributes to the conservation of biodiversity and ecosystem services (Section 3.2.3.5).

- *Participation in the expansion and management of protected areas:* Any expansion of protected-area systems, whether on a large scale like the projects of conservation alliances (Section 4.5.3) or small-scale national projects, must follow recognized sustainability standards, which as a general rule include participation, also in decision-making. Protected areas that engage local stakeholders are significantly more effective in achieving their conservation goals (Oldekop et al., 2016). In relation to IPLCs, a key requirement for local implementation – in addition to participation – is the recognition of rights, including land rights (Geldmann et al., 2019). The rights-based approach should be implemented consistently; for example, the evictions and resettlements from protected areas that occurred in previous nature-conservation projects are fundamentally incompatible with this approach (Tauli-Corpuz et al., 2018). The GEF's Inclusive Conservation Initiative project (GEF, 2019) is an example of IPLCs' support for nature conservation; after an evaluation, it should be scaled up if the results are positive.
- *Address the development interests of IPLCs:* The interests of the people and communities that depend directly on ecosystems must be taken into consideration; this applies in particular to their economic interests beyond securing basic needs through hunting, gathering and extensive food cultivation. To ensure the long-term success of nature conservation, it should work not only with them, but also for them wherever possible (Armitage et al., 2020). Support projects of development cooperation (DC) aimed at improving and diversifying livelihoods and creating alternative income and development options for local people, especially IPLCs, are therefore a good idea in order to reduce their dependence on extractive land use (leading to forest degradation) and to safeguard the areas in the long term (Walker et al., 2020). New DC projects should also explore combining sufficiently large and interconnected core areas with sustainable use in transition areas, as well as combining traditional knowledge and science (Díaz-Reviriego et al., 2019) with strong (government) institutions.
- *Appreciation of and safeguards for the rights of IPLCs:* The recognition, upgrading and formalization of IPLCs' traditional rights and traditional knowledge should be strengthened at the UN level. Germany's federal government can help here, for example by supporting better representation for IPLCs in multilateral bodies. At the national level, the WBGU recommends that states adapt their national legislation and governance accordingly to support ICCAs (Tran et al., 2019). The federal government can make a

contribution here by further strengthening its support to national governments in adapting and shaping their systems of national governance so that participation by local and indigenous groups in the planning and implementation of protected-area or biodiversity strategies is better promoted (Walker et al., 2020). Since the conservation of biodiversity is closely linked in these areas to the conservation of cultural diversity, indigenous knowledge (Cámara-Leret et al., 2019) and linguistic diversity (FPP et al., 2016), integrated strategies are suitable ways of simultaneously conserving biological and cultural diversity in ecological hotspots (Gorenflo et al., 2012).

Strengthen the financing of protected-area systems

Progress has been made with expanding the global network of protected areas; however, financial resources for effective biodiversity conservation are still lacking (Coad et al., 2019). Public and private funding is needed to support existing and new protected-area systems. Given the very attractive cost-benefit ratios of ecosystem conservation for the common good, public funding for protected-area systems should be increased and, where possible, combined in a synergistic way with private funding. Public-private partnerships, matching private funding with public funds and the establishment of mixed-finance protected-area funds for financing and managing protected-area systems can be useful approaches here, and should be increasingly implemented at the national and international level. In protected areas where limited economic use is envisaged, the increased use of incentive-based mechanisms such as payments for ecosystem services (Box 4.2-1) can increase the acceptance of regulations in protected-area systems. The effectiveness and efficiency of the deployment of financial resources for biodiversity conservation and in protected areas should be routinely monitored in order to improve implemented governance mechanisms and achieve the maximum impact with the available resources. Improved transparency and communication of the benefits of biodiversity conservation and protected areas can raise awareness and increase willingness to pay in this context.

- *Regard protected-area systems as part of regional development:* According to the IPBES, enabling and strengthening financial mechanisms for ecosystem conservation and restoration inside and outside protected areas is "critically important, particularly in developing regions" (IPBES, 2019a: Ch. 5). However, developing countries and emerging economies, where most of the biodiversity is located, cannot always give top priority to biodiversity conservation. For this reason, international support for the conservation and establishment of protected-area systems should always be provided in the context of the long-term economic development of surrounding regions, especially in developing countries. Planning development cooperation and protected-area systems together can reduce the local opportunity costs of their conservation and establishment, making biodiversity conservation and ecosystem services worthwhile.
- *Encourage industrialized countries to assume more international responsibility:* Given that the industrialized countries, and not least the EU, share responsibility for the global biodiversity crisis, they should not only set a good example and strengthen nature conservation at home but also take on additional responsibility and make greater and more sustained use of their financial strength abroad to protect biodiversity (Drenckhahn et al., 2020). Currently, international financing for biodiversity conservation accounts for less than 10% of national funding (OECD, 2020a). The WBGU therefore recommends both increasing funding for international cooperation in existing institutions (such as the GEF and UNDP's Biofin Initiative) and creating new forms of long-term international cooperation within the framework of 'global conservation alliances for ecologically valuable landscapes' (Section 4.5.3). Debt-for-nature swaps could also give developing countries more financial leeway if designed appropriately and in a targeted manner. A further strengthening of international payment flows for nature conservation at both public and private levels could also be achieved by opening up national offset systems (as regulated, for example, in Germany's Federal Nature Conservation Act) to international investment in protected-area systems, subject to strict monitoring and reporting requirements.

Strengthen protected-area systems in the post-2020 framework of the Biodiversity Convention

The expansion and management of protected-area systems should be permanently organized in such a way as to prevent biodiversity loss as effectively as possible. With regard to the post-2020 framework of the CBD, the WBGU confines itself at this point to recommendations in the context of protected-area systems; further recommendations on the CBD can be found in Section 4.4.1.2 (on the apex target: Box 4.4-3).

As a target for the CBD, the WBGU supports protecting 30% of the Earth's surface (CBD, 2020). At the same time, it warns that assessment systems and target-setting for the global protected-area system should not be reduced to area targets alone and that the negotiations should not focus exclusively on this point. Otherwise, there is a risk that protected-area systems, while being large enough in principle, will not have the necessary impact for biodiversity conservation (Barnes et al., 2018; Geldmann et al., 2019; IPBES, 2019a: Ch. 3.7). Much greater emphasis should therefore also be placed on quality in both setting and implementing targets (Coad et al., 2019). In addition to reaching the 30% area target, the German federal government should work to ensure that the existing Aichi quality criteria for protected areas, as set out in Aichi Target 11, retain their validity in the post-2020 framework and are in no way watered down. They should also continue to be taken into account in practice (Section 3.2.3.3): preference should be given to designating ecologically valuable areas (e.g. biodiversity hotspots, key biodiversity areas) as well as areas that are at particular risk, and to ensuring representativeness not only of species but also of ecosystem types (IPBES, 2019a: Ch.3.7; Watson et al., 2020). Interconnectedness (e.g. corridors, stepping stones) and integration into the landscape are further crucially important qualitative criteria. In the landscape context, strategies for expanding and interconnecting protected areas should be closely linked to the restoration of ecosystems (Aichi Target 15; Section 3.1). Both objectives, ecosystem conservation and restoration, can be implemented more effectively if they make better provision for the impacts on IPLCs and their social and cultural contexts (Section 3.2.3.5; IPBES, 2019a: Ch.3.7).

For all criteria, it is crucial to agree ambitious outcome-based targets that can be measured by indicators and thus implemented (Geldmann et al., 2019; Green et al., 2019). Additional indicators should also be agreed to address whether the global protected-area system has the necessary resources (managerial and financial) to meet the targets set (Coad et al., 2019). The post-2020 framework should furthermore include improved compliance arrangements, e.g. with a commitment to reporting by the Parties on target achievement (Editorial, 2020b; UNEP-WCMC and UNSD, 2019). In the wake of the agreement on a new post-2020 CBD framework, the German federal government should adapt and scale up existing development-cooperation funding programmes for biodiversity and protected areas. Improved support for key multilateral actors such as UNEP-WCMC, IUCN and NGOs is also advisable, as they play an important role in the still insufficient implementation of biodiversity targets.

3.2.6 Research recommendations

Use participatory research approaches more widely

In view of the considerable worldwide expansion of protected-area systems considered necessary by scientists (Section 3.2.3.3), participatory research on the impact, design, establishment and management of protected areas, as well as their relationship to local populations, should be greatly strengthened (Gaston et al., 2008).

Intensify socio-ecological research on protected areas

In the light of the SDGs and the IPBES status reports, there should be more intensive study of the role of protected-area systems in the overall socio-ecological system in relation to the Great Transformation towards Sustainability. Such research should include the impact of protected areas on human well-being (Naidoo et al., 2019), including health. Social-science research on the human dimension of protected areas is especially difficult in some regions in developing countries and emerging economies; support is needed here.

Examine the quality of the protected-area systems

Although there is a global overview of protected areas and coverage of endangered species, there is as yet no global dataset on the coverage of critical ecosystem services (UNEP-WCMC, 2018:13). Similarly, there is no comprehensive global overview of the status of protected-area connectivity (UNEP-WCMC, 2018). Another research gap is a global baseline for 'other effective area-based conservation measures' (OECMs), i.e. areas with a conservation impact that do not have official protected-area status, to better assess their contribution to global conservation goals (UNEP-WCMC, 2018). The analytical framework has not been sufficiently processed and the data pool is insufficient for an overarching and participatory assessment of management quality (monitoring effectiveness and equity; Barnes et al., 2018). In this context, the WBGU recommends securing and increasing research investment in global databases covering the status of protected areas, ecosystems and endangered species (IPBES, 2019a: Ch.3.7). This includes analyses of threats to and the degradation of protected areas, as well as an improved spatial understanding of their drivers; analyses of adaptation challenges to protected areas are also needed, e.g. from increasing land-use pressures or from climate change (Jones et al., 2018).

Promote monitoring and citizen science

Given the recommendation to heed not only the quantity but also the quality of protected-area systems (Section 3.2.3.3), improved indicators, monitoring and integration of quality criteria are needed (Geldmann et al., 2019). Research collaborations should be strengthened to support developing countries in the monitoring and data analysis of biodiversity in protected areas. There should be targeted funding to ensure that better use is made of the considerable potential of citizen science for improving both the pool of research data and monitoring, even including the SDGs (Box 3.2-2). Furthermore, greater involvement of the local population is important to promote the vision of an increasingly globally interconnected, collective environmental awareness (WBGU, 2019b:351) and a changed, earth-system-preserving approach to nature and the land.

Research the financing mechanisms of protected-area systems

The range of estimates of funding and expenditure needs for protected-area systems shows that the data basis is still inadequate and should be improved – e.g. as part of the World Database of Protected Areas (WDPA; Section 3.2.3.7; Waldron et al., 2013; Emerton et al., 2006; OECD, 2020a). There has also been too little research on the impact of different funding mechanisms; efficiency potential could perhaps be leveraged here (Waldron et al., 2017; IPBES, 2019a: Ch.6).

Study the influence of telecouplings

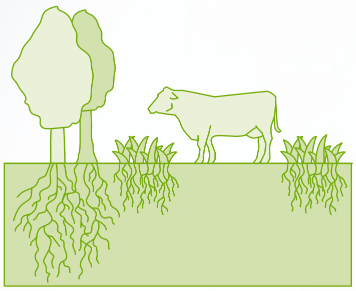
There has been too little study of the impacts of telecouplings on protected-area systems, mainly via world trade, which increases land-use pressures and land-use competition, as well as of possible responses to them and actions (e.g. tariffs; Díaz et al., 2019).

Research and strengthen the role of Indigenous Peoples and Local Communities

The data situation with regard to the areas managed by IPLCs (ICCAs) is still insufficient (Section 3.2.3.5). The global mapping of ICCAs (Global ICCA Registry) and knowledge on the governance methods, biodiversity and conservation effectiveness of ICCAs should be improved (Corrigan et al., 2016; Di Gessa et al., 2008; IPBES, 2019a: Ch.1.2). Illuminating more precisely the relationship between biological and cultural (especially linguistic) diversity is important both for the range of ecosystem services and for safeguarding indigenous knowledge (Cámara-Leret et al., 2019; Gorenflo et al., 2012).

Greening of industrial agriculture using the EU as an example

Sustainable increase in the productivity of subsistence agriculture using sub-Saharan Africa as an example



Agroforestry and other diversified farming systems achieve their high productivity through intensive promotion and use of ecosystem services.

Orientation of agricultural trade towards sustainability and resilience

LEGEND

Trilemma

Multiple-benefit strategies

Governance

3.3
Diversify farming systems

Agriculture is a crucial factor in the land-use trilemma. Using the examples of industrial farming in the EU and subsistence farming in sub-Saharan Africa, this section develops three multiple-benefit strategies which aim at a diversification of the farming systems and can be used to overcome the trilemma: the greening of EU agriculture, a sustainable increase in agricultural productivity in sub-Saharan Africa, and resilience, environmental protection and climate-change mitigation in global agricultural trade.

3.3.1
Current farming systems are approaching their limits

Agriculture has many different manifestations worldwide depending on agro-ecological, economic and cultural conditions. They range from industrial farming focusing on a small number of crops, to subsistence-oriented, traditional forms of land use and to a wide variety of agricultural forms typical of the respective region. This section discusses two examples of agricultural land use from the perspective of the trilemma of land use (Chapter 2): (1) industrial agriculture in the EU and (2) subsistence agriculture in sub-Saharan Africa. These two farming systems are priorities in German and EU's agricultural and development policies.

In the following, the WBGU takes a systemic look at these two farming systems, which consist of interacting factors or system elements:

- land-use intensity and its sub-aspects such as management practices, use of inputs, timing and spatial aspects,
- land cover, e.g. arable land, grassland, wetland, forest or scrub,
- the different stakeholders, including agricultural training, extension services, trade, agricultural organizations and interest groups,
- farming conditions, e.g. farmers' motivation, livestock, income and its origin, e.g. production of quality products with a regional reference, direct marketing, rural tourism, contractual nature conservation, biomass cultivation or decentralized energy supply (Knickel et al., 2004).

This systemic perspective forms the basis for developing recommendations for a transition of land use towards sustainability, in which agriculture plays a key role. Such a transition of land use involves a multifunctional design and diversification of farming systems, which are also reflected in the landscape.

3.3.1.1
Industrial agriculture: the example of the EU

Industrial farming in the EU in its current form is a major contributor to environmental problems and GHG emissions, due, among other things, to narrow crop rotations and an excessive use of fertilizers (mineral fertilizers and liquid manure). This further reinforces trends caused by the ongoing structural change in the EU agricultural sector. The main impacts of industrial farming on the land-use trilemma are outlined below.

Contamination of the groundwater by overfertilization

Industrial agriculture is heavily dependent on applications of mineral fertilizer, which have increased approximately tenfold over the past 60 years worldwide (Mateo-Sagasta et al., 2018). If this trend continues, about 250 million tonnes of fertilizer nitrogen could be needed every year by 2050 (Tilman et al., 2011), twice the amount currently used in a year (Mateo-Sagasta et al., 2018). The applied mineral fertilizer accumulates in soils, water and biomass, leading to soil degradation among other problems (Mateo-Sagasta et al., 2018). The future availability of phosphorus, one of the non-substitutable nutrients in mineral fertilizers, is also limited, so, for this reason too, industrial agriculture will come up against limits in the near future (Vaccari, 2009; Blackwell et al., 2019).

Furthermore, mineral fertilizers are not the only source of nitrogen and phosphorus: in areas with industrial livestock farming too much nitrogen and phosphorus, as well as antibiotics from animal excreta, also enter freshwater ecosystems and groundwater (Mallin and Cahoon, 2003; MacDonald et al., 2011; UBA, 2018b, 2019d). In Germany, nitrate pollution exceeds the EU limits (UBA, 2020). The excessive accumulation of nutrients overwhelms the land's capacity to absorb it, so that human and animal health and the condition of water bodies are impaired by eutrophication (Galloway and Cowling, 2002). People are at increased risk of developing asthma, allergies, cancer or other chronic diseases due to environmental effects caused by excess nutrients (Peoples et al., 2004; Euiso et al., 2005; Ward et al., 2018). Fish species that can adapt to low-oxygen conditions become dominant and disrupt the ecological balance in aquatic systems (Soares et al., 2006). Plant and animal species adapted to nutrient-poor living conditions are displaced (UBA, 2019e). Due to the use of

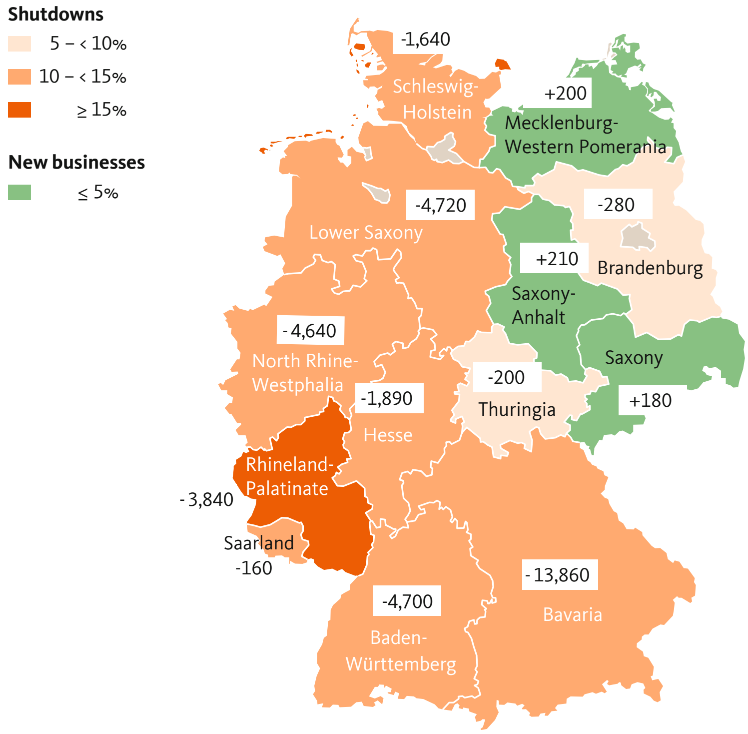


Figure 3.3-1
Change in the number of agricultural holdings in Germany from 2010 to 2018, federal states excluding city states.
Source: Crolly, 2019; Heinrich Böll Foundation, 2019a

antibiotics, antimicrobial resistance builds up in humans, leading to approx. 33,000 deaths in the EU each year (Cassini et al., 2019).

Threats to biodiversity from pesticides and land-use uniformity

The excessive use of pesticides, i.e. agents for the targeted control of weeds, pests and diseases, causes considerable losses of biodiversity, e.g. declines in pollinators such as bees and other insects, but also in birds and soil organisms, and leads to threats to populations of wild herbs (BfN, 2018; Leopoldina et al., 2018). The main cause is the preventive and blanket application of broad-spectrum herbicides (e.g. glyphosate), fungicides and insecticides (Wissenschaftlicher Beirat des Nationalen Aktionsplans zur nachhaltigen Anwendung von Pflanzenschutzmitteln des BMEL, 2019). When used in this way, pesticides not only kill the target organisms but also affect many neutral and beneficial species, undermining natural self-regulatory mechanisms (Schäffer et al., 2018). Moreover, in the case of many of these agents, one-sided and massive use has led to widespread resistance in target organisms worldwide (Pimentel and Burgess, 2014). Global pesticide use has increased sharply, especially since 1990, with Spain, France, Italy and Germany accounting for around 70% of use in the EU (Eurostat, 2020b). Most importantly, the efficacy – i.e. the longevity and toxicity – of insecticides has also greatly increased (Simon-Delso et al., 2015). Pesticide residues in food and contamination of surface and groundwater by pesticides from agricultural land have been shown to harm human health. An epidemiological study conducted in France shows that certain types of cancer occur significantly less frequently in people who eat a diet based mainly on organically grown food (Baudry et al., 2018).

Another cause of biodiversity loss is the extensive mechanization of agriculture over the past 100 years and the associated creation of ever larger fields (Hampicke, 2018). Small-scale, diverse land use has often had to give way to large-scale, single cropping in narrow crop rotations. The use of chemicals together with the monotonization of land use are regarded as major contributors to agrobiodiversity loss (IPBES, 2019b).

Contribution of industrial agriculture to greenhouse-gas emissions

The Intergovernmental Panel on Climate Change (IPCC, 2019a) attributes 23% of anthropogenic GHG emissions to the food system (Chapter 2), and industrial agriculture in the EU is one of the largest contributors (WMO, 2018). The main sources of emissions are forest clearance for land conversion, the conversion of grasslands to farmland, nitrous oxide (N_2O) from mineral fertilizers, and methane (CH_4) from ruminants and wet rice cultivation (IPCC, 2019b). Around 94% of ammonia (NH_3) emissions come from agriculture, especially from the storage and spreading of liquid manure and the use of inorganic nitrogen fertilizers (2015 data; EEA, 2020). In addition, peatland drainage causes about 100.5 Mt of CO_2 emissions per year, making the EU the second largest peatland CO_2 emitter after Indonesia (Berge et al., 2017).

Industrial intensive livestock farming (factory farming) is an example which shows that the EU is also responsible for emissions elsewhere, since the high demand for feed and the associated spatial decoupling of feed production from animal husbandry lead to telecouplings (Section 2.3.1; Lenschow et al., 2016). The EU is the main importer of soybeans, and in Germany more than 80% of them are used for intensive livestock production (Grenz et al., 2007). Land-use changes – such as the clearance of rainforests in favour of the cultivation of fodder crops such as soybeans and for grazing land in intensively managed monocultures – thus cause GHG emissions indirectly and over long distances; in the long term, they reduce the capacity of these converted areas to absorb CO_2 (Lenschow et al., 2016).

Industrially produced meat and dairy products need a lot of water

The industrial production of meat and dairy products is also associated with a high demand for water. Taking into account the water required for the entire production process (direct and indirect) the average water footprint, as measured in litres per kg, is about 15,400 litres for beef from industrial production (figures for comparison: 4,300 l per kg for chicken, 822 l per kg for apples). Most of the water (98%) needed for beef is used for feed production (Hoekstra and Water Footprint Network, 2017; Mekonnen and Hoekstra, 2012). Moreover, the industrialized production of meat and dairy products occupies about 77% of global agricultural land (UN Environment, 2019). It is therefore much less water- and soil-intensive to focus on crop production for direct human consumption than to prioritize animal production.

Structural change in EU agriculture

The continuing structural change in EU agriculture has a wide range of implications for sustaining the natural life-support systems, for the inclusion of small and medium-sized enterprises in particular, and for the *Eigenart* of (artisanal) agriculture (normative compass, Box 2.3-1). The lack of job opportunities in rural areas is driving the migration of younger and more highly qualified people to the cities.

For example, the number of farms in Germany has fallen from just under 630,000 in 1990 to around 360,000 in 2018 (a decline of over 57% in just under 30 years), with considerable differences between the federal states (Fig. 3.3-1). Small farms in particular have been abandoned. Similar trends can be seen for the EU as a whole, where the number of farms – particularly small ones – fell by almost 30% between 2005 and 2016 (Crolly, 2019).

Such a structural change has negative impacts when landscapes become desolate and village communities are lost. If rural population density falls below a critical value due to out-migration, infrastructure deficits may arise, for example in the areas of mobility, healthcare or access to telecommunications services (Neu and Nikolic, 2015). Structural change can also lead to the impairment of socio-economic and cultural functions as well as the diversity of rural regions (Möllers and Glauben, 2011). Such a loss also reduces the possibilities of income diversification for small and medium-sized farms. In the meantime, these generate about 10-20% of their income from agritourism (EU Parliament, 2013).

The industrialization of agriculture has also accelerated the loss of *Eigenart* in the sense of culturally diverse possible uses of biodiversity (BfN, 2018). Of the approximately 6,000 plant species used for agricultural production, fewer than 200 contribute substantially to global food production (FAO, 2019e). Just nine crops provide 66% of global cereal production and only four – rice, wheat, maize and potatoes – provide 60% of global calories (FAO, 2019e; FOLU, 2019). Livestock numbers are also now heavily concentrated and permanent grassland is declining. Over 70% of grasslands in central Europe have been converted to intensive management over the last 50 years (Rose et al., 2012). In industrial farming, livestock production has become almost completely decoupled from crop production, i.e. farmland (Naylor et al., 2005), and the production of cereals (including maize) has been increasingly shifting from production for human consumption to animal-feed production (Pingali, 2015). For example, nearly two-thirds of the world's maize production is now used as livestock feed, while only 13% is consumed by humans (OECD, 2019).

Undesirable developments in industrial farming and in the food system

- *Concentration processes:* The global concentration processes in industrial food production, food processing and the food trade are trends that stand in the way of defusing the land-use trilemma. In recent decades, the global agricultural industry has become highly concentrated on a small number of companies. For example, four agricultural corporations dominate the world market in seeds and pesticides

Box 3.3-1

The EU's Common Agricultural Policy

The EU's Common Agricultural Policy (CAP) has existed for almost 60 years. Initially, the prices of many agricultural products were supported by the establishment of market regulations; this had the desired effect of significantly increasing productivity and improving the food supply in Europe. In the early 1980s, however, the income-oriented CAP caused massive surplus production ('butter and cereal mountains', 'milk and olive-oil lakes'), and high export subsidies increased expenditure to as much as 70% of the total EU budget. Product-specific intervention prices, which were paid per unit of weight, encouraged overfertilization. This in turn degraded soils and polluted water bodies (Brandt, 2004; Johann Heinrich von Thünen-Institut, 2020).

Reform process and key shortcomings

The CAP has been the subject of continuous reforms since 1992. Guaranteed intervention prices were reduced for many products and direct payments to farmers were initially intended to compensate for income losses. With its Agenda 2000 project, the EU developed the two-pillar system: a first pillar for market and price policy and a second pillar, which is much smaller, for the promotion of rural development. The direct payments of the first pillar were linked to environmental and animal-welfare requirements through cross-compliance regulation. The decoupling of direct payments also means that they are no longer based on the production of specific crops but linked to the land area. The main beneficiaries of this are large arable farms that own a high proportion of their land, as well as trading and processing companies; special crop farms and refining plants with a high value added per unit of land benefit less (Forstner et al., 2018; Simoncini et al., 2019). However, to date, not all direct payments have been decoupled from specific products, so that certain production incentives still exist. In addition, land subsidies sometimes do not benefit farmers, but go, for example, to joint-stock companies or other beneficiaries that acquire land on a large scale (EU, 2020).

In Germany, for example, 10% of farms are run as partnerships, GmbHs, cooperatives or AGs; together they manage more than a third of the land used for agriculture, with a high proportion of the land in the eastern German Länder in particular (BMEL, 2018b). Smaller farms and those that lease a high proportion of their land thus hardly benefit at all from CAP subsidies.

The largest farms – 1.8% of all recipients – receive 32% of the direct payments totalling around €40 billion (Pe'er et al., 2019). Large farms can produce more cost-effectively and efficiently due to economies of scale and therefore have more scope for investment, e.g. in soil-friendly machinery or more spacious stables. However, they tend to specialize, so that natural resources are used very one-sidedly and ecosystem services are lost. Vulnerability to weather extremes and price fluctuations are also increasing. Negative environmental impacts are thus not directly dependent on a farm's size but on the diversity of the land use (UBA, 2018b).

Since 2013, the CAP has incorporated environmental and climate targets for the first time by tying 30% of direct payments (via 'greening') to three mandatory environmental measures which go beyond the cross-compliance regulation (EU Commission, 2020f): (1) crop diversification, e.g. farms with more than 30 ha of arable land must grow three crops (the main crop must not exceed 75% and the two main crops together must not exceed 95%); (2) maintenance of permanent grassland, which must not be converted into arable land; and (3) ecological priority areas (areas with trees, hedges or fallow land) with a minimum land share of 5% for holdings with more than 15 ha of arable land. In addition to greening, specific agri-environmental protection and climate-change mitigation measures were anchored in the second pillar (AUC II) (Fig. 3.3-2).

As a result, greening has primarily led to an increase in intercropping and legume cultivation; however, it cannot remedy the ecological deficits of the cultivated landscape (Hampicke, 2018). Thus, although soil fertility has somewhat improved as a result of legume cultivation, diversified production structure in the true sense of the word has not benefited. The audit by the European Court of Auditors on

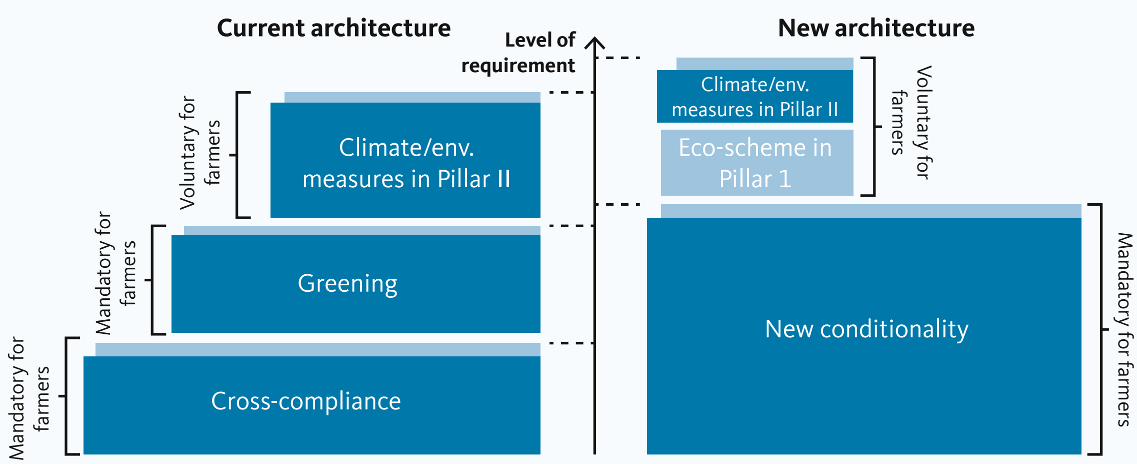


Figure 3.3-2
Current and future architecture of EU agroenvironmental and climate-change policy.
Source: WBGU, own presentation based on Meredith and Hart, 2019

the ecological effectiveness of greening also comes to the conclusion that the measures taken so far hardly improve environmental protection and climate-change mitigation (ECA, 2017). In five member states, the measures have led to positive changes on only 5%of agricultural land, as most farmers (65%) did not have to change their practices to receive the greening payments. Greening thus remains just another instrument of income support and moreover increases the complexity of the CAP. There is also a lack of concrete targets for evaluating greening measures (ECA, 2017). Another criticism is that the CAP does not impose deterrent sanctions on farmers who break environmental laws, but only reduces subsidies. Since 2017, member-state governments have been able to impose administrative sanctions in addition to subsidy reductions. However, the example of the fertilizer ordinance in Germany implementing the EU Nitrate Directive (EU, 1991) shows that there are considerable deficits in the enforcement of regulatory requirements.

The CAP post-2020

Thus, despite the reform efforts, the CAP still faces criticism as environmental indicators continue to deteriorate (Pe'er et al., 2019; Simoncini et al., 2019). For example, the EU proposes nine objectives for the CAP after 2020 that combine economic, environmental and social aspects (EU Commission, 2018c, d, e). Three policy instruments are envisaged to bring the CAP in line with these environmental and climate-change objectives (Fig. 3.3-2): (1) the already known, mandatory cross-compliance measures, which are linked to direct payments and also contain some modified elements of the former greening measures ('conditionality'), (2) voluntary new so-called 'eco-schemes' of the first pillar, which essentially replace greening, and (3) voluntary regulations of the second pillar related to environmental protection and climate-change mitigation (WBAE, 2019).

In addition to these three policy instruments, a 'new implementation model' is envisaged, which shifts more of the task of implementing concrete measures to the member states and gives them more room for manoeuvre. The EU then only lays down targets and broad intervention categories. This is supposed to make it possible for the CAP to be implemented in a simpler, more flexible and more target-oriented way. As regards the design of the measures, each member state draws up a national strategy plan, which must be submitted to the EU Commission for approval. One criticism of this reorganization of the CAP after 2020 is that the new implementation model gives the member states too much room for manoeuvre. States could thus continue to pursue an income policy because they shy away from the higher administrative costs of implementing environmentally or climate-relevant measures, or because they lack resources and personnel or do not see the need. Instead, according to the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection, the EU should lay down concrete outcome-based indicators for the member states (WBAE, 2019).

The voluntary objectives of the CAP after 2020 are based on the Farm-to-Fork strategy presented by the European Commission as part of the European Green Deal. By 2030, the use of synthetic chemical pesticides and hazardous pesticides is to be halved, the use of fertilizers reduced by at least 20%, and the use of antibiotics in livestock farming halved. In addition, organic farming in the EU is to be expanded to 25% of agricultural land by 2030 (EU Commission, 2020d). In the WBGU's view, these targets are desirable but still problematic, since they are based on voluntary commitments.

(Fröndhoff, 2018). Increasing corporate concentration is also taking place in the food sector (IAASTD, 2009; Section 3.4.1). In 1999, for example, there were eight large retail chains in Germany accounting for 70% of total food retail sales. Following a number of acquisitions, this number has now been reduced to four major companies (Edeka, Rewe, Schwarz-Gruppe and Aldi), which account for 75–95% of total sales (Bundeskartellamt, 2014). The participation of leading retailing companies in purchasing cooperatives significantly strengthens their bargaining power vis-à-vis suppliers (Bundeskartellamt, 2014). In the EU, the ten largest retailers have a market share of over 50% (Heinrich Böll Foundation, 2017). In the food industry, the structure is generally comparatively heterogeneous, although strong concentrations can be seen in the meat sector, the dairy industry and the sugar industry (Monopolkommission, 2012). A relatively new phenomenon is the additional reinforcement of concentration processes made easier by digital platforms through mergers of agricultural-machinery producers with seed and agrochemical companies (WBGU, 2019b). Corporate concentration in the retail and food industries has increased the price pressure on agriculture (Schöpe, 2005). Agriculture remains a 'price taker', i.e. market prices are accepted as given and the volume of sales is adjusted to the price. The only way to influence the price is with cooperatives (Simons et al., 2020).

- *Role of lobby groups:* Further barriers to a transformation of the farming system towards sustainability are a number of lobby groups with close ties to the food system. In Germany, for example, many top managers in supervisory and control bodies of the agricultural and food industry simultaneously hold influential positions in politics, the executive and the Farmers' Association (NABU, 2019; Heintz, 2013). However, distinctions must be made here, as there are other interest groups that advocate the greening of industrial agriculture by strongly promoting organic farming (e.g. Biopark; Arbeitsgemeinschaft bäuerliche Landwirtschaft).
- *Women farm owners are at a disadvantage:* In Europe today, 80% of farm managers are men, and in Germany as few as 8.7% of farms are managed by

women (genanet, 2020). According to genanet (2020), female owners are also at a disadvantage in decision-making processes, and their opportunities for participation are lower overall.

- *EU Common Agricultural Policy:* The EU's Common Agricultural Policy (CAP) originally aimed its support measures primarily at improving productivity and raising income to put farmers on a more or less equal footing with other occupational groups. Environmental, spatial and societal services provided by the agricultural sector were largely disregarded (Schöpe, 2005). In the meantime, the CAP also supports socio-economic development in rural areas and rewards structural as well as agri-environmental measures, but, to date, area-based direct payments still account for the bulk of the support given, while climate and environmental objectives remain secondary (Pe'er et al., 2019; Simoncini et al., 2019; details in Box 3.3-1). In 2010–2014, EU subsidies accounted for an average of over 35% of agricultural factor income; direct payments to farmers accounted for 28% (EEA, 2020). Agricultural expenditure's share of the EU budget was 37% in 2018 (EU, no date). The EU's agricultural interest groups in particular are vehemently pushing for the preservation of CAP income support (DBV, 2018).

3.3.1.2
Low-yield subsistence farming and persisting food insecurity: the example of sub-Saharan Africa

Subsistence farming in sub-Saharan Africa – particularly in the semi-arid regions – is faced with a triple burden in terms of the land-use trilemma:

1. agricultural yields are too low to support reliable food security,
2. climate change is already causing considerable yield losses, and agriculture has so far only adapted to climate change in certain locations (IPCC, 2019a),
3. increases in production, which to date have been realized predominantly by means of land conversions, endanger biodiversity and intensify competing uses.

Food insecurity and seasonal hunger in rural areas

After years of improvement, the number of people suffering from hunger has been on the rise again since 2014. In 2019, 690 million people, or 8.9% of the world's population, were affected by hunger (FAO, 2020). This means that the world is moving away from SDG 2, which envisages an end to hunger by 2030. On the African continent, the proportion of undernourished people was more than double the world average at 19.1% in 2019. This is the highest percentage in the world and affects more than 250 million people (FAO, 2020).

Violent conflicts, together with chronic hunger and climate change, are among the main reasons for food insecurity (FAO, 2020). In semi-arid regions, which are the focus of this study, the causes of conflict include the political discrimination of pastoralists compared to other population groups. This manifests itself in low societal esteem and low participation, in arbitrarily imposed restrictions on land use and the constant fragmentation and reduction in the size of grazing areas. Another factor is the growing number of animals, which exceeds the capacity of the degraded pastures. Finally, for many decades, arable farmers have increasingly been encroaching on grazing areas, displacing pastoralists (IFAD, 2020; Bukari et al., 2018; African Center for Strategic Studies, 2019).

Chronic hunger, on the other hand, is based on structural poverty and is mainly a problem in semi-arid regions such as the Sahel countries (Mauritania, Burkina Faso, Mali, Niger, Chad, Senegal, Sudan) and mainly in rural areas there (World Bank, 2017b; FAO, 2019d). At the same time, predictions for population growth are the highest in these countries. Estimates for the period from 2015 to 2050 are more than 150%, and in Niger as high as approx. 200% (BPB, 2017). Smallholder families suffer from hunger especially in seasonally recurring phases. These phases occur mainly in the period between harvests, when the people's own stocks have been used up or sold, but the next harvest is still several weeks or months away (von Grebmer et al., 2013). Due to climate change, these periods of shortage are tending to widen. In the meantime, more and more smallholder families even see themselves as net consumers, i.e. the additional quantities purchased each year exceed the quantities produced (Welthungerhilfe, 2019).

Since agriculture in sub-Saharan Africa is small-scale and the vast majority of these family farms have very limited access to financial and natural resources, the risk of seasonal hunger affects a very large number of people. There are estimated to be about 30–50 million smallholder farms with about 200 million people in the region (Lowder et al., 2016). Farm sizes range from 0.5–3.5 ha and the trend is downward (Lowder et al., 2016). A wide range of historical, political and economic causes have led to this problematic situation, but today it finds expression primarily in the form of insufficient productivity for field crops (amount harvested per hectare). Although yields in sub-Saharan Africa too have improved slightly in recent decades, this increase is much smaller than in other regions of the world and not sufficient to meet the needs of the growing number of people given the declining amount of farmland per household (Fig. 3.3-3).

The low level of land productivity of cereals, but also

Figure 3.3-3
Development of cereal yields in kg per ha by world region.
Source: Tian and Yu, 2019

of other crops in sub-Saharan Africa, is accompanied by increasing soil degradation, as the nutrients removed by the crops cannot be adequately replaced. This 'extractive' soil use, in which nutrients are removed but not returned via fertilization, is also known as 'soil mining'. The causes are manifold: over the last few decades, traditional methods practised by arable farmers, such as regenerative fallow or symbiosis with pastoralists, have been replaced by a form of land management that has to make do with very low fertilizer inputs (of approx. 8-12 kg of nitrogen per ha) and no fallow period (Wynants et al., 2019). In Germany, about ten times as much mineral fertilizer is used per ha (AfDB, 2016). Traditionally, the pastoralists supplied animal dung for the arable farmers' fields, while arable farmers supplied the pastoralists with grain. In recent decades, however, this symbiosis has reversed into a latent and sometimes overt conflict in which population groups ostensibly fight over access to land, but where there are in fact multiple political causes (Wynants et al., 2019; Osama, 2014; Gender-Jilg, 2013).

In semi-arid regions, plant-based biomass as fertilizer is only available with a high input of labour and not in the required quantities. However, because mineral fertilizer is too expensive for most smallholders, small farms are dependent on fertilizer subsidies. While around 80% of small farms in many countries receive such subsidies through input subsidy programmes (ISPs), the quantities are far too small, as already mentioned above (Jayne et al., 2018a, b). Together with the overgrazing of land bordering on the croplands to the north, used primarily by pastoralists, this practice has led to the most severe land degradation in the world (ELD and UNEP, 2015).

However, the wide range of differing data on the extent of the degradation must also be mentioned; this is caused by different survey methods and also due to the fact that some examine soils (arable land) and others land (including all uses, vegetation cover and water cycle). Frequently cited is the 1990 Global Assessment of Soil Degradation (GLASOD), according to which 65% of agricultural soils in sub-Saharan Africa are degraded (19% of them severely); this corresponds to about 321 million ha (FAO, 2015d). A long-term study of the dynamics of global land productivity conducted between 1999 and 2013 states that over this period, across the African continent, about 22% of the land surface showed declining or unstable land productivity (Cherlet et al., 2018). These figures make it clear that not only agricultural soils, but also other land areas in Africa are degraded. If other studies are included, the figures for Africa range between 9 and 5,233 million ha (IPBES, 2018b:236).

In addition to the insufficient supply of nutrients, other reasons for the degradation of soils used for agriculture lie in the concentration of arable farming on only a few types of crops, above all maize. Introduced to the continent in colonial times, this relatively

Box 3.3-2

COVID-19-related food crisis in sub-Saharan Africa – the double pandemic

Breakdown of supply chains

Most African countries have only a small number of trading partners, primarily China, the USA, India and the EU. At the same time, they rely heavily on exports of primary goods to China and the EU to help them refinance imports of essential goods. The disruption of supply chains because of COVID-19 has therefore quickly led to financing gaps, including for food imports, e.g. in Nigeria, South Sudan or Congo, not least as a result of low global prices for crude oil and minerals (OECD, 2020b). The absence of foreign direct investment due to increased volatility on the financial markets has also increased the fragility of the food supply. Countries that are normally exporters of staple foods are stopping or limiting exports due to COVID-19-related shortages, e.g. rice exports from Vietnam or India (OECD, 2020b; Hartwich and Hedeshi, 2020; WEF, 2020). The fracturing of supply chains also causes shortages of mineral fertilizers, seeds, farm machinery and tools (WEF, 2020). The countries of sub-Saharan Africa face COVID-19-related shortfalls of between US$37bn and US$79bn for their own production (World Bank, 2020a). COVID-19-related trade blockages and delays in the supply chains also lead to food spoilage in fields or at borders, thus contributing to the food crisis (Dongyu et al., 2020; Gaupp, 2020).

Rising food prices

The COVID-19 pandemic is leading to the first recession on the African continent in 25 years. The absence of tourists from Europe, capital flight and a 23% fall in migrant remittances to these regions are important factors here (OECD, 2020b; Hartwich and Hedeshi, 2020; World Bank, 2020a). Panic food buying is pushing up food prices further (OECD, 2020b). Not only the urban poor, who rely on public food markets, but also the rural population (in the inter-harvest period) are affected by these price increases (IMF, 2020). Restrictions on movement mean that workers are no longer mobile for agriculture, and this also leads to higher food prices. According to the FAO, a non-seasonal price increase of 10-20% could be observed in parts of West Africa in July 2020 (FAO, 2020j). In South Sudan, prices for wheat have risen by 62% and for cassava by 41% since February, while Russia, Kazakhstan and Ukraine for their part have already limited wheat exports and Egypt is massively increasing its wheat reserves (Gaupp, 2020).

Famine crises as a consequence of the COVID-19 pandemic

The COVID-19 pandemic will most likely trigger a famine in sub-Saharan Africa, because both regional food production and food imports will decline (World Bank, 2020a), while there will also be COVID-19-related income losses (Gaupp, 2020). This will affect up to 90% of informal workers in the Least Developed Countries (LDCs) and especially Internally Displaced Persons (IDPs) and refugees, i.e. populations who were already living in precarious situations before the pandemic. People in Ethiopia have been particularly severely affected as this crisis has coincided with the locust plague (FSIN, 2020b). Famines often lead to social unrest and riots, which further exacerbate them (Gaupp, 2020; IOM, 2020; World Bank, 2020a). It is estimated that, for example, 30 million people in Ethiopia (IMF, 2020) and 40 million people in West Africa (AfDB, 2020) are at risk of a food crisis. Low- and Middle Income Countries (LMICs) are expected to experience higher levels of child mortality due to the impacts of the COVID-19 crisis on the health system and because of precarious food supplies. At the time of writing this report, the Lancet Global Health Report fears that child mortality could be up to 1.1 million higher over the next six months in LMICs due to COVID-19-related disruption to the health system and to precarious food supplies (Editorial, 2020a). In addition, the fact that schools are closed means that many children receive one meal less per day (FAO, 2020j).

Measures to cushion the effects of the COVID-19 crisis

With its ‘Feed Africa Response to COVID-19’ strategy, the African Development Bank is seeking to establish a system of food production on the African continent that is geared towards self-sufficiency and is more resilient to global shocks in world trade. According to FAO, such measures should be introduced across borders and trade barriers reduced as much as possible, especially within regions, (FAO, 2020j; Renzaho, 2020). Gaupp (2020) also proposes a global financial transaction tax against the food speculation by intermediaries that can occur in the global and regional food trade. The World Bank, the OECD and the IMF are advocating temporary debt relief and food aid (World Bank, 2020a; OECD, 2020b). At the same time, it is important to improve the availability of information on COVID-19-related impacts and the planned relief measures. The German Federal Ministry for Economic Cooperation and Development (BMZ) has adopted an Emergency COVID-19 Support Programme, which will be backed by an additional €3 billion to support the countries most affected by the pandemic and its consequences (BMZ, 2020a). Remittances from migrant workers to their families in their countries of origin are another lever. These are essential to enable many people to feed themselves adequately (FAO, 2020j). To counteract the decline in remittances, the WBGU believes that international financial institutions could reduce transaction costs (SDG 10c).

Taken together, these effects show that the COVID-19 pandemic is severely exacerbating problems and hitting the lowest-income countries hardest. With regard to African food production and trade, short supply chains and local value creation should be urgently boosted to increase resilience to external disruptions (OECD, 2020b).

water-intensive crop with its long vegetation period, which already reacts sensitively even to short periods of drought, is now also grown in locations that are fundamentally unsuitable for maize. The yields fluctuate accordingly. One important cause of the excessive spread of maize is the problematic design of ISP subsidies, most of which apply only to maize, since the aim is to secure national food supplies. For example, maize cultivation has gradually marginalized more drought-tolerant crops like sorghum and millet as well as other typical crop species, which, in addition to exacerbating seasonal food shortages, has led to a diet that is too unbalanced (Santpoort, 2020).

The impact of climate change on agricultural yields

While Africa generates only 3.7% of global GHG emissions (Ritchie and Roser, 2017), the consequences of climate change are hitting this continent harder than any other (FAO, 2018c; Welthungerhilfe, 2019).

West Africa, in particular, is already experiencing rapid climate change characterized by widespread warming and an increased frequency of extreme weather events (Sultan and Gaetani, 2016). The assumption is that yield changes are primarily caused by temperature increases and vary in combination with what are then wetter or drier conditions and higher CO_2 concentrations (IPCC, 2014b; Sultan and Gaetani, 2016). Estimates of the degree by which yields for agricultural crops in sub-Saharan Africa will fall on average by the mid-21st century range from 11% (Roudier et al., 2011) to 22% (Niang et al., 2014); in neither case do these figures take into account adaptation measures or the possible CO_2 fertilization effect. This effect is estimated to be smaller for C4 crops, such as maize, sorghum, millet, sugar cane, than for C3 crops (which constitute the majority of crop types) and is likely to amount to several percentage points (<5%, Fischer et al., 2002) if atmospheric CO_2 concentrations double, depending on region and other variables, and might be higher for tuber crops (McGrath and Lobell, 2013).

Ramirez-Villegas and Thornton (2015:13) identify broad beans, maize, bananas and crabgrass as being highly sensitive to climate change and predict that locations suitable for these crops in Africa will decline by 30–50% by 2050, which would particularly affect the Sahel. Higher-than-optimum growing temperatures are the main reason for this, although in some cases there is also less rainfall than required (Ramirez-Villegas and Thornton, 2015:13). Some countries, especially in East Africa, can partially compensate for the changes, or may be positively affected if they are able to relocate arable land to higher altitudes. However, locations for perennial crops are likely to decline significantly due to rising temperatures (Niang et al., 2014).

For some cereals, the predictions are uncertain; for example, in some studies sorghum is considered relatively robust (Ramirez-Villegas and Thornton, 2015) but in others highly vulnerable (Sultan et al., 2013). Only cassava, Africa's most important tuber, is consistently regarded as a relatively resilient arable crop. It is likely to spread as a result of climate change and possibly produce higher yields than before in central and eastern Africa by 2050 (Jarvis et al., 2012; IPCC, 2014c), before these then probably also decline (Niang et al., 2014). Although cassava thus has a lot of potential, this crop needs quite a lot of water and consumes a lot of nutrients from the soil. Therefore, and also for reasons of taste, it can only complement cereal crops, but not replace them.

In addition to quantity, climate change also reduces the quality of crops. Model calculations show a reduction in the iron and zinc content in cereal crops at higher air temperatures. Deficiencies in these micronutrients reduce the body's defences against malaria, tuberculosis and other diseases that are prevalent in the region (Kubota, 2019).

The extent of yield reductions depends, among other things, on the form of cultivation employed. Crops grown in rainfed agriculture, the most common form of cultivation in sub-Saharan Africa, are far more sensitive than those grown in irrigated agriculture.

Another very important factor is the extent of global warming and whether it can be limited to 1.5°C or 2°C. Within this range, even small increases seem to lead to sharp declines in yield. Warming of more than 2°C results in strongly negative impacts on all crop types, irrespective of the form of cultivation (Faye et al., 2018).

In temperate zones there is the option of switching to crops from subtropical or tropical regions when temperatures rise. However, for countries that already have temperatures above the crop's growth optimum there are hardly any options left for such a switch. In this respect, too, the tropics and subtropics are at a disadvantage compared to temperate climate zones, which is another reason why the 2°C climate guard rail should not be exceeded under any circumstances.

Sub-Saharan Africa's adaptation measures to climate change are insufficient

To mitigate declines in agricultural yield in sub-Saharan Africa, there are several options for climate adaptation and resilience enhancement. These adaptation measures relate above all to dealing with increased rainfall fluctuations; they are less effective against heat stress. However, up to now, farmers have lacked the knowledge and means to systematically implement such adaptation measures (Jayne et al., 2018b). Although all African countries have drawn up National Adaptation Programmes (NAPs) for climate change – as a prerequisite for funding from the Global Environmental Facility (GEF) – these are only individual measures at different levels, the selection and prioritization of which are only plausible in some cases (Tab. 3.3-1). There is also a lack of extension services and a financing mechanism to enable smallholder farms and pastoralists to implement any adaptation measures at all (Nzuma et al., 2010).

Box 3.3-3

'Greening of the Sahel' – marginal or significant effect?

The 'greening phenomenon' in the Sahel illustrates how differentiated the effect of climate change is and that it does not always have straight-line effects in one direction. Accordingly, the West Sahel has been experiencing increasing amounts of rainfall over the past few decades, while the region has been historically known for a high level of rainfall variability from one decade to the next and between years. Satellite images indicate greening effects over the past few decades; they show that the vegetation cover that forms in this region after the rainy season is denser than in previous years. This effect is attributed to CO_2 fertilization, which, however, only becomes visible when precipitation has actually fallen. Although rainfall in the Sahel has indeed increased in recent decades compared to the 1970s and 1980s, it has by no means increased compared to the decades before then (1950s and 1960s). These large variations in rainfall in the Sahel, which have been recorded from time immemorial, have long fuelled doubts about the greening effect.

However, recent simulations unequivocally prove the greening effect and that its main cause is climate change (Park et al., 2016; Pausata et al., 2020): the relatively high and sharply rising temperatures of the Mediterranean Sea cause more humid air to reach the Sahel in June, resulting, on average, in more rainfall, which in turn generates more plant growth. This phenomenon is also expected to have an impact on rainfall in the region in the future (Park et al., 2016; Pausata et al., 2020).

Soil measurements confirm these statements at least in part. For example, robust, albeit small 29-43 mm per year) increases in precipitation have also been documented in the West Sahel (Maidment et al., 2015). By contrast, in the eastern Sahel, rainfall decreased by 14–65 mm per year over the same period compared to previous decades (Maidment et al., 2015).

While these changes in precipitation have not yet been decisive for pasture and cropland production, greening could still become significant in the future, as further increases in Mediterranean sea temperatures can be expected, thereby reinforcing this effect (Park et al., 2016; Pausata et al., 2020). This would possibly have a positive impact on pasture and arable farming, but could also be accompanied by numerous side effects which, together with rising temperatures, might be either positive or negative. Up to now, it has not been possible to predict such effects (Pausata et al., 2020).

Although different priorities will obviously need to be set in each case, given different challenges in individual countries and regional climatic conditions, Sustainable Land Management (SLM) by farms does not appear to be seen as an adaptation priority. In the WBGU's view, however, sustainable land and soil management is essential to the question of whether there can be a future for agriculture in the semi-arid regions of Africa.

Biodiversity: wealth and considerable losses

The African continent currently hosts about a quarter of the world's biodiversity (UNEP-WCMC, 2016b:IV); however, this diversity is declining rapidly, as in all regions of the world (UNEP-WCMC, 2016b; IPBES, 2019b). Biodiversity relates to three levels: ecosystem diversity, species diversity and genetic diversity (CBD, 1992). Accordingly, all discussion on biodiversity loss in the context of agriculture relates to the following three levels (FAO, 2019e): The *first level* addresses biodiversity that is lost when near-natural ecosystems are converted into agricultural land. The *second level* comprises agrobiodiversity and the naturally associated, accompanying vegetation on agricultural land. This is disturbed, for example, by the use of herbicides to destroy weeds. The *third level* comprises the genetic resources for breeding crop varieties and animal breeds, which is particularly important for maintaining genetic diversity within crop species, varieties and breeds, as well as for individual stocks.

The more one-sided agriculture becomes, the greater the risk to the diversity not only of cultivated species, but also of cultivated varieties and breeds with their specific characteristics. There can also be tension between the different levels of biodiversity, for example when intensive cultivation is carried out to protect natural areas from further land conversion, but this intensive use destroys agrobiodiversity and pollutes the environment with chemicals. This dilemma cannot be completely resolved, but must be negotiated in each case within the framework of an integrated landscape approach (Box 2.3-3) and with consideration of the other trilemma dimensions of food security and climate-change mitigation.

The most important drivers of biodiversity loss in sub-Saharan Africa are population growth combined with low-yield agriculture, which leads to ever new land conversions and a further fragmentation of the landscape. While fragmentation primarily leads to the loss of necessary corridors and habitats for migrating wildlife and birds, one-sided cropping systems and land degradation primarily reduce agrobiodiversity (UNEP-WCMC, 2016b). Thus, soil degradation leads to one-sided weed populations that are difficult to regulate. One-sided agriculture using the same varieties and species over and over again also drives the loss of genetic diversity, leading to the disappearance of old animal breeds and cultivars (FAO, 2019a).

Table 3.3-1
The 16 measures listed as priorities in national adaptation programmes for ten African countries.
Source: WBGU according to Nzuma et al., 2010

Priority measures in the climate-change adaptation plans of African countries (Burundi, DR Congo, Ethiopia, Eritrea, Kenya, Madagascar, Rwanda, Sudan, Tanzania, Uganda)	Number of countries wishing to implement this measure
1. Development and promotion of drought-resistant and early maturing varieties	10 out of 10
2. Use of renewable energy sources, such as solar and hydro energy and hydropower	10 out of 10
3. Rainwater harvesting with the help of small dams; irrigation	7 out of 10
4. Reduction of livestock by sale and slaughter	5 out of 10
5. Cross-breeding, grazing ban, keeping smaller livestock species such as sheep and goats	5 out of 10
6. Establishing or ensuring the protection and restoration of vegetation cover in degraded land areas and mountain regions at the national level	5 out of 10
7. Introduction of integrated systems of disease surveillance and response, and emergency preparedness to prevent, mitigate and respond to epidemics	5 out of 10
8. Use of traditional methods to protect natural forests, use of foodstuffs, etc.	4 out of 10
9. Clear demarcation of protected areas to avoid their destruction by (human) intervention	4 out of 10
10. Introduction of programmes for community-based management of e.g. forests, grasslands and national parks	3 out of 10
11. Supporting meteorological services to provide weather forecasts, early-warning systems and climate data	3 out of 10
12. Promotion of and support for aquaculture, poultry farming, etc. as alternative income options	3 out of 10
13. Development and dissemination of guidelines for the use of medicinal plants and alternative medicine	3 out of 10
14. Soil protection through seepage trenches around houses, planting turf, terrace cultivation, digging trenches to divert runoff, mulching, planting trees	3 out of 10
15. Reinforcement of agricultural extension services	3 out of 10
16. Coastal protection by constructing dams, integrated coastal-zone management	3 out of 10

Governance against food insecurity and biodiversity loss

The policies pursued to date by African countries to protect biodiversity relate not only to expanding protected areas but, above all, to conserving genetic resources for agricultural breeding. Aichi Target 13 stipulates that the genetic diversity of livestock breeds and crop species and varieties should have been stabilized by 2020 (CBD, 2010a). However, the mid-term review (UNEP-WCMC, 2016b:22) indicated that the extinction risk of local breeds was unknown for over 90% of species. In view of cultivation practices, it must be assumed that the diverse old sorghum and millet varieties in particular will continue to record large losses, as maize continues to prevail as it has in the past (Bazile et al., 2005). It is also apparent that the importance of agrobiodiversity conservation has yet to be acknowledged in sub-Saharan Africa (Khumalo et al., 2012). Although the CBD's Aichi Target 7 also calls for agrobiodiversity through sustainable agriculture for the African continent by 2020, the mid-term review (UNEP-WCMC, 2016b:21) states: "The extent and trends in sustainable agriculture (…) cannot be measured in this region due to a lack of data." This demonstrates first of all the need for monitoring and data-processing systems.

3.3.1.3
Impact of international agricultural trade on resilience to crises and on sustainable development: the examples of the EU and sub-Saharan Africa

Criteria such as sustainability and resilience to food crises have hardly been taken into account up to now in international agricultural trade, which also shapes reciprocal influences on sustainability to a high degree as an essential link between agricultural production methods in different parts of the world. *Resilience* is defined as the capacity of the food system to be robust in standing up to shocks and climate change (Tendall et al., 2015; Ansah et al., 2019). This is important to ensure food security worldwide in the long term, especially in net food-importing countries. *Sustainability,* by contrast, primarily concerns environmental and social aspects as well as economic implications for income and poverty. The problems discussed in more detail below are partly specific to the EU and African countries, but also apply elsewhere. When considering these problems, it is important to bear in mind that international agricultural trade can both promote sustainable development and strengthen the resilience of food systems, but it can also work against both of these objectives. Therefore, it depends in each case on the design of the respective trading regimes.

Development of international agricultural trade

International trade in agricultural products has increased more than tenfold over the past 60 years (Schmitz et al., 2012; FOLU, 2019; D'Odorico et al., 2018), and the trend is still upward (Lassaletta et al., 2014; Seekell et al., 2018). The main factors contributing to this have been the liberalization driven by the WTO, the globalization of the financial and goods markets, but also rising per-capita income, falling transport and communication costs and digitalization. In 2017, the ten most important exporting countries for agricultural products (EU, USA, Brazil, China, Canada, Indonesia, Thailand, Australia, India and Argentina) were responsible for almost two thirds of world exports by value. Indonesia, Thailand, Australia, India and Brazil have particularly high annual growth rates of between 14% and 24% (WTO, 2018). Among the main importers (EU, USA, Canada, South Korea, Russia, as well as China, India, Japan and Mexico), the top ten account for about 70% of total imports by value. From 2000 to 2017, the value of global food imports approximately tripled to US$1.43 trillion. In the case of countries that are particularly vulnerable to food shortages, the figure even increased fivefold (FAO, 2018e, g). Most developing countries, especially in sub-Saharan Africa, are dependent on food imports in the meantime (Alexandratos and Bruinsma, 2012). The EU is the largest trading partner with the African continent, with an export share of around 31% (of which 12% is food) and an import share of 29% (of which 14% is food; Eurostat, 2020a).

International agricultural trade and vulnerability to food crises

A small number of net exporting countries supply a large number of net importing countries (Seekell et al., 2018), which increases vulnerability to food crises. For example, grain exports are concentrated in a few exporting countries and companies. Disruptions to trade chains in these countries threaten the food security of up to 200 million people, 90% of whom live in sub-Saharan Africa (Bren d'Amour et al., 2016). The risk of global food crises can be triggered by production losses (e.g. due to weather extremes or pest infestations), economic or political changes, or other disruptions in the main exporting countries (Seekell et al., 2018; Bren d'Amour et al., 2016; Marchand et al., 2016). Current experience in the course of the COVID-19 pandemic makes these risks particularly evident. Furthermore, self-imposed export restrictions by major exporting countries cause staple food prices to rise, which, as early as 2007, triggered food shortages, social unrest and violence in many developing countries, especially in sub-Saharan Africa (Buhaug et al., 2015).

The role of the EU as a major food exporter

As a result of the CAP, the EU became a major net exporter of agricultural products in the 1980s, with distorting effects on competition. Until the early 2000s, surplus products were dumped on the world market by means of export subsidies at prices that were below production costs, thus destroying many markets and incentives for food production in sub-Saharan Africa (Brandt, 2004). Despite the abolition of export subsidies in 2013, farms in the EU continue to benefit from direct payments. However, these are estimated to have little (Rudloff and Brüntrup, 2018; Matthews et al., 2017) or an unclear (Matthews and Soldi, 2019; Urban et al., 2016) impact on development; decisive is the extent to which the direct payments are decoupled from production and thus no longer distort trade (Boysen-Urban et al., 2020). For Uganda, for example, it is assumed that the removal of EU agricultural support would have only a marginally positive impact on its economy and poverty indicators (Boysen et al., 2016).

Long-distance effects of agricultural trade

Demand in the EU for agricultural products produced far away usually involves telecouplings (long-distance effects) which have a direct impact on the environmental situation in the producing countries. For example,

Box 3.3-4

Land Grabbing

Major investors from abroad and external decision makers are gaining increasing influence over Africa's agricultural land (Batterbury and Ndi, 2018:573). Large-scale land acquisitions (LSLAs) or land grabbing, defined as the sale or lease of large tracts of land to (usually foreign) actors such as states, agri-business corporations or financial investors, are on the rise (Borras Jr et al., 2011; Borras Jr and Franco, 2012). The African continent has been regarded as a focus of land grabbing since the 2000s (e.g. Chu, 2011; Galaty, 2013; Oya, 2013; Batterbury and Ndi, 2018; Ashukem, 2020). For all African countries combined, a total of 565 land transfers covering an area of 14.3 million ha had been registered by mid-2020. Letters of intent exist for a further 9 million ha (The Land Matrix, 2020a). These 23.3 million ha of land sold or leased to foreign users already arithmetically comprise the total agricultural land of Tanzania, Kenya and Zambia combined. The main targets of land grabbing in sub-Saharan Africa are Ethiopia, Angola, Democratic Republic of Congo, Cameroon, Mozambique, Madagascar, Tanzania and Zambia, and the agents are often European or Asian investors (The Land Matrix, 2020b).

Although large-scale land acquisition can also have a positive impact by adding value to otherwise fallow land and providing employment for local people (Herrmann, 2016), the dominant agro-industrial intensive methods used – which focus mostly on the export production of agricultural commodities and/or fuel and animal feed, but rarely food – can lead to the overexploitation and contamination of soil and water resources (Borras Jr et al., 2011; Borras Jr and Franco, 2012). Drivers are high fertilizer and pesticide application and irrigation-intensive land use (Galaty, 2013; Rulli et al., 2013).

Land grabbing frequently has a negative impact on local food self-sufficiency because the land sold or leased to foreign investors is no longer available for food production. The same applies to local water resources (Borras Jr and Franco, 2012). In any case, large portions of externally acquired land often lie fallow for speculative reasons (Levien, 2018). In addition, legal loopholes and unclear legal and ownership structures relating to land tenure are exploited, making it difficult to enforce claims for domestic use (Deininger and Byerlee, 2011). In sub-Saharan Africa, too, states that are highly susceptible to corruption provide a good breeding ground for land grabbing (Transparency Germany, 2020). Moreover, because traditionally agreed land-use rights without registered land titles are the rule, it is very difficult to prevent external investors from investing in land (Batterbury and Ndi, 2018). The impact of large-scale land acquisition on nomadic pastoralists, as users of common land, is particularly negative because sales of regularly used grazing land often happen unexpectedly and without their being aware of it. For example, in the Afar region of Ethiopia, foreign companies use the areas near the river for water-intensive sugarcane cultivation, which impedes river access for local livestock (Rettberg, 2009). The states where the land purchases mostly originate (e.g. South Korea, China, Saudi Arabia or even the United Kingdom) are not sufficiently motivated by regulations to take fairness and sustainability concerns into account (Wolford et al., 2013). Digital solutions, such as blockchain technologies, offer opportunities for greater transparency and can mitigate vulnerability to corruption in land transactions (WBGU, 2019b).

the high demand for soybeans or palm oil in the EU is met by cultivation with high environmental costs in the producer countries Brazil and Indonesia (Lenschow et al., 2016). This also applies to export products from sub-Saharan Africa such as coffee, cocoa, tea or palm oil. Agricultural production there leads to more environmental damage than it would in importing countries due to inadequate enforcement of environmental regulations, for example in terms of water pollution or reduced soil fertility due to phosphorus depletion in the soil (Schipanski and Bennett, 2012). Countries exporting meat and feed are particularly affected, as their environmental costs are not included in pricing (Galloway et al., 2007). They become competitive at the expense of the environment because external costs are not internalized (Naylor et al., 2005).

Case studies show that forests, pastures and arable land with high ecological and cultural value have often been used for the export-oriented intensification of agriculture and the establishment of plantations for growing products for export (cash crops; Jadin et al., 2016; Henders et al., 2015). According to FAO data, 80% of the 8.8 million ha of forest lost every year is due to conversion to cropland, and around 30% of its agricultural production is exported (BMEL, 2020e). In addition to timber, the main products traded are palm oil, soybeans and beef; the production of these four products alone is blamed for almost 70% of deforestation (Lawson, 2014; Weisse and Goldman, 2017). Furthermore, agricultural trade contributes significantly (29–39%) to deforestation-related CO_2 emissions; this applies in particular to trade with meat and oilseed (Pendrill et al., 2019). Also, 30% of globally threatened species can be linked to agricultural trade between developing and developed countries (Lenzen et al., 2012). Global agricultural trade is a major contributor to the spread of invasive species (Pyšek et al., 2010; Seebens et al., 2015). Moreover, social aspects in the export-oriented plantation economy, such as child labour in cocoa production in West Africa, also come in for criticism (Luckstead et al., 2019).

However, agricultural trade can also have positive environmental effects. If, for example, agricultural production is outsourced to countries with sufficient water and soil, imports of these foodstuffs combined with the 'virtual water trade' can alleviate regional water shortages in the importing country. It is estimated that 8% of the total water required for agricultural production could be saved via international trade (Oki et al., 2003). Some food-importing countries, also in sub-Saharan Africa in particular, thus already benefit from 'virtual' trade in land, water and nitrogen (Dalin and Conway, 2016; Grote et al., 2008). In addition, the transfer of environmentally friendly technologies to developing countries and the increased demand for sustainable foodstuffs trigger positive structural and production effects.

Economic partnership agreements between the EU and the ACP countries

Under certain conditions, Economic Partnership Agreements (EPAs) enable the developing countries associated with the EU in Africa, the Caribbean and the Pacific (ACP countries) to use tariffs to protect their own markets against import dumping. But by no means all African countries have ratified the EPAs so far, and only a few are implementing their right to tariffs, partly because the interests of their own political decision-makers are divided. The mass of the urban population benefits from cheap imported food, which would cost a lot more if it were produced in the countries themselves. This constellation seriously impairs domestic agricultural development and also the expansion of economic sectors that are not yet competitive (infant industries) along the value chain.

Conclusions

Agriculture in the EU and in sub-Saharan Africa each face specific problems of sustainable land management. Although subsidy-based agricultural policies and support programmes respectively claim considerable shares of agricultural budgets (40% of the EU budget and 30–70% of agricultural budgets in sub-Saharan African countries; Jayne et al., 2018a), problems such as further farm closures in the EU, poverty and hunger in sub-Saharan Africa, and environmental problems in both regions have not been solved. International agricultural trade can increase vulnerability to food crises, but it also has the potential to offset food shortages in times of crisis and to have a positive impact on sustainable land use.

3.3.2 Multiple-benefit strategies for the diversification of farming systems

The following multiple-benefit strategies can significantly help diversify farming systems and thus make an important contribution to overcoming the land-use trilemma. Following the presentation of an overarching goal (Section 3.3.2.1), value-added strategies for the agricultural sector are formulated that can mitigate the trilemma:

- the greening of industrial agriculture in the EU (Section 3.3.2.2),
- the sustainable enhancement of productivity and climate-change adaptation of subsistence farming in sub-Saharan Africa (Section 3.3.2.3),
- the orientation of agricultural trade towards resilience and sustainability (Section 3.3.2.4).

In addition, Section 3.3.2.6 discusses fifteen example components of multi-benefit strategies for the agricultural sector. These components comprise diverse agricultural production systems (e.g. agroforestry, aquaponics, rice intensification, conservation agriculture) that can be specifically linked with known and new methods and cultivation practices (e.g. organic fertilizers, precision agriculture or no-till farming) and principles and continuously improved. The above-mentioned seven principles were developed with the aim of promoting a transition of land use towards sustainability, specifically in the agricultural sectors of developing countries and emerging economies (Fig. 3.3-4).

3.3.2.1 Overall goals and principles

Depending on the respective world region and the agro-ecological conditions, specifically adapted strategies must be developed for the transition of land use towards sustainability in the agricultural sector – this is shown by the following remarks on industrial agriculture in the EU and on subsistence farming in sub-Saharan Africa. What the strategies have in common, however, is the focus on ecologically intensive systems, i.e. diversified and multifunctional production systems geared to sustainability. They place people at the centre and incorporate traditional local knowledge, build on it, substantiate it and develop it further together with scientists (Section 3.3.2.6; Component 1: Agroecology).

The following overarching principles provide orientation for the design of diversified farming systems. They contain the essential facets of an integrated landscape approach (Box 2.3-3), which, however, must be regionally adapted in each case.

- *Principle 1: Diversification:* Closely linked to the idea of multifunctionality, diversification comprises agricultural production methods that, by increasing the number of crop species in the form of spatial mixing or successive crop rotations, minimize production risks, improve adaptation to climate change, strengthen ecosystem services, preserve genetic diversity, recouple crop production with livestock farming and thus also promote a varied diet.
- *Principle 2: Participatory and inclusive approaches:* By involving farmers in research and experiments

and drawing on their experience and initiatives in environmental protection and nature conservation, practical and locally adapted innovations for sustainability can be promoted, including the creative power and empowerment of local people.

- *Principle 3: Internalization of ecologically damaging effects:* Environmental impacts of agriculture, such as excessive nutrient and pesticide inputs into surrounding ecosystems, humus depletion due to overuse, and soil degradation, should be taken into account as costs, reflected in prices (internalized) and thus limited.
- *Principle 4: Conservation and enhancement of ecosystem services:* Agriculture is critically dependent on the provision of ecosystem services because it makes extensive use of land and water among other things. This concerns the production of agricultural goods, soil formation, nutrient cycles, water-pollution control, biodiversity, carbon storage, landscape aesthetics as well as erosion control. Agriculture should be geared towards the conservation of these ecosystem services.
- *Principle 5: Exchange of inputs:* In the EU's industrial agriculture, reduced use of fossil fuels, mineral fertilizers and synthetic chemical pesticides can conserve biodiversity and reduce GHG emissions. This requires other methods of securing or increasing yields, or other production systems. The use of knowledge, e.g. on biological, ecological and cultural measures, of data and (inter alia digital) technologies (such as drones, precision agriculture, organic fertilizers, biological crop protection), as well as renewable energies and capital, offers options and can also help to save labour.
- *Principle 6: Rehabilitation of degraded soils:* In subsistence farming in sub-Saharan Africa, only the demand-oriented use of organic and mineral fertilizers as well as soil-conservation and other adaptation measures can counteract soil degradation and restore soil value. Extension services and financial support are needed to enable small farmers to implement such measures consistently and with the necessary staying power.
- *Principle 7: Promoting agriculture geared towards a circular economy:* In a future-proof farming system, manure and crop residues should be recognized as valuable resources, waste avoided, and nutrients (including phosphorus) recycled. The spatially and, in some cases, socio-culturally decoupled farming systems should be reconnected in order to close (nutrient) cycles again.
- *Principle 8: Promoting climate adaptation and resilience:* Projected yield declines from increased rainfall variability and heat stress as a result of climate change underline the need for resilient, diversified farming systems. The occurrence of pandemics and crises (COVID-19 pandemic, famines) also illustrates the important role of resilience in the food system. Shortening and unbundling value chains in international agricultural trade can create systems that are more resilient.

The two photographs in Figure 3.3-5 show examples of regionally adapted, diversified farming systems. Such sustainability-oriented, multifunctional landscapes not only enable the production of food and public goods, they also make landscapes more attractive, creating opportunities for value creation through agritourism and recreation. Charming cultural landscapes with great diversity, such as Tuscany or the rice terraces in Asia, are world cultural heritage sites and places of inspiration for literature, painting and music.

3.3.2.2
Greening of industrial agriculture in the EU

Following on from the EU-specific problem areas (Section 3.3.1) and on the basis of the eight principles, the EU needs a strategy for the systematic, consistent ecological transformation (greening) of industrial agriculture. This involves diversifying as quickly as possible a form of production that is heavily dependent on external inputs (purchased fertilizer, animal feed, etc.) towards multifunctional cultivation systems (such as organic farming, agroforestry, agrophotovoltaics or precision farming). In addition, fertilizer and pesticide inputs should be greatly reduced and more biodiversity-friendly solutions and cycle-oriented systems implemented.

Advantages of greening industrial agriculture

The positive effects of greening industrial agriculture on biodiversity, climate-change mitigation and food security are numerous and scientifically proven (Section 3.3.2). For example, greening promotes biodiversity conservation, increases pollination, and reduces the number of pathogens and pests (Lampkin et al., 2015; Tscharntke et al., 2005). Furthermore, fields that are farmed organically have approx. 30% more biodiversity than those on conventional farms (Wissenschaftlicher Beirat des Nationalen Aktionsplans zur nachhaltigen Anwendung von Pflanzenschutzmitteln des BMEL, 2019). Agroecological practices can reduce the need for synthetic pesticides, one of the main causes of biodiversity loss (IPBES, 2019b; Gurr et al., 2016), and increase soil fertility (Stein-Bachinger et al., 2020). More biodiversity in agriculture also has a positive impact on adjacent protected areas (Häkkilä et al., 2017). In general, greening helps to protect agricultural land of high environmental value (BfN, 2017).

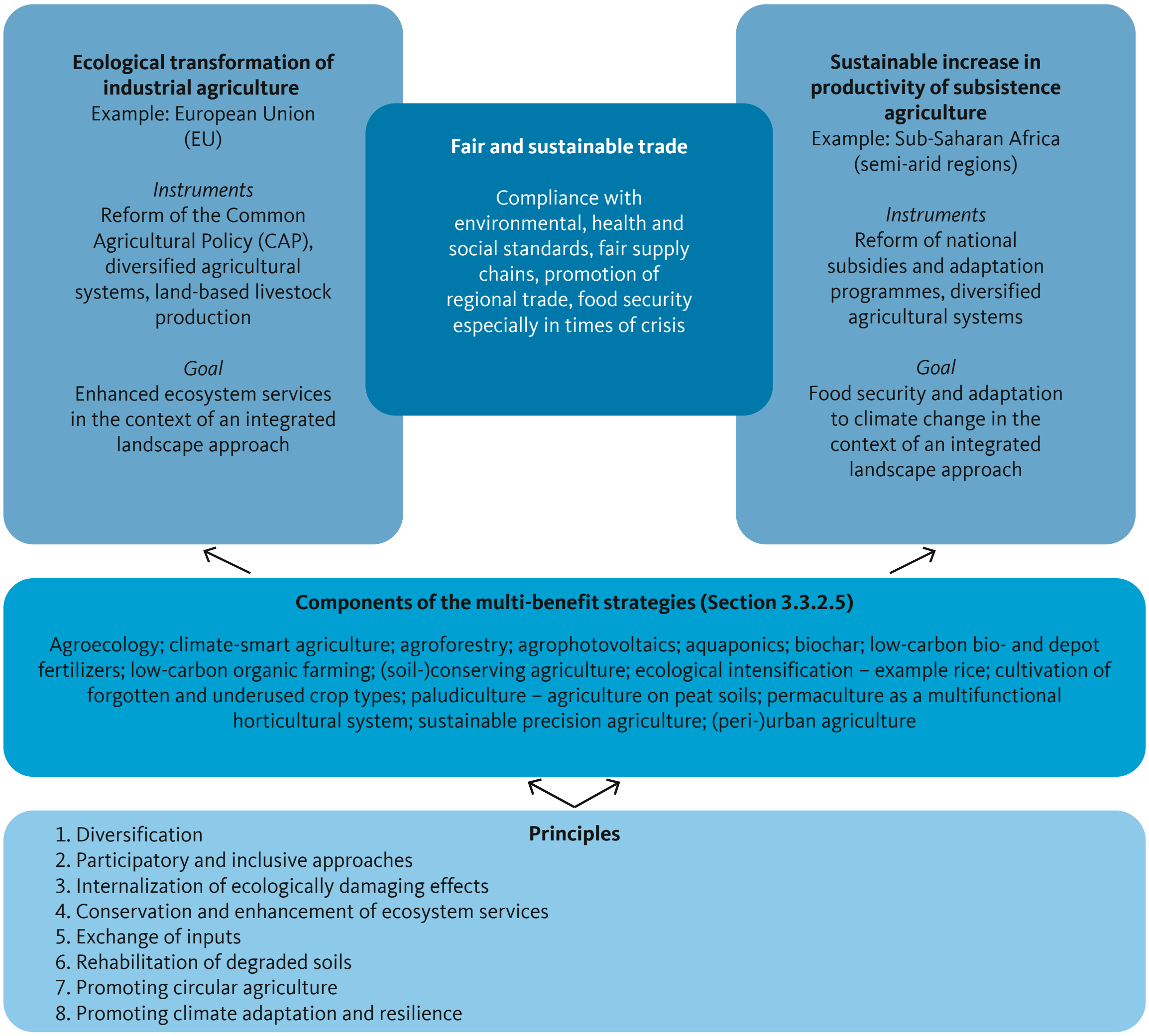


Figure 3.3-4
Multiple-benefit strategies for the agricultural sector and principles for defusing the land-use trilemma.
Source: WBGU

The greening of agriculture also increases resilience to climate change (Tscharntke et al., 2011). More effective use of fertilizers reduces nutrient inputs into soils and surrounding water bodies and contributes to climate-change mitigation by preserving the carbon-sequestering soil microbiota (Sutton et al., 2011). Diversified farming systems (e.g. agroforestry systems) promote CO_2 absorption. Strengthening the multifunctionality of some systems can also improve land-use efficiency (Weselek et al., 2019). Organic farming is currently gaining ground as a particularly resource-conserving, environmentally compatible production system. The global market for organically grown produce more than quadrupled from 2000 to 2015 (Lernoud and Willer, 2018). The German Federal Government aims to expand the share of organic farmland to 20% of total agricultural land by 2030 (BMEL, 2019c). The European Green Deal's Farm-to-Fork strategy aims to expand organic farming to at least 25% of the EU's agricultural land (EEAC, 2020).

Greening would also lead to changes to the remaining 75% of the EU's land farmed in a conventional industrialized way: the Farm-to-Fork strategy aims to reduce pesticide use by 50% and fertilizer use by at least 20% by 2030, as well as reducing sales of antimicrobials (e.g. antibiotics) for livestock by 50% (EEAC, 2020). Precision-agriculture approaches, for example, can help reduce inputs as they offer potential for ecological intensification, i.e. for increasing yields while at the same time curbing environmental damage (WBGU, 2019b).

Figure 3.3-5
Regionally adapted, diversified farming systems. Left: Chianti region, Tuscany, Italy. Range of hills with cypresses, vineyards and olive groves; right: South Sulawesi, To'pao village, Indonesia. Rice terraces and agroforestry systems (coffee, cocoa, cinnamon, pepper, vanilla) in a forested rocky landscape.
Sources: photograph left: ©Ulrike Grote and Frank Neubacher; photograph right: Silke Stöber (SLE, Humboldt University Berlin)

Solving agricultural land-use problems through greening

The extent to which increased greening can solve the acute problems of agricultural land use depends in each case on the systems and methods used. Organic farming offers considerable potential for increasing biodiversity, closing cycles and contributing to food security. It also sets high standards for animal welfare and husbandry.

In the EU, acceptance of and willingness to pay for organically produced food is on the increase. However, due to its lower yields (in plantation agriculture 5%, in arable agriculture 25%; Seufert et al., 2012; Rahmann and Oppermann, 2010) organic agriculture has a similar, in some cases even slightly higher CO_2 footprint per kg of food produced than industrial agriculture. The CO_2 footprint is a measure of all greenhouse-gas emissions generated in the life cycle of a product (Hoekstra and Wiedmann, 2014; Section 3.3.2.5). The lower yields are partly or fully offset by the higher carbon sequestration, which is not included in the CO_2 footprint. Organically cultivated soils have a 10% higher soil organic carbon content and a 256 kg C per ha higher annual carbon sequestration rate (Box 3.3-11). These average values mean that organic farming's cumulative climate-protection performance is 1,082 kg CO_2 equivalents per ha per year (Sanders and Hess, 2019b). Although organic farming is relatively labour-intensive, digital precision-farming approaches can be applied here to reduce labour input (WBGU, 2019b).

Forms of greening based on reducing livestock numbers and stocking densities and re-coupling crop and livestock production reduces dependence on feed imports and thus also the negative environmental effects in producer countries. Extensive grazing protects biodiversity and solves problems of the overfertilization of soils and water bodies with manure, but it cannot offer an all-encompassing solution (Box 3.3-2). Feeding changes and breeding can also contribute to reducing emissions (Barkhausen, 2019). For example, New Zealand aims in future to price GHG emissions from livestock by including the agricultural sector in emissions trading (Rychlik, 2019; Kerr and Sweet, 2008).

Pesticides are a special problem, but they can increasingly be replaced by alternatives that are already known and ready for use. The necessary agroecological practices (Section 3.3.2.2) have long been called for by NGOs (4th International Conference on Chemicals Management, 2015; Haffmanns, 2019) and can be introduced into the follow-up SAICM Beyond 2020 agreement now being prepared. Although estimates suggest a 17-40% loss in yields without pesticide use (Pimentel and Burgess, 2014), this is based on conventional farming systems without any other crop-protection measures. Furthermore, calculations of yield loss without pesticides do not take into account the environmental and yield services that are lost as a result of destroyed biodiversity (e.g. pollinators, aquatic and soil organisms). Farming systems that largely avoid pesticides and mineral fertilizers, such as organic farming, extensive farming systems or land managed under agri-environmental schemes, tend to have higher agrobiodiversity (Stoeckli et al., 2017).

A case in point is Denmark, where pesticide use has been reduced by 44% since 2013 through the introduction of a toxicity-based staggered incentive tax, largely without income losses for farmers (Kohli, 2019). The Scientific Advisory Council of the German Federal Ministry of Food and Agriculture (2019) suggests considering the introduction of incentive taxes in Germany on pesticides.

In order to implement a successful greening strategy, which should be accompanied by a fundamental CAP reform in the EU, a change is needed in the awareness of pesticide users. This should be backed up by more information on the ecological implications of foodstuffs in order to promote healthy and environment-friendly diets (Section 3.4). This can only succeed if the food industry also supports this transformation process.

Practical approaches to greening agriculture

Cooperative models that enable more inclusion as well as the application of an integrated landscape approach offer starting points to stop the decline of biodiversity on arable land. Such eco-schemes of the CAP's first pillar, which would replace the existing 'Greening' scheme (Box 3.3-1), should be made more target-oriented and opened up to include animal-welfare measures (WBAE, 2019). One concrete approach to designing and implementing measures to achieve biodiversity conservation, climate and water protection under the voluntary eco-schemes is to introduce a points or bonus system to reward farmers for their ambition or investment in the provision of public goods and ecosystem services (Neumann et al., 2017; DVL, 2020). The reward would to be made available by granting a public goods bonus from the first pillar. Calculations on the public goods bonus have shown that it certainly represents a practicable and administrable implementation model that has a positive impact on the environment and the climate (DVL, 2020). Further proposals have been made on the design of direct payments (BfN, 2020).

The efficiency of the CAP can be increased by linking direct payments exclusively to agricultural purposes and benefiting the tenants of agricultural land. Since the decoupling of direct payments, a growing proportion of direct payments has been transferred to the owners of the land as the overall high share of leases in Germany has risen (Forstner et al., 2018). Paying CAP subsidies to non-farmer owners, e.g. insurance companies and banks, is inefficient as this amounts to a redistribution of CAP funds away from agriculture and an increase in leasing prices, which are regionally aligned with direct payments, making it more difficult to lease agricultural land (Forstner et al., 2018).

The 'Dutch Model' serves as a European prototype for the cooperative implementation of agri-environmental measures (e.g. nature-conservation-oriented ditch cleaning, riparian strips, later mowing times to protect birds, conservation of grassland). Since 2016, all agri-environmental and climate-change-mitigation measures in the Netherlands have been implemented and controlled by what are known as countryside conservation associations, of which farmers are also members. This cooperative landscape approach supports multifunctionality, reduces bureaucracy and offers farmers incentives to engage in conservation (Terwan et al., 2016). In Switzerland, on the other hand, a model is used that focuses not on cooperation among farmers, but on spatially interconnecting individual agri-environmental protection and climate-change-mitigation measures (Batary et al., 2011; Tscharntke et al., 2012). In Germany, there are countryside conservation associations in which nature conservation organizations, farmers and local politicians join forces to preserve near-natural landscapes or create new ones in the respective region, in the course of which the implementation of contractual nature conservation becomes the focus of the work of such conservation associations (Metzner et al., 2013; Boller et al., 2013). For example, in addition to countryside conservation associations, Bavaria has created the position of a wildlife habitat advisor (Janko et al., 2016), who advises individual farmers, supports the implementation of voluntary measures to enhance wildlife habitat and seeks to establish model areas (Müller, 2019).

Humus certificates for production systems that verifiably achieve carbon sequestration by humus formation are controversial (Wiesmeier et al., 2020). Humus certificates are considered unfair since the potential for humus formation is greater the lower the humus content is as a result of previous farming practices; only those who have not previously invested in humus formation benefit. By contrast, intrinsically motivated farmers who had already invested do not benefit. As a counter-argument, reference is made to measurement problems and displacement effects as well as the complete reversibility of humus formation. Overall, it should be emphasized that the debate on CO_2 certificates can provide a positive impetus for farmers to increasingly address the sustainable management and humus supply of their soils (Wiesmeier et al., 2020).

3.3.2.3
Sustainably increase agricultural productivity in sub-Saharan Africa, achieve climate adaptation and food security

Because of the specific conditions for subsistence farming in sub-Saharan Africa (Section 3.3.1.2), different strategic approaches are required there from those used in industrialized EU agriculture. The smallholder farms and pastoralist families in semi-arid regions affected by seasonal hunger need a marked increase in productivity so that food is available to everyone throughout the year. To this end, degraded soils and pastures should be restored by sustainable and integrated land and nutrient management. The farming systems could furthermore be diversified and intensified with the help of various components in such a way as to generate multiple benefits that diffuse the land-use trilemma.

Despite climate change, a doubling of the currently still very low agricultural yields is regarded by numerous experts on sub-Saharan Africa as realistic and also sustainably possible, regardless of whether it is achieved with organic, conventional or integrated strategies (Tittonell et al., 2016; AfDB, 2016; Tadele, 2017; van Ittersum et al., 2016). However, although such a forecast sounds positive, this doubling is not enough to meet the rising demand caused by the already existing large deficit and the expected further medium-term population growth (Section 3.3.1.2). This is especially true if the policy is that the current self-sufficiency level of about 80% should not fall sharply in the future and at the same time there should be no further land conversions (van Ittersum et al., 2016). Although imports of (basic) foods do not fundamentally counteract the goal of sovereign food security, the resource-poor Sahel countries in particular are already barely able to pay for their growing food imports (van Ittersum et al., 2016; AfDB, 2016; Section 3.3.1.3). However, land conversions should also be avoided wherever possible to prevent further land degradation and biodiversity loss and to minimize GHG emissions. It is therefore necessary to supplement the approach of raising productivity with other strategies along the value chains and outside agriculture. Only then can food sovereignty be achieved. Some of the possible supplementary strategies are touched upon at the end of this chapter.

Productivity increases and climate adaptation based on a combination of agroecological and conventional measures

In the meantime, there is a broad consensus among scientists that raising productivity in sub-Saharan Africa requires sustainable land management (SLM; Janzen, 2016; Njoroge et al., 2019; Nkonya et al., 2016c). This can only be achieved if the already degraded and mineralized soil is organically enriched again (for example with manure or biomass) and simultaneously supplied with nutrients that can be quickly absorbed by plants (for example mineral fertilizers). In concrete terms, agroecological and conventional measures must be interlinked and geared to climate change in a way that achieves both higher yields and resilient climate adaptation. The great challenge is then how the site-specific combination of approaches can be implemented with broad effect within the societal contexts (Section 3.3.3.2).

While agroecological (adaptation) measures to safeguard and increase yields focus on the use of organic fertilizers and aim to diversify crop types and strengthen ecosystem services (Section 3.3.2.6, Component 1), conventional measures are based primarily on the use of purchased inputs such as high-yielding varieties (e.g. hybrid varieties), mineral fertilizers, pesticides and irrigation technology.

However, both agroecological and conventional approaches have their limitations under semi-arid and poverty conditions.

- Agroecological measures reach their limits where biomass is scarce, because then they require a very high labour input and a lot of water and cause high transport costs (Place et al., 2003).
- Conventional inputs, on the other hand, are themselves expensive – in sub-Saharan Africa, most mineral fertilizers and pesticides are imported, and diversified (high-yield) seeds are hardly available and very expensive in most locations, so that resource-poor smallholders lack access to them if they do not receive subsidies. However, if inputs are made available in the form of loans, as is often the case, then such use additionally involves high production risks. These can cancel out the multiple benefits, e.g. in the event of drought, or exacerbate losses. In addition, there are the environmental and health risks if, for example, pesticides are applied without protective clothing, used in excess or stored incorrectly (Section 3.3.1). Irrigation measures range from very costly to very low-cost measures with very different levels of sustainability depending on water resources, irrigation systems, etc. Low-cost strategies are described below.
- Away from the debate on the pros and cons of organic versus conventional agriculture, it is now scientifically proven and also widely accepted that degraded soils in sub-Saharan Africa can no longer produce sufficient yield effects with a nutrient management focused solely on applications of mineral fertilizer (Folberth et al., 2014; Ramirez-Villegas and Thornton, 2015; Tittonell et al., 2016; Jayne et al., 2018a). It has been known for decades that the use efficiency of tropical soils with mineral fertilizers is lower than soils in temperate zones (Kumwenda et al., 1996). More recently, however, it has become increasingly clear that severely degraded soils often only respond at all to mineral fertilizer applications after a longer delay, so that in some cases their original yield capacity is only regained after seven to ten years, or not at all (soil memory effect, heterosis effect; e.g. Tittonell et al., 2016). The failures of the

industry-affiliated, mineral-fertilizer-focused NGO Alliance for a Green Revolution in Africa (AGRA) are therefore not surprising. They were unable to reach the target of doubling agricultural productivity in sub-Saharan Africa by 2020 using conventional strategies: over a 12-year period, yields increased by only 18% for a range of crops and by 29% for maize (Wise, 2020).

For this reason, too, applications of mineral fertilizer should not be used in isolation, but should always be combined with agroecological measures in such a way that the two approaches can mutually benefit each other in terms of their effects and costs. Such a combination increases yields much more significantly, quickly, sustainably and efficiently than one of the two fertilizer measures alone, while simultaneously strengthening the smallholder farms economically (Vanlauwe et al., 2002; Folberth et al., 2014) when organic fertilizers (e.g. animal manure) are available. In addition, the respective disadvantages of the individual strategies are kept within limits in this way. The individual techniques for restoring soils, e.g. how conservation agriculture with permanent plant cover can stop soil erosion and still harvest more, are discussed in Box 3.3-12.

Because of the long time it takes to fully regenerate soils and the high labour input required by most rehabilitation techniques, there is little or no incentive for smallholders to implement such measures on a continuous basis. Sustainable land management should therefore be urgently implemented before degradation sets in. However, once this moment has passed, there is no time to waste in putting such management into practice, because the time to recover is disproportionately prolonged and the cost then increases sharply (Janzen, 2016; Njoroge et al., 2019; Nkonya et al., 2016a).

Organically enriched soils are not only higher yielding and act as carbon sinks, they are also the key agricultural strategy for resilient climate adaptation. This is because humus-rich soils with a high proportion of organic matter are better able to absorb heavy precipitation and thus prevent flooding and water erosion. They also store water longer and are therefore less sensitive to drought. In the language of climate adaptation, therefore, organically enriching and covering soils is considered a no-regret or low-regret measure, meaning that it also entails no (or only few) disadvantages and costs should the expected precipitation changes not occur (IPCC, 2019b; Martin, 2012). The potential costs and drawbacks of adaptation measures should therefore always be considered as well, as the impacts of climate change cannot be precisely predicted at a specific location and time (Martin, 2012; Berck et al., 2018). Adaptation measures can themselves also lead to higher emissions (maladaptation; Chapter 2) or – like irrigation – increase the pressure on (natural) resources. The more expensive the adaptation measures are and the more they target specific expected changes, the higher the risk of further exacerbating the already highly precarious situation of smallholder agriculture in sub-Saharan Africa and other regions of the world.

Crop diversification increases resilience and nutritional quality

The problem of one-sided, uniform agriculture does not only exist in industrialized countries; in the course of recent decades, low-yield subsistence farming in sub-Saharan Africa has also become heavily oriented towards maize cultivation (Section 3.3.1.2). There is a lot of potential for reducing risk and raising productivity in a locally adapted diversification of crop types, e.g. with sorghum, millet and legumes in combination with cash crops such as sisal, cotton and sesame and including the integration of fruit and nut trees (e.g. mango and leguminous plants), supplemented, for example, with the cultivation of 'forgotten' and underutilized crop types (Section 3.3.2.6). This also applies to the starvation phase at the end of the inter-harvest period of the main crops. In addition, locally adapted diversification also boosts employment and income, and promotes healthy diets and resilience to crop failure (Kissoly et al., 2020; Section 3.3.2.6). Extension services, versatile seeds and sufficient manpower are needed to implement such diversification strategies.

The establishment of supplementary, sustainable irrigation systems is important to bridge the nutrition-poor inter-harvest period and ensure a continuous supply of basic foodstuffs. As technical irrigation infrastructure involves high investment and operating costs and often raises sustainability issues, the focus here is primarily on simple, affordable rainwater-harvesting techniques which are primarily concerned with not allowing rainwater to run off unused (Filho and de Trincheria Gomez, 2018). For example, contour stone walls can greatly increase the soil's precipitation infiltration capacity, so that yields can be more than doubled in some cases (Terra Verde Förderverein, 2020; FAO, 1996a). Some surface waters can be put to better use by creating river sills, allowing water to spread more easily in dry valleys and be used there to grow crops (BMZ, 2020c). Another simple irrigation technique is low-evaporation subsurface irrigation using plastic bottles that are joined together (Fig. 3.3-6; Pellmann, 2017). The use of treadle pumps can also greatly increase agricultural yields in areas close to rivers or where groundwater levels are high. All these measures are cost-effective and proven, but they do involve a lot of work (Fox and Rockström, 2000; UNESCO, 2018).

Figure 3.3-6
Green River Principle: economical and cost-effective method of subsurface irrigation according to Pellmann, 2017, in Garissa, Kenya. Empty plastic bottles are joined together, perforated, wrapped in newspaper and laid in the subsoil. The barrels contain the water, which runs down a slight gradient into the joined bottles. The photograph shows that nothing would grow without irrigation because of the dry climate, but with irrigation a yield is produced (here indigenous African leafy vegetables).
Source: Silke Stöber, SLE, Humboldt University Berlin

Benefit-sharing agreements between arable farmers and pastoralists

In addition to arable farming, transhumance is of great importance in the Sahel and in semi-arid regions of sub-Saharan Africa. Traditionally living in a symbiotic relationship with arable societies – where the pastoralists provide the manure and arable farmers the grain – the relationship between these two groups, who usually interact peacefully on a day-to-day basis (Bukari et al., 2018), has increasingly turned into one of conflict in recent decades, particularly in Sahelian countries (Shettima and Tar, 2008; Turner, 2004; Oyama, 2014). This relationship, along with the infiltration of fighters from outside, for example in Mali, has long since taken on dangerous forms and includes the potential for civil war to erupt (African Center for Strategic Studies, 2019).

These conflicts become visible in everyday disputes over increasingly scarce land and water resources. However, the underlying causes are of a political, socio-cultural and societal nature and can be summarized as follows (IFAD, 2020; Bukari et al., 2018; African Center for Strategic Studies, 2019):

1. Political discrimination against pastoralists, which is manifested in low societal esteem and little participation, in arbitrary legal restrictions on land use, and in an ongoing fragmentation and downsizing of grazing grounds, e.g. through undeclared land investment by third parties or insecure lease contracts.
2. A decades-long increase in encroachment by cropping communities into grazing areas, often with no regard for established pastoralist migration routes and without creating access corridors for livestock to waterholes, with the result that the irrigation infrastructure of arable farms is destroyed by animals in search of water, or that pastoralists are further displaced.
3. Livestock herds that are too large for the shrinking pasturelands, further accelerating their degradation.

Thus there is an urgent need to establish new rules for sustainable pasture management. The reciprocity of the problem and its causation by both populations should not be lost sight of (Nkonya et al., 2016b). Measures such as changing grazing routes, portioning pastures and reducing the size of livestock herds are crucial, but at the same time arable soils need to be restored and used more sustainably to avoid further land conversions at the expense of pastures. In order to return to a form of shared resource management, the WBGU recommends first reviving traditional institutions of conflict mediation and then adapting them to current needs, e.g. for fair decision-making processes (IFAD, 2020). During the subsequent negotiations, all-party benefit-sharing agreements should be developed that are effective beyond the community level to govern shared grazing and cropland use. To this end, these agreements should be anchored in government agencies, and publicized and supported at the international level, e.g. by advocacy groups (for example the International Crisis Group). Only by being formalized or publicized can these agreements carry weight. The adaptation plans of the environmental authorities, which today focus on 'reducing livestock numbers' but less on the necessary management changes in arable farming, primarily speak the language of those whose interests lie in arable farming. The lists of adaptation measures would therefore have to be revised in the interests of anti-discrimination (Section 3.3.1.2). There are already examples and proposed methods for implementing such joint management (e.g. IFAD, 2020; FAO, 2016d), which have also been elaborated as a multi-level approach.

Funding channels for achieving broad-based implementation of agroecological and adaptation measures

The restoration of soils, the diversification of farming systems and the use of techniques presented in detail in Section 3.3.2.6 as components of multiple benefits, must also remain profitable in the business sense in the longer term. However, their initial adoption or adaptation requires start-up funding over a period of about ten years to enable the many millions of smallholder farms and pastoralist families to follow the recommendations, even though success may be slow in coming. A suitable instrument for this could, for example, be the Input Subsidy Programmes (ISPs; Jayne et al., 2018b), which exist in most African countries to subsidize fertilizers. In addition to increasing mineral fertilizer applications to 50 kg nitrogen per ha, the establishment of a second pillar – by analogy with the CAP – is recommended, which could 'green up' the existing programmes that focus only on mineral fertilization (Jayne et al., 2018b; Section 3.3.2.3). Furthermore, these ISPs, which have so far only targeted certain crops and benefited only arable-farming families, would have to aim at crop diversity, increase beneficiaries' freedom of choice and include pastoralist families.

Rural development measures or programmes in sub-Saharan Africa should generally be designed in such a way that, wherever possible, the vast majority (>80%) of smallholder farms and pastoralist families can benefit from them (Rauch et al., 2016). In addition to social reasons, there are also economic reasons for this. Because the population engaged in agriculture (including livestock farming) still make up the majority of Africa's total population (about 60%), their broad inclusion in rural development measures also indirectly saves costs. These costs would otherwise arise if those excluded – e.g. the poorest farm households and pastoralist families – were instead provided with livelihood security through, for example, cash payments, as has been discussed internationally for some time (Burchi and Strupat, 2016).

Interim conclusion: initiating gentle structural change

Overall, therefore, a gentle structural change should be initiated that leads to a marked increase in productivity while excluding as few people as possible (Rauch et al., 2016; Brüntrup, 2020). To achieve this, the WBGU believes that an inclusive strategy should be adopted that also involves resource-poor smallholder and poor pastoralist families, and develops value chains and local employment, thereby focusing on the retention of rural labour (Freguin-Gresh et al., 2012; Rauch et al., 2016). While German development cooperation has so far paid very little attention to pastoralists, there are already many activities relating to the value-chain approach and to boosting employment (GIZ, 2016). In order to improve the chances of success and to broaden the impact of such activities, international trade regimes and supply chains would also have to be designed fairly (Section 3.3.2.4).

Increasing food security by promoting employment along agricultural value chains and in non-agricultural sectors

To achieve sovereign food security, non-agricultural strategies are necessary and useful in addition to agricultural and rural development, employment initiatives and technical innovations along the value chains. Of the total of four strategies discussed here, three are briefly presented and the fourth is dealt with as a strategy for global agricultural trade in Section 3.3.2.4:

1. *End food losses through better storage:* In contrast to food wastage in industrialized countries (Section 3.4), food losses primarily occur directly after production at the beginning of the value chain and play a major role in sub-Saharan Africa, especially in cereal production. Thus, 120–170 kg of cereals per person per year are lost there in this way, which is about a third of the amount consumed by an average person in a year (FAO, 2011a:5). In the case of vegetables, the biggest losses occur during transport and marketing, e.g. due to a lack of refrigeration facilities; in the case of cereals, losses occur mostly during storage (Kumar and Kalita, 2017). The main

cause can be found in the traditionally built granaries, which are increasingly at high risk in some areas due to the use of unsuitable clay and to heavy rainfall (Kumar and Kalita, 2017) and, in years of low harvests, from theft, especially if they are located in isolated farms (Neubert et al., 2011). In addition, maize hybrid varieties, which make up the overwhelming bulk of stored grains in most regions of sub-Saharan Africa, are not as storable as, say, traditional varieties because of their grain consistency (Neubert et al., 2011). However, even simple measures such as sturdily constructed, well-ventilated granaries and storage in suitable sacks could prevent these losses almost completely (Kumar and Kalita, 2017). In practice, it is recommended that grain is stored at the municipal or cooperative level rather than on individual farms. E-vouchers can be used to confirm the amounts stored and theft can be prevented by posting guards (Neubert et al., 2011).

2. *Harnessing urbanization and migration for rural development:* Migration to the cities is a tradition and is often still a form of occupational migration in Africa today (Migration Data Portal, 2020). But it can often also be understood as a rural exodus due to extreme poverty, as a form of adaptation to climate change (e.g. fleeing drought), but also as compensation for inadequate social security systems (Steinbrink and Niedenführ, 2017). This form of migration enables individuals to generate income in cities on a temporary or permanent basis, which they usually share with the remaining family members in the countryside through remittances. Such migration constitutes a development measure if those who remain behind are better able to secure their livelihoods with the additional funds or are even enabled to put the money to productive use for the further development of their farming operations, e.g. by using it to implement adaptation measures (Steinbrink, 2017; Berck et al., 2018). However, such a strategy reaches its limits when the city destinations' capacity to absorb migrants is overstretched, or if migration leads to labour shortages in rural households and thus undermines rural livelihoods. Successful occupational migration also presupposes that there are enough jobs at the destinations, for example through industrialization, as was the case within Europe in the 19th century. In sub-Saharan Africa, however, such expectations should not be set too high, partly because of the digitalization of industrial manufacturing processes (Lohnert, 2017). Furthermore, African cities are already home to many young people and young professionals who tend to be better educated than rural youth (Lohnert, 2017). Therefore, migration to Europe can also be a useful adaptation strategy if migrating family members find employment and the corresponding remittances are used productively or as an adaptation measure (Musah-Surugu Issah et al., 2018; Ng'ang'n et al., 2016; World Bank, 2020b; Bendandi and Pauw, 2016). The fact that in 2018 the official volume of remittances worldwide was US$689bn shows that the amounts involved are significant (World Bank, 2019). That is four times the amount of official development cooperation (World Bank, 2020c).
3. *Economic empowerment of women reduces the scale of land conversion in the medium term:* Educational measures and the economic empowerment of women lead to falling birth rates (Schwikowski, 2019; Marten, 2019). Africa and India are still the only major regions in the world where these mechanisms have not yet taken effect. Education and female empowerment are therefore urgently needed in these regions, as this would slow down population growth and thus reduce the pressure for land conversion in the medium term. Educational programmes that also teach family planning to women and men, a better chance of secondary school education, and more employment opportunities, e.g. along the agricultural value chains, could increasingly enable women to earn their own income. If such an approach were linked to the development of social security systems, then the idea of having a large number of children as a form of security in their old-age would no longer seem so attractive for parents (Sippel et al., 2011). This would lower the birth rate and thus help defuse the land-use trilemma.

3.3.2.4
Gearing agricultural trade towards resilience and sustainability

The diversification of farming systems also plays a key role in gearing international agricultural trade more towards sustainability (Section 3.3.1.3) and resilience.

Potential of a reorientation of agricultural trade towards sustainability

The diversification of farming systems has the potential to improve food security in sub-Saharan African countries. In the EU, for example, the recoupling of animal and crop production would reduce dependence on feed imports (Section 3.4). In sub-Saharan Africa, sustainably oriented productivity increases could support the country's own food supply and thus prevent dependence on net imports from increasing further, especially in the field of staple foods. Shortening and unbundling international value chains in the agricultural sector and

Box 3.3-5

Certification schemes and geographical indications (designations of origin)

Numerous voluntary certification schemes have been initiated over the past decades, e.g. Fair-Trade or Organic labels, to promote sustainable production and earning opportunities, especially for small-scale producers in developing countries. These two programmes are run by different certification bodies (Fair-Trade Labelling Organizations, International Association of Organic Agriculture Movements). However, their effectiveness has only been partially proven empirically. Few to zero income effects are generated by, for example, Fair-Trade-certified coffee production in Ethiopia (Jena et al., 2012) and Peru (Ruben and Fort, 2012) or by certified pepper production in India (Parvathi and Waibel, 2016). Reasons include inadequate information policies, a lack of market transparency, the mismanagement of production cooperatives, a lack of education, and the sale of coffee beans to private traders instead of certified buyers because of financial constraints (Jena et al., 2012). Cocoa farmers in Côte d'Ivoire have been able to increase their productivity, but the proceeds have still not generated enough income (Rusman et al., 2018). Other studies show significantly positive income effects for Fair Trade coffee from Uganda (Chiputwa et al., 2015) or India (Karki et al., 2016b), for example. The trend is moving towards dual certification (Organic and Fair Trade). Dual certification only generates benefits for producers if there is also a substantial price advantage in the long term (Parvathi et al., 2017).

Legally protected geographical indications (designations of origin) are also used above all in Europe but also elsewhere (BMEL, 2019). As long-term state property rights, they enable the producer countries to develop their export markets and to obtain higher prices for local products. In this way, they can promote sustainable production in a similar way to certification schemes. Well-known examples – such as basmati rice or Ethiopian Sidamo and Harar coffee – refer to regions of origin with unique qualities or production methods. Geographical indications also offer protection against counterfeiting and the misuse of designations of origin (Grote, 2009). The attempts to register US patents on basmati rice show that the protection of geographical indications for foods from developing countries deserves support. India succeeded in monitoring and at least partially countering such unfair trademark applications by setting up a Basmati Development Fund (Jena and Grote, 2012). Another high-profile case involved the use of the Sidamo and Harar designations of origin for coffee, with Starbucks ultimately having to acknowledge the Ethiopian government's trademarked geographical indications (Dowideit, 2007). This illustrates how national government interests can affect agricultural value creation in developing countries.

The expansion of such certification programmes (Fair Trade, Organic) contributes to the internalization of environmental costs and thus to sustainability. There is still a lot of potential here: in 2014 only about 590,000 producers on 1.3 million ha in sub-Saharan Africa had an Organic certification and just over 1 million producers on 870,000 ha had a Fair Trade certification (Lernoud and Willer, 2018). This corresponds to 0.1% and 0.07% of Africa's agricultural land respectively and was also concentrated in a few countries such as Ethiopia, Côte d'Ivoire, Ghana, Kenya and Tanzania (Lernoud and Willer, 2018). If certification systems are expanded, however, it must be ensured that producers receive a price premium which contributes towards reducing poverty.

It should also be ensured that sustainability aspects are taken into account in certifications or protected geographical indications, which are also adapted to the local environment. This can be exemplified by ham produced under the protected designation of origin 'Dehesa de Extremadura'. The pig herds here are fed with acorns from oak-wooded pastures that are typical of the Iberian Peninsula and are often Natura 2000 sites. Production under certification contains minimum ecological standards, but there are no rules that take into account the specific needs of the fragile and exceptionally valuable ecosystem (e.g. with regard to tree-regeneration measures in the Dehesa). Degradation of the Dehesas can already be observed (Beaufoy, 2009).

strengthening intraregional trade – especially between African states – would also increase resilience to crises. The repeated occurrence of acute pandemics and crises (COVID-19, SARS, Ebola, the 2008 food crisis) underlines the added value of regional value chains.

The orientation of agricultural trade towards sustainability also has the potential to reduce undesirable telecouplings such as indirect negative environmental effects. In agricultural export production, for example of palm oil, more economically and environmentally viable options for oil palm plantations can be created by introducing more extensive management practices in the producing countries (Darras et al., 2019b). This also applies to many other products such as coffee, tea, cocoa, flowers and cotton that are exported from sub-Saharan Africa to the EU. Exports of coffee, cocoa, tea, fruits, cotton, sisal, sesame, etc. generate important income in the (sub-)tropical producing countries and help to achieve equilibrium in trade balances. Organic labels or Fair Trade offers can have a supporting effect here.

Regional trade agreements with environmental regulations

Environmental protection, climate-change mitigation and sustainable land use should also be strengthened in the WTO, in regional free-trade agreements, economic partnership agreements (EPAs) between the EU and ACP countries and in investment agreements. Since all WTO member states are also simultaneously parties to the Paris Agreement and many other multilateral environmental agreements, the climate and environmental goals should be recognized and actively implemented. International trade law must not be a hurdle but a driver to achieve the goals of the Paris Agreement (Zengerling, 2020:58). Closer cooperation between climate, environmental and trade regimes is a prerequisite for achieving this.

Appropriate safeguards should be laid down within the framework of regional trade agreements to ensure that foreign trade in agricultural products does not shift agriculture-induced environmental degradation to producer countries (Seekell et al., 2018; Schmitz et al., 2012). The number of regional trade agreements with environmental provisions has increased significantly over the last two decades (George, 2014).

One promising new plurilateral initiative is the so-called ACCTS (Agreement on Climate Change, Trade and Sustainability) between New Zealand, Fiji, Costa Rica, Norway and Iceland. In September 2019, these five countries launched negotiations (New Zealand Ministry of Foreign Affairs and Trade, 2020) for a new joint agreement on climate change, trade and sustainability with the aim of implementing three key measures: (1) elimination of tariffs on environmental goods and new commitments on environmental services that should be transferable to all WTO members, in line with the most-favoured-nation (MFN) principle; (2) elimination of subsidies on fossil fuels; and (3) development of guidelines for voluntary eco-labels and related mechanisms (Steenblik and Droege, 2019). The ACCTS is open to further measures – also to the inclusion of additional WTO members.

Regional agreements should be more closely geared to country-specific circumstances

Reducing the import dependency of developing countries (especially in Africa) is an important long-term goal, above all in the case of staple foods. Economic partnership agreements (EPAs), i.e. special agreements for poor developing countries, can contribute to this goal.

Labour and environmental standards in EU foreign trade

The Supply Chain Act is planned at the German national and EU level to complement – or even to act as an alternative to – certification (BMZ, 2020c). The intention is to oblige domestic companies in future to guarantee within their own supply chain that foreign suppliers observe human rights and labour and environmental standards (Initiative Lieferkettengesetz, 2020b). Such laws already exist in France, the UK and the Netherlands, and there are comparable approaches in some Scandinavian countries (Initiative Lieferkettengesetz, 2020a). However, there is not yet any robust evidence on the effects of these laws.

Align EU agricultural-sector policies more closely towards the SDGs

The EU as a whole should develop a better understanding of the impact of its agricultural sector on developing countries' ability to meet the SDGs and on the role of agricultural subsidies (Yang et al., 2018). Non-sustainable imports, especially of animal products, feed and biofuels, should be avoided (Barthel et al., 2018; Matthews, 2018; Schulmeister, 2015). Agriculture can only develop in Africa if incentives for its own food production in rural areas is not counteracted by low-priced agricultural goods exports from heavily subsidized agricultural production in the EU. A change in the EU's CAP could also contribute to greater resilience in agricultural trade with Africa.

3.3.2.5
Greening versus intensification and the measurement of greenhouse gases: a classification

Demands on the farming systems of the future

Ecologically intensive farming systems, such as the examples recommended by the WBGU as 'components of multiple-benefit strategies' in Section 3.3.2.6 for the EU and sub-Saharan Africa, are not only geared to meeting sustainability, climate-adaptation and biodiversity requirements, but also claim to generate the lowest possible GHG emissions. Furthermore, these farming systems are intended to provide a sufficient and varied diet for a world population that will continue to grow regionally until 2050, which means that, in addition to claims to sustainability, high yields per hectare are also envisaged.

All these demands are addressed under the term 'land-use trilemma' (Section 2.2) with regard to the dimensions of food security, biodiversity conservation and climate-change mitigation: while the food-security dimension aims to ensure both sufficient calories and a high-quality supply of food, the biodiversity-conservation dimension refers not only to the conservation of biodiversity in natural or near-natural ecosystems, but also to agrobiodiversity and the conservation of genetic resources for agricultural breeding. The climate-change dimension is about minimizing GHG emissions, and about CO_2 sinks and resilient climate adaptation.

However, all the demands formulated above cannot be expected to be equally met with one farming system. It will not be possible to avoid trade-offs completely. The aim should be not only to balance them but also to minimize them as much as possible.

Comparisons between conventional and organic cultivation and their relevance for GHG emissions

In order to assess the climate relevance of conventional and organic farming systems, comparisons of GHG emissions are usually related to the productivity of the systems (CO_2 equivalents per kg of the product; in this case of the harvested crop). The main question is how the external environmental costs of industrial agriculture compare with the lower yields of organic farming and thus its higher land-use needs in terms of GHG emissions. The yields of organic farming are between 5% and 34% lower (Seufert et al., 2012), depending on crop type, management system and location, and in a global calculation lead to higher land use. The yield reductions are only very slight in the case of permanent crops (e.g. coffee, cocoa) and the cultivation of leguminous plants in tropical locations, but high for one-year arable crops (especially cereals) in temperate regions and for animal products (Seufert et al., 2012).

The result is that GHG emissions per kg of the product from the cultivation of most crops are about the same for the different farming systems, or rather organic farming produces slightly lower emissions per kg of product (Rahmann et al., 2008). This is a result of its higher land requirements: accordingly, the additional land conversions that would be necessary to produce the same crop volumes by organic farming generate such high GHG emissions that not using mineral fertilizers and pesticides can only just compensate for them. Although there are considerable differences between crop and livestock types – for example, permanent crops in organic farming generate lower emissions while livestock products in organic farming generate higher emissions (Rahmann et al., 2008; Searchinger et al., 2018) – this does not change the basic result. These findings are confirmed by Balmford et al. (2018), who therefore characterize high-yield agriculture as ecologically advantageous vis-à-vis ecologically intensive systems under the premise that land is scarce and provided that minimum sustainability requirements are met.

Even if these calculations initially sound sobering from the standpoint of organic farming, they can be put into perspective in many respects and at various levels:

- *Inclusion of negative emissions caused by humus enrichment in organic farming:* The results would shift in favour of organic farming if the calculations included on the one hand the negative emissions from carbon sequestration in organically managed soils, which have been shown to lead to considerable humus enrichment, and, on the other, the humus loss in conventional farming (Box 3.3-11).
- *System comparisons are preferable to those based on individual crops or animal species:* Comparisons based on individual crops and livestock product lines do not take into account the fact that the farming systems of conventional agriculture and organic farming as such diverge. For example, in organic farming, perennial crops and leguminous plants are usually integrated to a greater extent, and these involve lower emissions per kg of the product; furthermore, livestock farming, as an emissions-intensive production sector, is restricted from the outset by placing limitations on livestock concentration. Therefore, in practice, factory-farming product lines simply do not exist on organic farms. As a result, emissions per hectare are also much lower in organic farming than in conventional farming (Rahmann et al., 2008).
- *The preference for biodiversity over agrobiodiversity in the usual calculations may be unfounded:* When calculating the carbon footprint, it is (implicitly) assumed that biodiversity would be better protected if the land were no longer used for production instead of being farmed less intensively. And yet, traditional agricultural landscapes in Europe have supported biodiversity in many places over several millennia, so that the removal of agriculture here would impoverish biodiversity not stabilize it (Finckh, 2018).
- *The components of the multiple benefits must also be suitable for adaptation to climate change:* Conventionally used soils, which break down more carbon than they form, one-sided crop rotations and a low level of biodiversity with equally low ecosystem services are not resilient enough to climate change.

Ecological intensification as a continuum between greening and intensification

Measuring GHG emissions in relation to productivity can be useful if it is also compared with emissions per hectare. For example, Rahmann et al. (2008) show that emissions per hectare are much lower in organic farming than in conventional farming.

In the context of the strategy for sub-Saharan Africa, a systematic interlinking of both modes of production, agroecological and conventional, are more likely to defuse the trilemma than a decision in favour of one or the other system. Thus, 'integrated farming' could involve not only high productivity and averted inefficiencies, but also relatively high levels of agrobiodiversity. It depends on the starting point whether the policy should be to green or to intensify, and to what extent this is possible in order to generate high outputs with low externalities (Tittonell et al., 2016). The best elements of both organic and conventional agriculture should therefore be combined until truly sustainable systems emerge, as also noted by Qaim et al. (2018) in the debate on the findings of Balmford et al. (2018).

Accordingly, it is a continuum that seeks or approaches its optimum ecological intensification point for defusing the land-use trilemma (Fig. 3.3-7).

Nevertheless, organic farming is a good solution, especially in industrialized countries. Since it already works in practice and has incentive structures and suitable controls through higher prices, it should not be exchanged for integrated farming, for example, which perhaps no one will implement because incentive structures and regulations are lacking or still need to be set up (Qaim et al., 2018).

Increasing the efficiency of agriculture, dietary habits lower in animal products

At a higher level of observation, the comparative calculations on the carbon footprint can be further put into perspective or even completely nullified, namely if the paradigm of an unceasingly growing demand for food is called into question. Evidence shows that global calorie production already exceeds global requirements by around 20% (Berners-Lee et al., 2018; Section 2.2.2). If diets change and become lower in animal products (Section 3.4), which is also healthier, all the people alive in 2050 could already be fed today. Although this would require shifts in dietary habits, leading to a higher production of certain micronutrients (nuts, fruits, legumes; KC et al., 2018), this would be possible, and these more diversified systems are therefore targeted by the components of the multiple-benefit strategies in Section 3.4 below. In the debate surrounding the work by Balmford et al. (2018) cited above, it is a logical consequence that Schader (2018) emphasizes: "...recent research (shows) that sufficiency (consumption reduction) and consistency strategies (e.g. circular economy) also play a key role in the sustainability debate. In fact, compared to efficiency, these strategies often play a more crucial role in the food sector. The entire food system must therefore be considered and not just agriculture (...)."

Ecologically intensive farming systems require a lot of knowledge and are labour-intensive

Apart from all their advantages, ecologically intensive systems also involve specific costs. These lie mainly in an increased need for knowledge and labour, especially for the systems that produce a high output on small areas of land without chemicals (e.g. permaculture), because planting, weeding and harvesting at very different sowing and harvesting times can hardly be mechanized; it requires considerable knowledge for coordinating the different nutrient and soil requirements, as well as knowledge about how crop types can support each other or at least not harm each other. While labour is generally available in sub-Saharan Africa and other developing regions, the challenge is to make this labour productive enough to enable people to earn a minimum income. In some areas, digitalization can help here if it is adapted to the environment and socio-cultural conditions. However, transitional difficulties have to be reckoned with, e.g. in the rehabilitation or restoration of soils. Start-up financing is therefore necessary which – in the case of severely degraded soils – may also need to bridge a period of several years.

In the EU, by contrast, farm labour is always in short supply. The additional work would therefore have to be compensated by higher prices – as in the case of organic farming – or by digitalization. Approaches in which economies of scale can be achieved with cooperatives or solidarity-based agriculture are also suitable in both regions.

Most of the components of diversified farming systems described in the following section are scalable and meet the dimensions of the WBGU's normative compass (Box 2.3-1): scalability is increased when the knowledge required for these diversified production systems is passed on, and implementation contributes in this way to income improvement and to the stabilization of agriculture in an entire region (Wangpakapattanawong et al., 2017). Farmer field schools, reciprocal farm visits and demonstration fields are approaches that are potentially globally effective for promoting such systems, since not only individuals but entire regions should benefit (FAO, 2017d). An overarching transformation of land use and landscape design is further promoted by corresponding 'mainstreaming' of the allocation of regional or national support programmes, for example in the context of the EU's CAP or the ISPs of African countries (Section 3.3.3).

Furthermore, an important condition for success in the transformation is the inclusion of tried-and-tested production methods and cultural traditions (FAO, 2017d). The focus here is on local actors with their experience, observations and convictions. Their body of knowledge should be supplemented by joint testing and experimentation, by new knowledge and management methods, which in turn should be scientifically sound and further developed jointly, as already practised by the agroecology movement.

The agricultural production systems presented below can be adapted to different locations and – with the use of different usable varieties and species – can be combined in each case with specific local or indigenous production methods and cultural traditions. This empowers local communities in the use of their natural resources (Kremen and Merenlender, 2018). All of the farming systems shown in Table 3.3-2 also have considerable transformative potential; they can greatly improve the

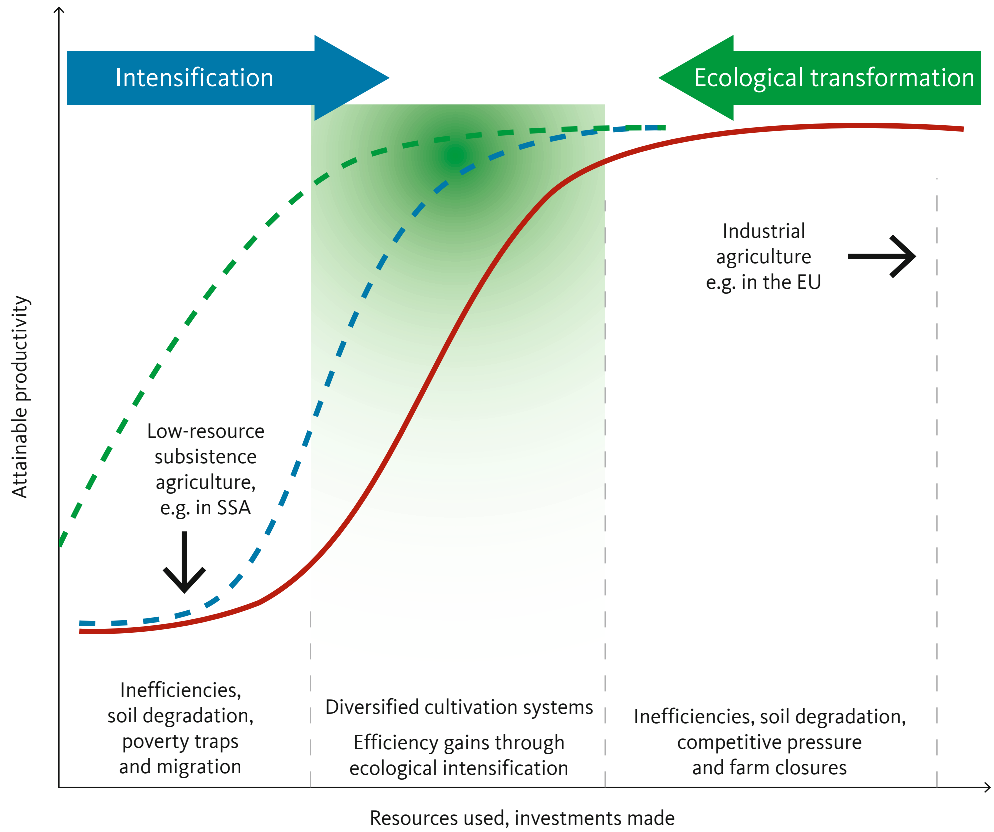


Figure 3.3-7
Achievable productivities of ecological intensification by location and path dependencies. The diagram shows that subsistence farming at low productivity levels leads to inefficiencies and soil degradation due to under-fertilization and thus causes poverty, while industrial agriculture with high productivity levels also leads to inefficiencies and soil degradation due to over-fertilization, and fierce competition also results in farm closures. The darker green the area is coloured, the more intensively and efficiently nature is used and the more ecological intensification is driven. Objectives are: the highest possible productivity with the highest possible ecosystem services (greening) and the lowest possible input of resources and investment. The dashed green line shows that greening is associated with productivity losses above a certain point, while intensification (blue dashed line) is associated with efficiency losses above a certain point. Diversified farming systems seek to improve the utilization of ecosystem services to achieve higher levels of efficiency while achieving sustainability.
Source: WBGU, based on Tittonell et al., 2016

initial situation relating to the trilemma of food security, biodiversity conservation and climate-change mitigation, and are thus valuable components of the multiple-benefit strategies presented. Some components refer only to individual measures, such as alternative fertilizers or resource-saving irrigation methods, each of which would have to be integrated into existing production systems.

3.3.2.6
Components of the multiple-benefit strategies

Fifteen multifunctional agricultural production systems, the concepts behind them and individual techniques for implementation are presented below (brief overview in Box 3.3-6). These components of the multiple-benefit strategies presented in this Section 3.3 can be implemented both in industrialized countries as greening and in developing countries as sustainable intensification – in different modes respectively. Table 3.3-2 provides a comprehensive detailed overview of a selection of these systems with rough estimates of their potential. Although not every system generates multiple benefits in relation to all dimensions of the land-use trilemma (Section 2.2), at least two dimensions are always positively influenced and none negatively. Assessments of the potential to reduce GHG emissions are partly dependent on the level from which it is examined.

Box 3.3-6

Brief Overview: Components of the multiple-benefit strategies for diversified farming systems

1. Agroecology as a metaconcept
2. Climate-smart agriculture as a metaconcept
3. Agroforestry
4. Agrophotovoltaics
5. Aquaponics
6. Biochar
7. Climate-friendly bio- and depot fertilizers
8. Climate-friendly organic farming
9. (Soil-)conserving agriculture
10. Ecological intensification – the example of rice
11. Cultivation of forgotten and underused crops
12. Paludiculture – agriculture on peat soils
13. Permaculture as a multifunctional market-gardening system
14. Sustainable precision agriculture
15. (Peri-)urban agriculture

Component 1: Agroecology as a metaconcept

Agroecology is both a branch of science and a movement aimed at transforming the entire food system. It thus represents more than a set of methods and is more of a metaconcept. Agroecology combines the social and ecological dimensions and aims to link traditional, local knowledge with scientific findings in a trans- and interdisciplinary way. The antithesis of industrial or conventional agriculture, agroecology aims at small-scale, diversified farming systems and focuses on optimizing nutrient cycles and ecosystem services, in a similar way to organic farming. Locally available resources (sun, water and soil, diversity of species and cultivars) and people's and communities' knowledge of how they interact make practical contributions to problem solving (FAO, 2020e; IAASTD, 2009). Agroecology works without certification or prohibitions and differs from organic farming in this respect. This makes the concept attractive (also for consumers, as products are not necessarily more expensive) and flexible (also for producers), as the latter are allowed to use conventional inputs if it is worthwhile for them or if they cannot make any progress with near-natural methods. However, this constellation without monitoring also creates risks for 'greenwashing', of course.

Founded in the 1970s and 1980s as the antithesis and an alternative to industrial agriculture, agroecology became a worldwide movement in the 1990s, driven by practitioners and NGOs. Today, it has gained recognition from many institutions and is also promoted by the FAO, among others (Youmatter, 2020; FAO, 2020e). In Germany, the BMZ and many NGOs (INKOTA, 2019), are working to propagate it. In recent years, numerous initiatives and platforms for knowledge exchange (e.g. www.agrarecology-pool.org) have been established to collect and further develop agroecological methods.

Agroecology goes beyond the production level and aims to link technical approaches with strategies such as the EU's Farm-to-Fork strategy or the cross-sectoral cascading use of waste water for irrigation (Ferguson and Lovell, 2014). Relatively small-scale linkages with a clear distinction from industrial processes are an important principle here. Together with R&D institutions, agroecology puts these practices on a scientific foundation for practical application (FAO, 2018a). Numerous examples demonstrate agroecology's great potential for increasing yields while at the same time conserving resources. Further aims are to stimulate the regional economy and improve health, prosperity, resilience and biodiversity. Agroecological networks are propagating the approach at the political level, and an initiative launched by the FAO, called the 'Scaling Up Agroecology Initiative – Transforming Food and Agriculture in Support of the SDGs', aims to help it make a breakthrough.

Component 2: Climate-smart agriculture as a metaconcept

Climate-smart agriculture (CSA) is also a metaconcept for a future-proof form of agriculture. It is based on three pillars: (1) sustainable increases in agronomic and economic productivity, (2) increases in resilience and adaptive capacity, (3) climate-change mitigation, i.e. reduction and sequestration of GHG emissions. CSA has a global agenda and aims to contribute to food security, the SDGs and the goals of the Paris Agreement (FAO, 2020b). The multi-stakeholder platform Global Alliance for Climate-Smart Agriculture (GACSA) was founded in 2014 as a catalyst and communicator for the dissemination of CSA technologies, together with the FAO as its main international partner. Its members also include many companies in the agricultural industry. This and certain priorities such as the focus on technologies (including genetic engineering and conventional inputs) has led critics to suspect greenwashing.

CSA offers a repertoire of different techniques and methods for both types of farming, industrial and smallholder. The subsumed practices include the range of sustainable diversified farming systems presented in this report, but also other, more technology-focused approaches. However, there are not yet any clear indicators or impact evaluations for CSA approaches

(ICRAF, 2019). CSA is criticized by civil-society organizations partly because such standards and definitions of sustainability are lacking (AbL, 2016). The GACSA supports large-scale applications of conservation agriculture based on herbicide resistance, individual approaches such as 'water-efficient maize in Africa', and numerous small-scale, agroecological approaches. CSA's weakness is seen in its being limited to production and in its technical focus. No concept is offered on how resource-poor smallholder farms might be included in measures (AbL, 2016), nor has any strategy been proposed or developed on how to achieve broad-scale effectiveness.

Component 3: Agroforestry

Agroforestry refers to a dynamic, ecological system that can diversify production by integrating i.a. trees, shrubs, palms or bamboo, into agricultural land and the agricultural landscape to generate social, economic and environmental benefits for local communities (FAO, 2015b). This form of farming already has a long tradition in many parts of the world (e.g. forest pastures and meadow orchards in Europe) and has been regarded internationally as an essential element of agricultural development since the 1970s. Agroforestry systems aim to diversify cultivation and nutrition, improve soil properties and increase the diversity and stability of ecosystems by integrating commercial trees (fruit, wood, leguminous plants for soil improvement) – into individual fields and entire landscapes (Fig. 3.3-8; Box 3.3-7). Trees can be integrated in a scattered way as individual stands, avenues, groups, forest plots or woods (Wangpakapattanawong et al., 2017:7). By contrast to the traditional form, modern agroforestry systems are adapted to the current state of agricultural technology, which reduces the extent to which the trees interfere with field cultivation (Bender et al., 2009).

Agroforestry systems can create a wide range of synergies. For the farm, trees bring ecological benefits by providing shade (i.a. for livestock) and space for beneficial organisms (e.g. birds, insects), thus also reducing the need for pesticides. Nutrients are recycled, reducing the need for fertilizers. Annual crops grow better and the soil's water-storage capacity increases (Wangpakapattanawong et al., 2017). Furthermore, substantial humus enrichment (+18%) has been demonstrated in the rows of integrated trees (Seitz et al., 2017). There are also economic advantages in that the trees (fruits, wood, etc.) provide another, usually long-term and intergenerational, additional agricultural income. Product diversification also helps to spread risk (Nahm and Morhart, 2017). Through their multifunctionality, trees improve the utilization of land, labour and capital (Wangpakapattanawong et al., 2017) and maintain the land's value-creating function (Langenberg and Theuvsen, 2018). In terms of site selection, in Germany medium-quality arable soils tend to be more suitable as agroforestry areas (e.g. strip implementation of short-rotation woods) in order to achieve higher profitability than with individual crops. The combined yield should be about 110% to generate enough income to cover the higher labour input (Langenberg and Theuvsen, 2018). Regulatory effects include carbon storage, erosion control, modified microclimate, water regulation, wind protection, biodiversity enhancement, habitat linkage for plants and animals, and biological control of pests and diseases. Agroforestry also supports the fixation of nitrogen (in the case of leguminous trees), nutrient and water cycles, photosynthesis and soil fertilization. Positive cultural effects relate to ecotourism, the beauty of the landscape, shade and meeting places, as well as religious significance (Wangpakapattanawong et al., 2017).

Challenges need to be overcome in the implementation and management of agroforestry systems. Additionally planted trees compete with cultivated crops for space, light, nutrients and water. Agroforestry systems need to be carefully planned and adapted to local conditions in order to limit negative effects on cultivated crops. This requires expertise, since trees take years to grow, and a suboptimal selection of tree species may fail to produce the desired synergies. Additional diseases or pests may occur and find a habitat in the diversified agroforestry systems (Wangpakapattanawong et al., 2017:16; Nahm and Morhart, 2017). When combined with livestock, browsing damage to the planting material can occur, as can soil compaction caused by trampling (Spiecker et al., 2009).

The integration of trees and the structural diversification of cultivated land can restrict the use of agricultural machinery and techniques (Wangpakapattanawong et al., 2017:16). Because agroforestry is based on long-term planning, regional utilization options and framework conditions are also critical. Another barrier is occasional scepticism on the part of farmers towards agroforestry systems. The main obstacles to implementation here are small agricultural plots, information deficits and a lack of public support. For example, farmers in Kyrgyzstan feared that the reintroduction of agroforestry systems (in this case agricultural products combined with windbreaks) would reduce crop yields as a result of the additional shade, but were unaware of benefits such as the additional wood resource, the fact that crop yields were actually higher, reduced soil degradation and less wind erosion. To counteract such problems, cooperative models should be pursued and active support provided by local government (Ruppert et al., 2020).

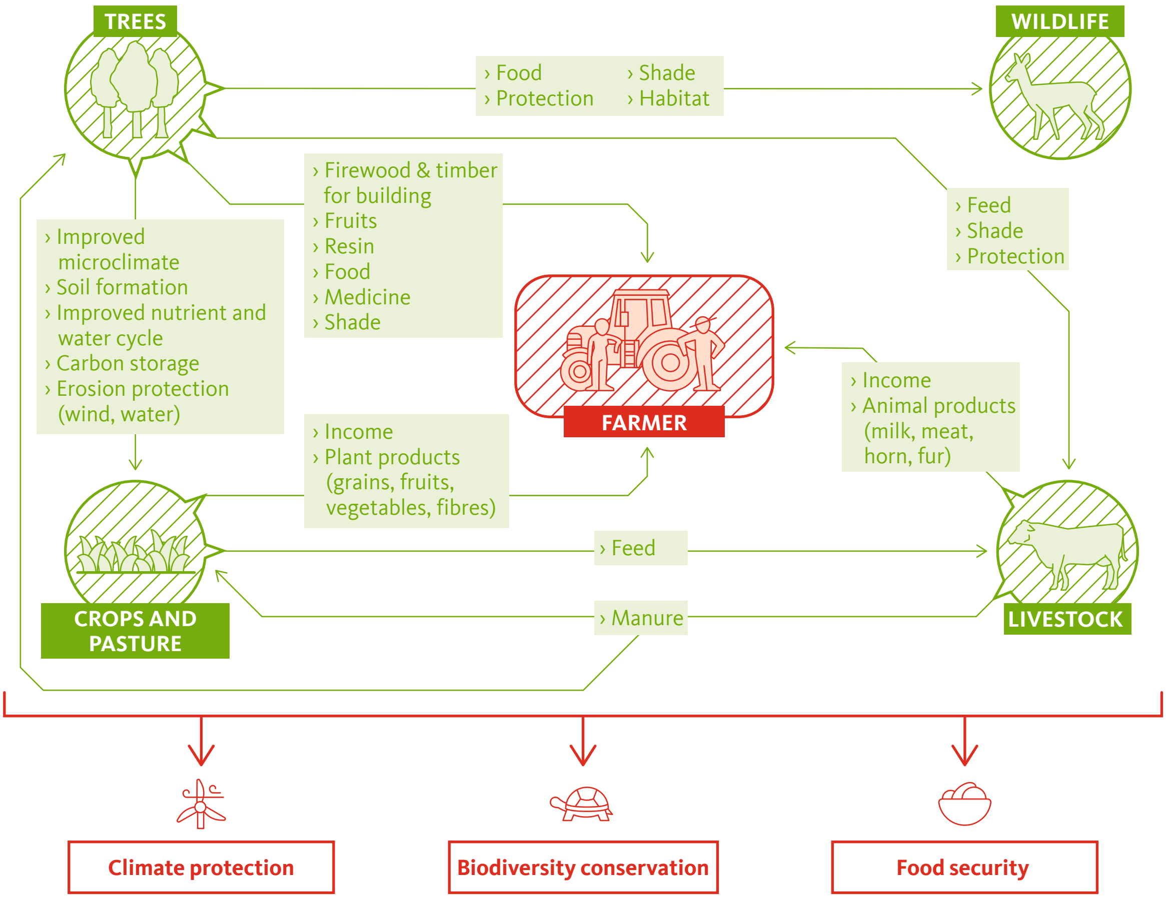


Figure 3.3-8
Synergies of agroforestry systems.
Source: WBGU, graphics: Ellery Studio

Component 4: Agrophotovoltaics

Agrophotovoltaic (APV) systems have been known as a concept for three decades (Goetzberger and Zastrow, 1982) and combine PV systems and agricultural production on the same area of land (Figs. 3.3-12, 3.3-13).

Combining different production systems increases land-use efficiency compared to producing agricultural products and energy separately (Dupraz et al., 2011; Marrou et al., 2013b) and, in general, raises the productivity of the land (Dupraz et al., 2011; Elamri et al., 2018; Valle et al., 2017). Thus, on the one hand, APV offers great synergy potential for regions with a high population density (Dinesh and Pearce, 2016), but also – independently – for semi-arid and arid regions. There, for example, APV reduces the water losses that result from high solar radiation and evaporation (Marrou et al., 2013a; Ravi et al., 2016).

The installed capacity of APV systems worldwide totals around 2.9 GW, and there is a large amount of additional area potential (technical potential in Germany: 1.7 TWp); at the same time, the systems are cheaper than small PV roof systems and also offer farmers the additional benefit of protection against damage from hail, frost and drought (ISE, 2020). PV systems also improve the water-use efficiency of the agricultural land beneath them (Adeh et al., 2018; Elamri et al., 2018; Marrou et al., 2013b). Shielding from solar radiation creates advantages specifically for plants in arid regions (Harinarayana and Vasavi, 2014). Energy provision generates additional income (Dinesh and Pearce, 2016; Malu et al., 2017) and supports rural decentralized energy systems (Burney et al., 2010; Harinarayana and Vasavi, 2014; Malu et al., 2017; Herran and Nakata, 2012).

The main challenge for agrophotovoltaics lies in finding the optimum balance between agricultural and energy production for each site, as a higher density of PV modules increases energy production, but in turn has an adverse effect on agricultural production as a result of excessive shading (Dupraz et al., 2011). In addi-

Box 3.3-7

Wide diversity of agroforestry variants

According to the FAO, agroforestry systems have three subcategories each with their own designations, depending on the combination of trees, crops and livestock (FAO, 2015b; Fig. 3.3-9). The great diversity of variants of silvorable (trees and arable crops), silvopastoral (trees and livestock) and agrosilvopastoral (trees, arable crops and livestock) agroforestry systems is shown below.

Silvorable agroforestry systems

The FAO distinguishes between ten production systems, each with different objectives and uses. For example, many different tree species can be grown at different levels in multi-layered, densely planted stands. Similarly, multifunctional trees can be distributed randomly or according to certain patterns on farmland in the form of embankments, terraces or along plot or field boundaries. In the so-called Taungya system, plantations are additionally combined in the early stages with timber or field crops (Fig. 3.3-10). The cultivation of lignifying species in the form of hedges and crops in alleyways between these hedges makes microzoning and windbreaks possible. For the purpose of soil conservation and cultivation, trees can be used for soil reclamation on embankments or terraces with or without grass verges. In addition, trees that provide firewood can be grown on or around arable land (FAO, 2015a).

Silvopastoral agroforestry systems

According to the FAO (FAO, 2015a; Fig. 3.3-11), these include combined production systems such as:

1. *Trees on pastureland or grassland:* Here the trees are either scattered or arranged according to a pattern on the land.
2. *Protein banks:* Here, trees are used to grow high-protein forage on farmland or pasture land for use as cut-and-carry feed.
3. *Plantation crops on grasslands or with livestock:* These are combinations of livestock farming with e.g. coconut palms (as is common in Southeast Asia and the South Pacific).

Agrosilvopastoral agroforestry systems

These systems combine the cultivation of trees and crops with animal husbandry on one area of land. Production-system variants here are: (1) private gardens integrating all three uses around the owner's farmstead, (2) multifunctional wooded hedgerows (for grazing, mulching, green manuring, soil conservation, etc.), (3) bee-keeping and trees used for honey production, and (4) aquaforestry systems where fish ponds are lined with trees whose leaves serve as fish food (FAO, 2015a).

Agroforestry not only has a large diversity of variants, the scalability of systems is also high. They are easily adaptable, as different farming systems allow the integration of trees (from single trees to forest stands) on everything from individual fields or farms right up to entire landscapes. The FAO proposes, among other things, the 'Think Big' principle for application: the landscape should be considered as a whole, including its biophysical (topography, climate, land use, veg-

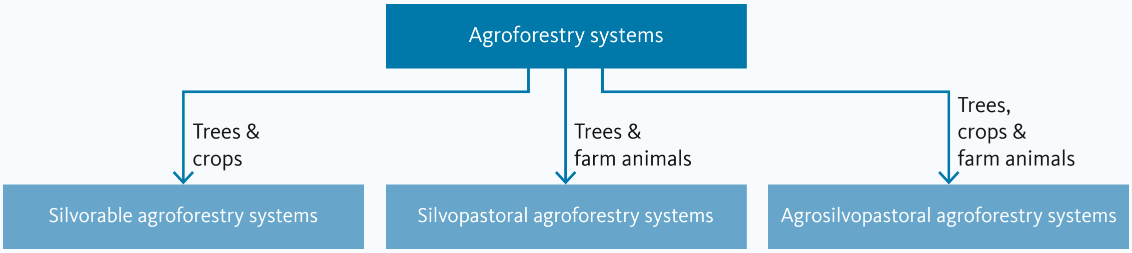


Figure 3.3-9
Subcategories of agroforestry systems.
Source: WBGU based on FAO, 2015a

Figure 3.3-10
Silvorable agroforestry systems.
Source: Image left: Christian Dupraz (INRA); image right: Agforward project 'Squashes in SRC silvoarable system, Wakelyns Agroforestry' (CC BY-NC-SA 2.0), flickr.com

Figure 3.3-11
Silvopastoral agroforestry systems
Source: Phil McIver 'The watcher' (CC BY-NC 2.0), flickr.com

etation, soil types) and socio-economic components and actors (villages, farmers' organizations, farms, markets, government and other institutions). In addition, it is important to remember that trees need time to grow and should be seen by farmers as a worthwhile investment for the future (Wangpakapattanawong et al., 2017:21), which requires long-term planning security and clearly defined land rights.

tion, the supporting frames must be adapted to the requirements of the respective agricultural machinery (Weselek et al., 2019). Furthermore, dual land use is not yet provided for in the legal framework; farmers are not entitled to EU agricultural subsidies or to feed-in remuneration under the Renewable Energy Sources Act (EEG; Fraunhofer ISE, 2020). Since 2013, for example, APV systems on agricultural land in Japan have been eligible for approval if 80% of reference yields can be harvested under the PV modules; they are also subsidized by electricity utilities (Movellan, 2013). AVP use appears to be a particularly good idea in (rural) semi-arid and arid regions for crops adapted to shade (water savings, decentralized energy supply). It can also mitigate land-use competition in densely populated regions (Weselek et al., 2019), although it requires an adaptation of the regulatory frameworks for dual land uses (e.g. CAP and EEG).

Component 5: Aquaponics

Aquaponics combines the technologies of recirculating systems for aquaculture and for hydroponics in a closed-cycle system (Figs. 3.3-14, 3.3-15; Box 3.3-8). The latter is a water-based form of crop production that does not require the use of soil and is therefore considered an opportunity in areas with low soil fertility (Junge et al., 2017; Joyce et al., 2019).

Pure aquacultures are associated with a high nutrient input into the environment. At an average feed-conversion rate of 1:3 (Naylor et al., 2000), approx. 36% of

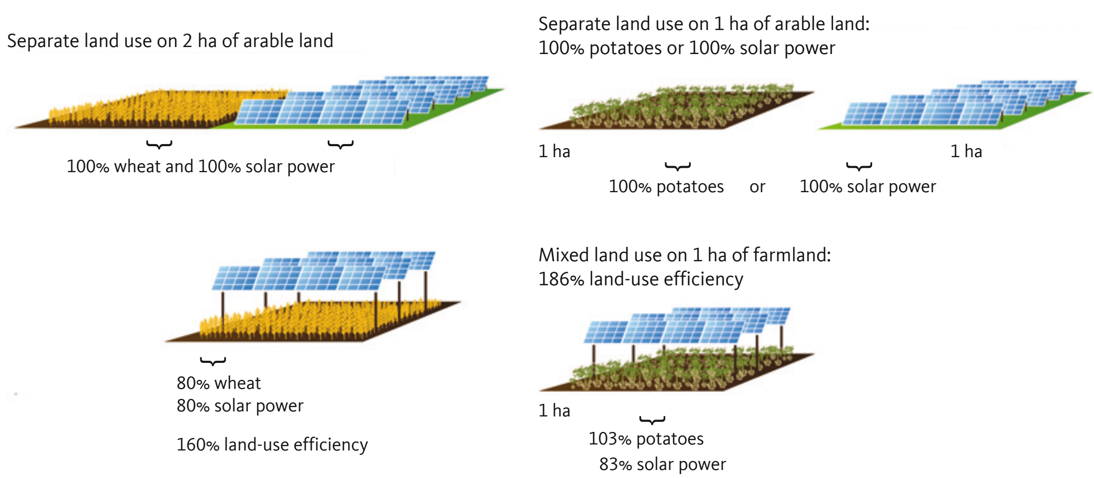


Figure 3.3-12
Advantages of mixed land use in agrophotovoltaic systems.
Source: Fraunhofer ISE (illustration potatoes © Happy Pictures / shutterstock.com)

Figure 3.3-13
Agrophotovoltaic systems.
Source: photograph left: Andrea Bauerle/University of Hohenheim; photograph right: ©Fraunhofer ISE

the feed is flushed out as organic waste (Brune et al., 2003). Target organisms absorb 5-48% of the nitrogen and 15% of the phosphorus (Gutierrez-Wing and Malone, 2006). Unused feed including unabsorbed nutrients, excreta, and pathogenic microorganisms enter surrounding water bodies via the waste water (Sugiura et al., 2006).

In aquaponics systems, by contrast, excreted nutrients are recycled by integration into water-based crop production, thus reusing aquaculture waste (Joyce et al., 2019). In this way, the nutrients from the food residues and fish excrement become a resource or fertilizer for the plants. These in turn clean the water, which can then be fed back into the fish tanks. Overall, a closed recirculating system can be created. Due to the circular water use, aquaponics systems have great water-saving potential and also reduce nutrient inputs into surrounding water bodies (Suhl et al., 2016). Economic benefits can arise from the production of further marketable products, although stocking densities are usually lower than in separated processes (Morgenstern et al., 2016). Aquaponics systems are adaptive and can also be used on small plots of land or in less favourable agricultural locations (e.g. in cities on rooftops or abandoned factory sites; Joyce et al., 2019).

Although aquaponics systems have gained in scalability, production size, and market acceptance over the past few years – aquaponics plants are becoming larger and more robust (Espinal and Matulic, 2019) – there are still challenges to be overcome. To date there have been few variations in crop and fish combinations, as nutrient and pH requirements cannot be met by all of them (Morgenstern et al., 2016). Optimizing control of the conversion of the nutrients produced by the fish and balancing these substances in the fish tanks and the plant beds is technically challenging (Junge et al., 2017). Nowadays, in order to boost economic benefits, systems that do not offer all potential environmental benefits (e.g. those that need the addition of extra nutrients) are also used, even though consumers assume these benefits when the term aquaponics is used (Lennard and Goddek, 2019). To counteract this development, the term aquaponics should be clearly defined in terms of the nutrients used (Lennard and Goddek, 2019). The concept does not envisage the use of antibiotics or chemical pesticides. Nevertheless, it is

Figure 3.3-14
Aquaponics systems.
Source: photograph left: ©Samaki Aquaponics, Enactus Aachen e.V. 2018; photograph right: Richard Munoz (Aquaponik-manufaktur.de)

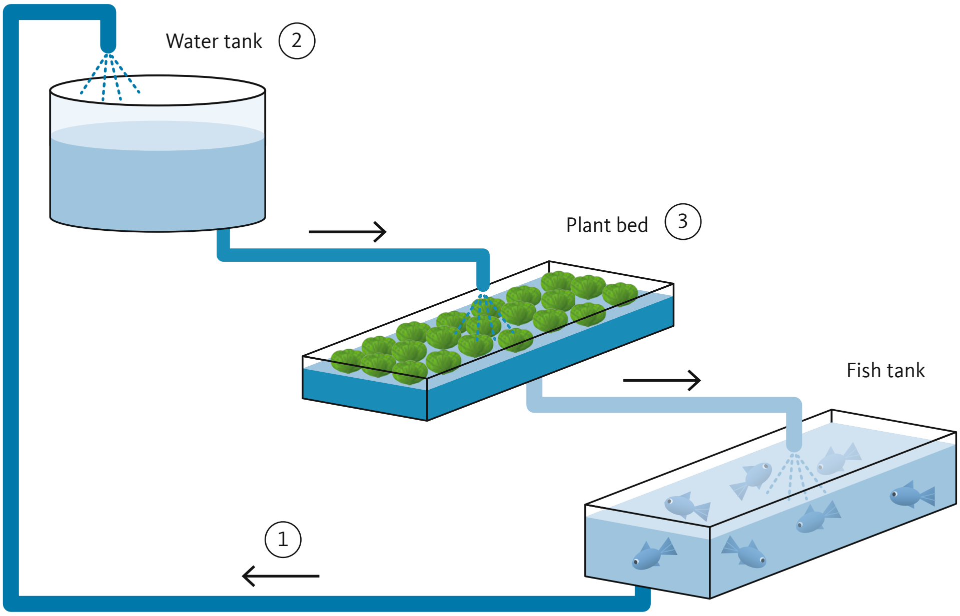


Figure 3.3-15
Simplified illustration of the functioning and structure of aquaponics systems. ① Feed residues and excreta get into the water because of the fish. ② Bacteria convert fish excreta and food residues into plant-available nutrients, and fresh water can be added. ③ The plants absorb the processed nutrients and thus filter the water, which is subsequently returned to the fish tank.
Source: WBGU, based on smallgarden-ideas.com

not recognized as an organic-farming practice and thus excluded from certification (Morgenstern et al., 2016).

Component 6: Biochar

Biochar is a carbon-rich product made by heating biomass in the almost complete absence of oxygen (incomplete combustion). Biochar's potential uses vary depending on the production process (Box 3.3-9; Fig. 3.3-17). It can replace fossil fuels by being used as an energy source, but can also be used as a filter material for cleaning exhaust air and waste water, and for making electrodes or fillers (Röhrdanz et al., 2019). For the construction industry, mixtures of biochar and inorganic clay provide an environment-friendly, energy-efficient insulation material with low vapour permeability, which reduces the thermal conductivity of building materials (Lee et al., 2019). Furthermore, biochar can be added to the soil for long-term carbon sequestration (Teichmann, 2014). The advantage of biochar over the original biomass is its high stability, so that the carbon is converted into CO_2 much more slowly by biochemical processes (Lehmann et al., 2009). In addition, the high process temperatures kill pathogens such as bacteria, and carbonization degrades antibiotics (Röhrdanz et al., 2019). Through its properties, biochar can also improve the nutrient- and water-retention capacity of soils and thus their agricultural productivity (Lehmann, 2007); the increased soil fertility is particularly relevant for tropical and subtropical regions.

Component 7: Climate-friendly bio- and depot fertilizers

The process for manufacturing conventional mineral fertilizers is based on fossil energy sources (Haber-Bosch process) and causes considerable GHG emissions. Since further emissions are released when they are spread on the fields, overall mineral fertilizers account for 7.7% of total agricultural emissions (FAO, 2017c), and their production requires 1–2% of global energy demand (Chen et al., 2018). Climate-friendly and less risky alternatives are therefore being sought.

Biomass can replace natural gas as the fuel in the Haber-Bosch process. In the case of sustainably grown biomass, this leads to reduced greenhouse-gas emissions (Chen et al., 2018). Using renewable energy to produce ammonia (Chen et al., 2018) can save up to 1.5 kg of CO_2eq per tonne of NH_3 produced (Pfromm, 2017). The production of ammonia can be coupled with the production of green hydrogen and renewable energy (Simon, 2017). In the future, the price of such fossil-free-produced mineral fertilizers is expected to halve, assuming that renewable energy dominates the power grid (Pfromm, 2017). But even if the production process (currently 1% of global GHG emissions) can be made more environmentally friendly, the emissions from application to the fields will remain the same

Box 3.3-8

Origins of aquaponics and possible applications

The origins of aquaponics date back to the 1970s. The first scientific publications emerged around 1980 (Lennard and Goddek, 2019). In 2015, the EU-Parliament called aquaponics one of the "ten technologies that can change our lives" (van Woensel et al., 2015). Even so, there has been little scientific research to date. The Leibniz Institute of Freshwater Ecology and Inland Fisheries in Berlin, for example, is conducting research on the Tomato Fish system with support from the BMBF (IGB, 2014). Aquaponics systems can range from small private systems to large systems run by commercial operators and come in three types: household aquaponics, social projects (school aquaponics) and commercial aquaponics. Work is currently underway to design aquaponics systems that meet all three pillars of sustainability (Junge et al., 2017).

Systems that combine plant cultivation with fish production – thus closing loops – are not new. In China, agricultural production systems of the rice-fish system (Fig. 3.3-16) have a long tradition. The FAO has listed these systems as Globally Important Agricultural Heritage Systems. In a synergy situation, the fish feed on leaves, weeds and insects, fertilize the plants with their excreta, regulate the microclimatic conditions, soften up the soil and generate movement in the water body. The rice plants provide shade and food for the fish. The consumption of rice and fish ensures a balanced diet for the farmers, and the reduced labour intensity in such rice fields takes some of the pressure off them. Furthermore, fewer chemical fertilizers and pesticides are needed for cultivation (FAO, 2020i).

Figure 3.3-16
Traditional combination of crops and fish (rice-fish system, or azolla-rice-fish farming).
Source: photograph left: Mieke Setiawati, UNPAD (Universitas Padjadjaran) Bandung; photograph right: ©FAO/Luohui Liang

(1.2% of global GHG emissions). Research is therefore needed into substitutes, such as biofertilizers or depot fertilizers (Box 3.3-10).

Component 8: Climate-friendly organic farming

Organic agriculture is a systemic alternative to industrial agriculture and relatively independent of farm size (Box 3.3-11). A key element is the closing of nutrient cycles, wherever possible by using the farm's own fertilizers and feedstuffs, by placing limitations on livestock concentration and/or by planting in longer crop rotation cycles (including undersowing). Mineral fertilizers and synthetic chemical pesticides are prohibited. The former are substituted by (on-farm) organic fertilizers and soil restoratives; chemical-synthetic pesticides are replaced by biological and cultivation measures. Higher product prices are made possible by a special system of certification, monitoring and marketing. These are justified mainly by the increased labour input generated by labour-intensive weed control (without herbicides). The lower yields make higher product prices inevitable.

Component 9: (Soil-)conservation agriculture

Key elements of conservation agriculture are zero ploughing, a permanent ground cover and adherence to a crop-rotation regime (Box 3.3-12). Minimizing movement of the soil has several positive effects, most notably the almost complete prevention of soil erosion, even during heavy rainfall. Furthermore, soil structure and water balance are improved, the infiltration of precipitation is increased and the formation of a plough sole is avoided (FAO, 2020d; Dumanski et al., 2006). Exactly how much carbon can be sequestered by conservation agriculture is a matter of controversy; however, a higher carbon stock in the soils of the majority of farms with conservation agriculture is undisputed (Govaerts et al., 2009).

In large-scale cultivation, conservation agriculture in combination with herbicide-resistance technology and the use of broad-spectrum herbicides in maize or soybean cultivation is already being practised on about 125 million ha (9% of arable land) globally (Pittelkow et al., 2015). This approach is particularly common in North and South America, Australia and New Zealand,

Box 3.3-9

Biochar: production, challenges and costs

When biochar is produced, parts of the biomass used (e.g. straw, green waste, biogenic household waste, liquid manure, fermentation residues or sewage sludge) break down in a gaseous, a liquid and a solid phase. The latter consists mainly of elemental, stable carbon and represents the actual biochar, which has similar properties to charcoal (Teichmann, 2014). There are various industrial production processes from pyrolysis and gasification (dry process – biochar) to hydrothermal carbonization (wet process – HTC coal). The process parameters differ (e.g. duration, temperature), as do the properties of the biochar produced in each case. These also depend on the initial biomass used (Teichmann, 2014). For carbon sequestration, it is mainly the more stable biochar from slow pyrolysis (> 250°C) that is used. However, it has economic disadvantages because, unlike the wet HTC process, the biomass has to be dried beforehand – a labour-intensive process (Libra et al., 2011). The non-energy uses vary depending on the production process (Fig. 3.3-17).

The main challenges are the energy required for production and the drying process prior to pyrolysis. The available biomass supply also influences the concrete GHG-avoidance potential and its costs. In addition, there can be competition for uses in food production and the use of biomass for energy (Teichmann, 2014). Above all, longer-term effects on plant growth have not yet been sufficiently researched. Biochar achieves yield increases averaging 10%, with a range from -28% to +39% (Jeffrey et al., 2011); negative effects on plant growth cannot therefore be excluded (Teichmann, 2014). Organic pollutants can form during the production of biochar, and this must be minimized by process technology. Due to the heterogeneous starting materials, production processes and application areas, further systematic investigations are required to gain a better process understanding of the effects of biochar in the soil.

At present, the possibilities for classifying biochar under fertilizer legislation in Germany are limited. Only the use of pyrolysis charcoal from untreated wood is permitted as a component of fertilizers, growing media and soil additives if it is to be marketed as a product (Haubold-Rosar et al., 2016). The costs associated with biochar production are reflected in the cost of the GHG avoidance achieved (over €100 per t CO_2). The potential in Germany is about 1% of the 2030 GHG-reduction target, and is limited by the availability of biomass (Teichmann, 2014).

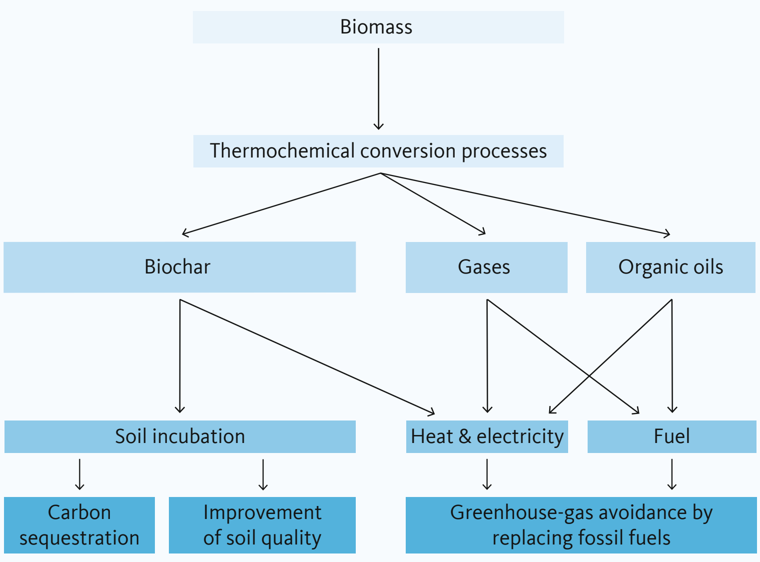


Figure 3.3-17
Biochar flow chart (without inclusion of use for energy).
Source: Teichmann, 2014:4

where it achieves much higher yields than conventional farming. In this way, however, conservation agriculture does not represent a multiple-benefits strategy, mainly because agrobiodiversity is lost as a result.

In small-scale farming, however, conservation agriculture is practised manually using a special hoe. It is propagated and promoted by FAO and various international development partners (FAO, 2017a). In Zambia, significantly higher and even up to double yields compared to conventional tillage are achieved using conservation agriculture. Although the labour costs also increase, the overall profit contributions are markedly higher (Haggblade and Tembo, 2003).

Component 10: Ecological intensification – the example of rice

Ecological intensification achieves higher outputs with lower inputs. The best-known example is root intensification in rice, which is also called rice intensification (Fig. 3.3-21). This was developed and optimized in 1983 from practical experience. Rice intensification is therefore a product of participatory research and is

Box 3.3-10

Biofertilizers and depot fertilizers: potential, effectiveness and barriers

Biofertilizers consist of microorganisms, fungi or algae and act within the plant itself or in the surrounding soil, the rhizosphere (Vessey, 2003). There, they fix nitrogen, dissolve phosphorus and, in this way, facilitate the plant's nutrient uptake. Biofertilizers can be applied in liquid form, as a powder or granules, and in peat (Herrmann and Lesueur, 2013).

- *Potential:* By restoring and strengthening the natural nitrogen and phosphorus cycles, biofertilizers can regenerate soils in the long term even where there is severe pollution from mineral fertilizers or crude oil. When combined with salicylic acid, they can also reduce soil contamination with toxic heavy metals (Khan et al., 2018) and increase the plants' tolerance to pollutants (Pandey and Singh, 2019). The manufacturing process is cost-effective and low in emissions.
- *Effectiveness:* Biofertilizers have a significant effect, although not until after a few years. For example, the yield of soybeans increased by up to 30% after three years (Lesueur et al., 2016); other studies report possible yield increases of 10–40% (AfDB, 2016; Mahanty et al., 2017). Their use enhances resilience to climate variability by strengthening the soil and roots; it also increases the plants' resistance to diseases and pests (Khan et al., 2018). Biofertilizers are genetically modifiable for different sites and applications and can be mixed with mineral fertilizers (Ye et al., 2020), which facilitates the transition between mineral and bio-use and/or reduces the use of mineral fertilizer. In addition, biochar can be used as a CO_2 sink and as a 'carrier' for biofertilizers in the soil. According to the European Biomass Industry Association (EUBIA, 2020), switching to biofertilizers would save up to 6 kg of CO_2eq per kg of nitrogen used.
- *Barriers:* Biofertilizers need a clear legal framework to guarantee quality controls and generate trust among farmers. The flow of information between science and agriculture on the advantages can make a decisive contribution towards counteracting the uncertainties of a fertilizer switch. The transitional period between the use of mineral fertilizers and biofertilizers can be bridged by providing financial security. Biofertilizers should be combined with mineral fertilizers. They require special precautions for storage and transport, as they are constantly fermenting.

Alongside biofertilizers, depot fertilizers can also be used as an alternative. They consist of compost and fermentation residues or other organic residues which are mixed with inorganic fertilizers N, P, K and compressed to form depot fertilizers. According to field trials, fertilizer savings of around 50% can be achieved (WEHLING Projekt GmbH, 2005).

regarded as an agroecological practice. The method was developed by Cornell University and further disseminated by NGOs and the FAO (FAO, 2016a).

In rice intensification, wet rice is planted at much wider intervals and, as a result, up to 85% less seed is required while achieving higher yields. The individual plant roots can develop better and thus make more effective use of nutrients. In addition, water savings of 30–40% can be achieved if irrigation is carried out using alternating wetting-and-drying systems. Moreover, this requires 15% fewer labour-hours overall and generates productivity and income gains of around 20–25% (SRI International Network and Resources Center, 2015).

The procedure initially contradicts centuries of experience with narrower planting spaces, which is why farmers are initially hesitant to implement it. Barriers to the adequate transfer of knowledge lie above all in the agricultural extension services in developing countries, which in most cases are not adequately equipped with personnel and further-training opportunities.

Scalability to all farm types and transfer effects are possible; the principle can theoretically be applied to all arable crops. Rice intensification is already highly popular, especially in Asia, but also in Africa. Application guides have already been made available in numerous countries and in many languages.

Rice intensification should be included in all agricultural extension services including monitoring systems and integration into the research landscape. Research is needed into the transferability of the root-intensification principle to other arable crops (cotton, maize, sorghum, etc.).

Component 11: Cultivation of neglected and underutilized crop species

Not only the rich range of existing, well-known crops offers opportunities for diversification but also the increased cultivation of 'neglected and underutilized crop species' (NUCs). These include, for example, African indigenous leafy vegetables, which are like spinach, and thousands of other cultivated species. During colonial times, forgotten crop species were often considered a 'poor man's crop' in sub-Saharan Africa (Stöber et al., 2017). Instead, people were encouraged to grow 'exotic' vegetables that originally came from colonial countries, such as tomatoes, onions, and carrots, which were more susceptible to disease and pests in tropical conditions, required more water and therefore needed to be irrigated. Forgotten crops typically require very little cultivation in their regions of origin and have a short vegetation cycle; resource-poor farmers can often grow and market them without any problems. Recently, forgotten crop species have received more attention from the German Federal Ministry of Education and Research (BMBF), German development cooperation and inter-

Box 3.3-11

Climate-friendly organic farming compared to conventional systems

Organic farming has numerous environmental advantages over conventional farming (Sanders and Hess, 2019). For example:

- nitrate leaching is reduced by 28–39%,
- no environmental toxins are released by pesticides or veterinary medicines,
- the density of soil organisms is increased by 78–94%,
- soil acidification is prevented,
- a considerable amount of carbon sequestration is achieved in the soil and can reach more than 250 kg C per ha, humus is built up,
- nitrous oxide emissions are approx. 24% lower,
- a higher nitrogen and energy efficiency is achieved,
- up to 95 more species grow on the fields,
- and resilient adaptations to climate change are achieved.

Depending on crop type, location and management, yields in organic farming are between 5–34% and an overall average of 25% below those of conventional cultivation. The smallest differences of about 5% are found in the cultivation of leguminous plants in rainfed agriculture and in perennial crops (permanent crops). Yield differences decrease over the years due to the increase in ecosystem services, but they do not reach conventional yield levels (Seufert et al., 2012).

Organic farming is first and foremost an issue of ecological sustainability and healthy nutrition, but it is also a strategy for climate adaptation. Resilience is improved by achieving soil with a several-times-higher buffer capacity, lower susceptibility to erosion, better soil life, better infiltration and higher aggregate stability (Sanders and Hess, 2019). Organically cultivated soils have a 14% higher soil carbon content than conventionally managed soils due to their supply of organic material (Sanders and Hess, 2019:145).

An appreciation for organic farming is growing in the EU and is promoted via the second pillar of the CAP (details in Box 3.3-1); the European Green Deal's Farm-to-Fork strategy also includes organic farming.

In developing countries, certified organic agriculture for self supply has hitherto served niche markets due to the higher prices, but it is important for global value chains such as organic cotton, organic coffee, etc. Here, Organic or Fair Trade labels are used to achieve higher prices in industrialized countries and thus higher incomes for producers.

Research approaches for climate-sensitive organic agriculture lie in the search for ways to reduce the number of animals as much as possible without causing bottlenecks in the supply of organic fertilizers, in the optimization of no-till, direct seeding methods (Berner et al., 2008; FiBL, 2019), and in the development of vegan systems that dispense with animal production altogether (biocyclic-vegan.org, 2020).

national organizations, among others (Bokelmann et al., 2016; FAO, 2018d).

The cultivation of forgotten crops has numerous advantages. It diversifies farming systems, raises nutritional quality and contributes both to income and to the conservation of valuable genetic resources. Some of these plants may also make a contribution to climate-change adaptation (FAO, 2018d; Padulosi et al., 2019). The cultivation of old crop species also has socio-cultural value and contributes to the preservation of traditional eating cultures (Krause et al., 2019; Padulosi, 2019; Padulosi et al., 2019; Stöber et al., 2017; Moraza et al., 2018). Some of the forgotten crops, such as the species of African green leafy vegetables, have a cancer-inhibiting effect due to their high antioxidant content and are also particularly beneficial to health due to their very high vitamin A content (Kebede and Bokelmann, 2017).

To promote the cultivation of forgotten crops, it is first important to preserve the knowledge that is still available on how to grow them and how to prepare meals, information that is already in danger of being lost today (Padulosi et al., 2019). In addition, these plants must be given an image boost, for example in local school gardens and universities, and be included in national dietary guidelines. In sub-Saharan Africa, the increased cultivation of forgotten crop species can also be an important key to improving the supply of healthy food.

Component 12: Paludiculture – agriculture on peat soils

Peatlands store 30% of the world's soil carbon, although they cover only 3% of the land surface (Joosten et al., 2012). They therefore contain twice the amount of biomass carbon as the global forest stands (EU, 2009b). Peatlands are rich in biodiversity and are the most spatially effective carbon stocks in the world (Verhagen et al., 2009). The draining of peatlands continues to increase worldwide, and their destruction by mining and the thawing of permafrost soils are also of global significance (Section 3.1.3). About 15% of peatlands are affected by degradation, generating a total of 6% of global GHG emissions (Joosten et al., 2012; Biancalani and Avagyan, 2014). While widespread draining is the main problem in many parts of the world, the inhabitants of the tundra are struggling with soil subsidence caused by thawing permafrost, while overgrazing and destruction by mining are causing the degradation of peatlands in the Himalayas (EU, 2009b). The rewetting of peatlands, their conservation and climate-friendly use with the help of agriculture on peatland soils (paludiculture, Box 3.3-13) is therefore of decisive importance for climate-change mitigation and is regarded by experts as 'low-hanging fruit for climate-change mitigation' (Joosten et al., 2012).

Box 3.3-12

(Herbicide-free) soil-conservation agriculture: advantages and barriers

When properly implemented, conservation agriculture has numerous positive effects on the soil. It is protected from direct sunlight and desiccation, and 95% of water and wind erosion can be stopped. The water balance and natural soil fertility improve and longer crop rotation cycles have positive effects on (agro-)biodiversity and prevent pest infestation (FAO, 2020d; Dumanski et al., 2006).

On smallholder farms in developing countries, conservation agriculture is used on approx. 6 million ha and is institutionally supported (e.g. by the FAO and development cooperation: Conservation Agriculture Farming Unit, 2019; IIRR, 2005). However, the method is *de facto* practised only on partial areas on small farms because of the increased labour required. Moreover, a lack of seeds for green manuring also often prevents mulching and the realization of long crop rotation cycles FAO, 2020c).

An example of a traditional form of conservation agriculture is 'ZaÏ' (Figs. 3.3-18, 3.3-19). Degraded and hardened, so-called 'lateritized' soils are rehabilitated with a pickaxe, a special pitting technique and targeted applications of mineral fertilizers.

In developing countries, extension services, the distribution of mulch seedings and possible remuneration for humus enrichment are key challenges. In Africa in particular, offering a free-of-charge exchange of ploughs for cultivators, harrows or ridging equipment is a prerequisite for the technology being implemented on a broad scale. Otherwise, the resulting manual work is often so great that only a partial area can be cultivated by conservation tillage.

Research on herbicide-free weed control in the context of conservation agriculture should be funded. The implementation of conservation agriculture has many advantages, but in practice it depends on successful weed control without ploughing and without herbicides (Fig. 3.3-20). Finding a solution without fundamentally endangering biodiversity and without causing excessive additional work is still a very relevant research question.

Figure 3.3-19
Millet in ZaÏ troughs. The lateritized soil was tilled and the troughs were stocked with seed and organic fertilizer. Erosion processes can therefore no longer take place. The plants develop very well.
Source: Hamado Sawadogo, ECHO Inc.

Figure 3.3-18
ZaÏ: a traditional method of soil restoration.
Source: ©World Agroforestry

Figure 3.3-20
Minimal tillage according to the principle of conservation agriculture. The ground is not ploughed, but only scraped open. The soil between the rows is not moved but covered with mulch material after the seed has been sown in the furrows.
Source: USAID Mikajy, Madagascar

Component 13: Permaculture as a multifunctional horticultural system

The concept of permaculture was developed in the 1970s and represents an intensive (horticultural) cultivation system in which crop species of different heights are grown as intensively as possible (Box 3.3-14). Its main characteristic is the optimum use of a limited space according to the principle of 'slow and small solutions'. Plants are arranged vertically and make optimal use of different spatial layers. In this way, with a high labour input, a high yield per unit area is achieved with diversified crop types each with different functions. Accordingly, permaculture is often used in periurban areas as a horticultural system in projects where space is in short supply and social goals can be ideally combined with horticulture. The gardens are planted, for

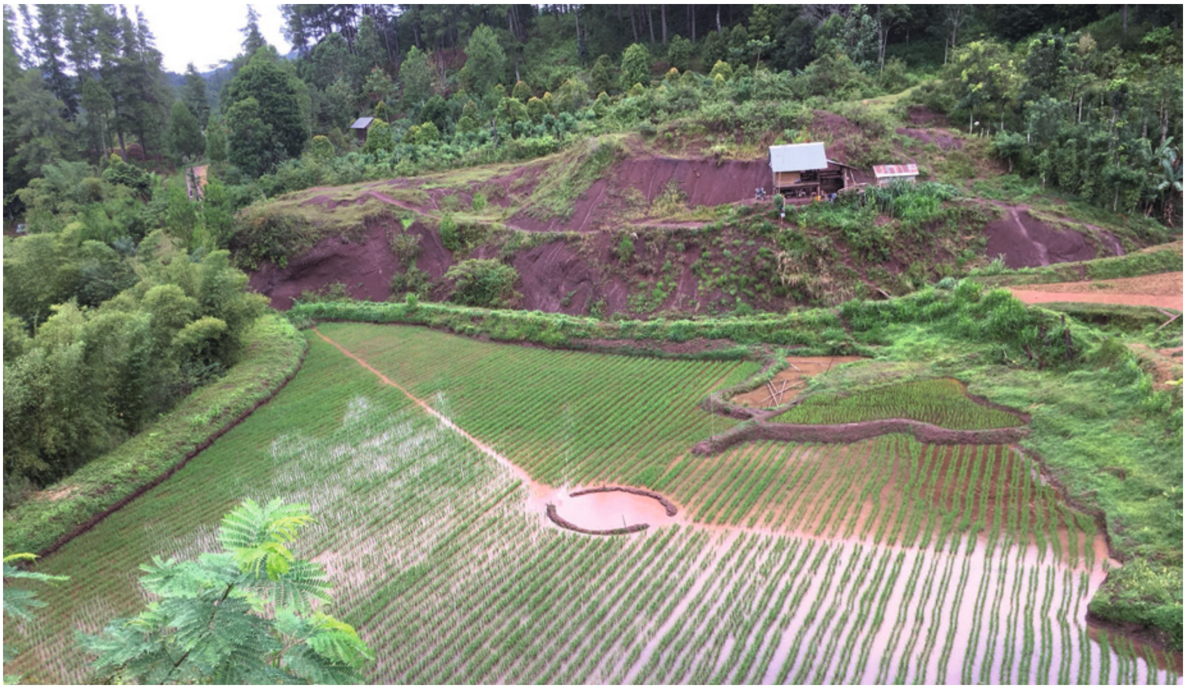


Figure 3.3-21
Rice intensification and rice-fish farming in Indonesia. The spaces between the rows of rice plants are wider than usual. This leads to intensive root development and a higher yield, and saves labour, seed and, in the case of alternating irrigation, water. Fish can also be kept in the water (tank irrigation; Box 3.3-7). The water surface can be covered with nitrogen-collecting azolla ferns, thus simultaneously supplying the rice plants with nitrogen while shading the water surface and limiting weed growth.
Source: Silke Stöber, Centre for Rural Development (SLE), Humboldt University Berlin, 2019

example, by civil-society groups and, in addition to diversifying their own diets, also serve as meeting and educational centres, recreational areas and excursion destinations. Healthy nutrition can thus be ideally linked with environmental, educational and social goals (Ferguson and Lovell, 2019).

Component 14: Sustainable precision agriculture

Today, the digitalization of agriculture also promises ecological intensification by utilizing inputs more efficiently through precision agriculture while simultaneously increasing yields and reducing environmental damage (Egli et al., 2017; Henry et al., 2018; Mauser et al., 2015; Schriijver, 2016; WBGU, 2019b).

Among other things, precision agriculture means that, by using digital systems, water, fertilizers and pesticides can be applied precisely according to the needs of the plants and soil quality (Gebbers and Adamchuk, 2010). Sensors are used to measure soil moisture and nutrients, drones for image recognition, and satellite-based positioning for the intelligent control of agricultural machinery (Walter et al., 2017). In this way, not only can the expected increases in demand be met, but the expansion of agricultural land into near-natural ecosystems and the associated loss of biodiversity can also be halted. The areas saved can then theoretically be used to generate 'negative emissions' (Section 3.1). Precision agriculture sometimes requires high investment, but it also enables yield increases, as well as lower inputs and sustainability costs, especially in water-scarce regions (Monaghan et al., 2013). Optimizing tillage, harvesting processes and harvest times can minimize crop losses and improve the quality of agricultural products (King, 2017; Monaghan et al., 2013).

Microdosing using robotics can save more than 90% of herbicides, and laser technology or mechanics could even replace the use of herbicides completely (King, 2017). Efficiency and quality improvements in fruit and vegetable production become possible by optimally timing mechanical harvesting (King, 2017). Cost reductions and yield increases are furthermore made possible by precision agriculture (Bramley, 2009). For example, yield increases of between 5 and 10% are possible for sugarcane in Brazil (Demattê et al., 2014). Ecosystems and food supplies are under less strain (CBD, 2014) when the systems really are used in the spirit of sustainability.

In order to achieve multiple benefits as outlined in the land-use trilemma, precision agriculture as presented here presupposes that the systems are also used with sustainability and biodiversity conservation in mind – i.e. are not geared to maximizing yield but to an ecological marginal profit (Box 3.3-15).

Box 3.3-13

Paludiculture: potential and barriers

With agriculture on peat soils (paludiculture), rewetted peatlands can be used in an environmentally compatible way for biomass production, for bioenergy, building materials, or as a growing medium. The yields that can be achieved with this method usually exceed those of conventional farming on other soils (Giannini et al., 2017; Wichmann, 2017). On rewetted moors, water buffalo can be kept for meat production and medicinally valuable plants cultivated (EU, 2009b). The University of Greifswald has initiated a database of crop species in Germany suitable for paludiculture; it already contains 184 species (Abel et al., 2013).

In the case of paludiculture, methane emissions initially increase due to rewatering, as microorganisms decompose organic material under the exclusion of oxygen, but CO_2 and N_2O emissions decrease at the same time. In the short term, these opposing emission streams can balance out to zero if there is a particularly large amount of fresh organic material on the rewatered peatlands (Joosten et al., 2012:37). In the long term, however, rewetted peatlands represent a carbon sink thanks to their continuous carbon storage and thus make a very important contribution to climate-change mitigation (Joosten et al., 2012).

Component 15: (Peri-)urban agriculture

(Peri-)urban agriculture refers to the production of food in cities and their environs. The use of (peri-) urban space for food production can be divided into three forms: (1) small-scale urban farming or urban gardening, often on fallow land or other gaps in built-up areas, which in some ways shows similarities with the classic allotment gardens, even if these are often not included in the analysis, (2) highly mechanized approaches (farm-free food) such as indoor farming with artificial light, vertical farming, aquaponics (component 5) or the use of sewage and waste as nutrients for the plants, (3) near-city agriculture, which traditionally is closely linked to the respective city but has become partially decoupled in the industrialized countries; here, the two can be re-linked under an ecological regime via concepts such as community-supported agriculture, organic box schemes or adventure farms.

The multiple benefits result from the interlocking of these three forms of use. The influence of cities on their environs and the use of new technological possibilities make both greening and the production of appreciable quantities of food possible. The latter applies primarily to fruits and vegetables, but not to grains or livestock (Grewal and Grewal, 2012).

However, probably the more important benefit of urban agriculture, especially in the form of urban gardening, lies in the re-connection of consumption with production, i.e. the creation of an awareness for foodstuffs, their origin, seasonal and regional specification and the challenges of production. Urban gardens are often places of learning and communication for acquiring basic knowledge about agricultural production and horticulture, but also meeting places for creating something together (WBGU, 2016a:318f.). The urban gardening scene is often closely linked with concepts such as slow food, food saving, vegetarian or vegan diets, and with the corresponding impact potential for avoiding food waste and changing dietary habits. In addition, urban gardens can take on important social functions as meeting places (urban-gardening.eu)

Especially in growing metropolises, challenges in urban farming can be caused by competition with other land uses, be it building development or renewable energy production. The scalability of small-scale urban gardening is severely limited by land competition and the fact that land in cities is usually expensive. Staple crops such as rice, wheat and maize, which take up large areas of arable land, are not at all suitable for cultivation in cities. As regards the technical solutions, the limits lie in the availability of light or energy and nutrients.

3.3.3 Recommendations for action

In order to promote a transformation of agriculture towards sustainability, the WBGU recommends measures of agricultural, environmental, climate and development policy, focusing on the EU and the countries of sub-Saharan Africa. The recommended measures aim to transform the one-sided, soil-degrading practices of both industrial agriculture and the subsistence farming practised by resource-poor smallholder farms – each with their negative effects on climate, biodiversity and nutrition – into the kind of diversified and soil-conserving farming systems outlined especially in Section 3.3.2. To achieve this goal, the WBGU recommends motivating farmers through more participation, extension services, financing and joint planning to enable them to actually implement such ecologically intensive systems. Specific framework conditions should be created to encourage a continuous dissemination of these systems. Incentive and reward systems and a continuous exchange of knowledge are important, since farmers provide services which are important for society; the impact of these services is not necessarily only felt

Box 3.3-14

Permaculture, principles and dissemination

Permaculture is based on three basic principles that illustrate the systemic aspects of nature and its use in cultivation: (1) each element in nature's system has multiple functions, (2) each function has multiple elements that sustain it, and (3) each function of the different elements is significant for the overall system (Fig. 3.3-22; Akhtar et al., 2015; Hathaway, 2016).

As in agroecology, cultivation is based on natural processes: the patterns in nature should first be recognized and then transformed in such a way that they can be beneficially applied to one's own cultivation system. This includes the cultivation of leguminous plants and the use of compost or biofertilizers (Didarali and Gambiza, 2019). An attempt is also made to create a balance between pests and beneficial insects without using pesticides.

The approach is already being applied in some developing countries and emerging economies. In Havana, for example, 90% of fresh vegetables are grown locally using organoponics, which is similar to permaculture. Using this method, yields in Havana have been increased from 1.5 kg per m² to 25.8 kg per m² (Cabannes, 2012). Permaculture gardens are also being successfully established in projects in refugee camps in Haiti with the help of the UN (Gans, 2010). In a project in Mali, yields were doubled compared to the regional average (UNCTAD, 2013:242). Especially in regions where food prices are volatile, cultivating one's own gardens can increase food security and quality. Access to and transfer of knowledge are key elements in the diffusion of permaculture (Krebs and Bach, 2018).

Figure 3.3-22
Permaculture garden.
Source: 'Vegetable garden, permaculture' local food initiative (CC BY 2.0), flickr.com

by them but sometimes only at the landscape level. Suitable financing channels for the EU are the reformed direct CAP payments, for sub-Saharan Africa the governments' reformed Input Subsidy Programmes (ISPs), as well as financing through development cooperation and international green adaptation funds, as already indicated in the respective multiple-benefit strategies. International agricultural trade is a third factor, and this must be consistently geared towards fairness, sustainability and resilience if it is to support the same goals.

3.3.3.1 Recommendations for action: greening industrial agriculture in the EU and the CAP post-2020

Press ahead with the reform of the CAP in the direction of environmental and climate policy

In future, agricultural policy should be more closely linked to environmental and climate policy. This means gearing direct payments within the framework of the CAP more closely towards maintaining ecosystem services that go beyond 'good farming practice'. The current area-based direct payments (CAP: Box 3.3-1; Section 3.3.1) should be transformed into payments for public goods and services that serve the common good and address sustainability concerns (Pe'er et al., 2019). Instead of 'light green' (i.e. hardly effective) measures that would be implemented even without subsidies, such as the cultivation of rapeseed as a crop-rotation element, 'dark green' agroenvironmental and climate-change-mitigation measures should be promoted that have a direct impact on the conservation and promotion of biodiversity (e.g. promotion of species-rich grassland by means of late mowing or grazing). Dark green measures should be further developed, despite the higher administrative burden, as they are usually more effective in promoting biodiversity (Lakner, 2020; Armsworth et al., 2012). Inputs of nutrients and pesticides into the surrounding ecosystems should be prevented in Germany by means of regulatory policy. With regard to pesticides, an incentive tax that is staggered according to toxicity and environmental characteristics is desirable, following the example of Denmark or France (Finger et al., 2017).

Strengthen the European Commission's instruments for reviewing strategic plans

The European Commission has announced that it will use all available planning instruments coherently in the spirit of the European Green Deal. These instruments include not only the national climate and energy programmes, but also the cohesion funds for rural development and the national strategy programmes increasingly planned for the CAP post-2020 to implement the common agricultural policy (Box 4.3-1; Köck and Markus, 2020:257). On the one hand, they allow scope

Box 3.3-15

Small-scale digitalized agriculture and pixel farming

In the future, small, light ‘agrobots’ could replace traditional heavy agricultural machinery such as tractors, which would probably reduce soil compaction and increase its aeration and ultimately its functionality. Instead of herbicides, initially autonomous robots like ‘Oz’ or ‘Dino’ (Fig. 3.3-23), could weed fields in the future.

Combined with novel approaches to digitally assisted field management using machine learning, there are great opportunities in alternative forms of application for implementing robotics (WBGU, 2019b: Section 3.3). Founded in 2019, Pixelfarming Robotics (pixelfarmingrobotics.com), based on the Horizon2020 research project ‘Pixel Cropping’ (wur.nl/en/project/Pixel-cropping.htm), is running until 2022 at Wageningen University in the Netherlands to explore the hypothesis that high-resolution temporal, spatial and genetic diversity promotes ecological processes that serve both crop yields and agroecosystems. Biological crop-protection methods make it possible to completely dispense with pesticides by optimizing combinations of different plants on the basis of their properties and interactions, thus increasing yields by up to 50%. In pixel fields, different food and crop plants can be grown in complex data-based neighbourhood arrangements which optimally meet their respective needs, also taking into account soil characteristics and other environmental conditions (Fig. 3.3-24).

Automation and robotics play a key role in scaling this new farming method, but are implemented differently from the hitherto dominant model of precision agriculture. The interdisciplinary research project also addresses questions thus raised about the design of socio-technical systems, e.g. the social implications of automation and the desired role of technologies in future agriculture. The focus is on the interdisciplinary exploration of alternative forms of collaboration between robots, humans and ecological processes in the sense of complementary addition instead of substitution. In practice, a ‘Pixelfarming Academy’ has been established as an educational institution, a cloud platform has been set up for controlling the robots using deep learning, and the first solar-powered prototypes have already been developed (Fig. 3.3-25). A timely scaling-up of pixel cropping or pixel farming in other countries would have the potential to use digital technologies innovatively for sustainable agriculture.

Figure 3.3-23
Weeding robot ‘Oz’ and large-scale vegetable weeding robot ‘Dino’ from Naïo Technologies.
Source: Naïo Technologies

Figure 3.3-24
Pixel fields.
Source: photograph left: Talis Bosma; photograph right: Peter van der Zee (www.wur.nl/en/project/Pixel-cropping.htm)

Figure 3.3-25
Pixel farming 'Robot Zero' and 'Robot One'.
Source: Pixelfarmingrobotics.com

for national *Eigenart* (distinctiveness); on the other, they aim to ensure that an integrated approach to agriculture is possible at the national level (EU Commission, 2018c). This form of gentle coordination is also, for example, at the foundation of the Paris Agreement and European energy and climate policy (Ringel and Knodt, 2017). According to the Commission's 2018 drafts for the CAP post-2020, the national strategic plans for implementing the CAP are to be linked to both the regulation on the Governance Energy Union and the LULUCF regulation (EU Commission, 2018c). To this extent, integration is envisaged on paper, which is something the WBGU welcomes. To ensure its success, the Commission plays an important role in monitoring the coordination and integration of policy areas. It should therefore have a set of instruments for reprimanding any lack of enforcement of integration and coordination by national strategic plans. A possible model here could be the mechanism of Article 23 of Regulation 1303/2013 with its common and general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund (EU Parliament, 2013). Here, in the absence of national policy-making, the Commission can, under certain conditions, bring about a Council decision leading to funding cuts.

Enshrine participation opportunities in the new CAP and promote education and training

A far-reaching reorientation of the CAP requires the inclusion of all available expertise in the fields of environmental policy, social policy and agricultural economics from science, civil society and practice. Transparency, accountability, participation and knowledge acquisition should already be strengthened during the reform process, thereby winning back legitimacy and public trust (Pe'er et al., 2019). "This requires opening and enabling public scrutiny of data, negotiation documents on the CAP reform and implementation data throughout the policy cycle and before approval. Conflicts of interest in decision-making and implementation need to be identified and overcome, and wider participation needs to be made possible" (Pe'er et al., 2020). Consequently, the WBGU also welcomes the idea of involving several affected Directorates-General in further strategy development (Pe'er et al., 2020). Furthermore, education and training programmes should be offered that provide information on diversified agricultural production systems and agroecological practices, explain the aims and requirements of agroenvironmental programmes better, and encourage participation (Lampkin et al., 2015; Stupak et al., 2019). Greater involvement of farmers and the co-production of knowledge by experts and farmers are very important reasons for active participation here (Müller, 2019). A better understanding among farmers of agroecological interrelationships is essential, as the conviction that fields should look 'tidy', i.e. with even growth and without 'weeds', is quite common. This underestimates the ecological value of 'untidy' areas of land (Stupak et al., 2019).

Promote the development and implementation of technical innovations for sustainability

In order to successfully adjust agriculture in the EU towards diversified, multifunctional farming systems, the development and implementation of technical innovations for sustainability and new agroecological practices should be promoted (Wanger et al., 2020). This helps maintain long-term soil quality – which is

Table 3.3-2
Overview of various components of multiple-benefit strategies. The table shows agricultural production systems that have the potential to help defuse the trilemma.
*The WBGU's assessment of the potential of selected systems for resolving the trilemma and of their geographical significance.
Abbreviations in the 2nd column 'Multiple benefit': CM: climate-change mitigation; CA: climate adaptation; B: biodiversity conservation; F: food security. The ratings do not indicate the absolute scale of benefit but rather the main points changed by the respective system within the framework of the trilemma. Furthermore, whether the effects occur depends on the design.
Source: WBGU

Component	Multiple benefit*	Brief description	Current significance in*		Geographical suitability or potential
			indus-trialized countries	developing countries	[Global potential for carbon dioxide removal (CDR)]
1. Agroecology	CM: + CA: +++ B: +++ F: ++	This metaconcept encompasses the entire food system and includes numerous methods and techniques for ecologically and socially sustainable agriculture, especially in smallholder systems worldwide. Ideally, innovations stem from practitioners and their experience, are then fed into science and jointly developed further.	+	+++	Worldwide potential, especially in smallholder structures.
2. Climate-smart agriculture	CM: +++ CA: ++ B: 0 or - F:++	Climate-smart agriculture is also a meta-concept that combines numerous techniques with a focus on increasing productivity, climate-change mitigation and climate adaptation. It represents an influential worldwide collective movement for such approaches, without sharp definitions or indicators, related to genetic engineering, chemical-based, but also agroecological and biological innovations for both industrial and smallholder agriculture.	++	++	Worldwide potential, danger of greenwashing
3. Agroforestry	CM: +++ CA: +++ B: +++ F: ++	Production system that diversifies production and diets by integrating trees, shrubs, etc. into agricultural land and into the agricultural landscape (FAO, 2015b).	++	+++	Potential above all in drier regions (Ruppert et al., 2020) [0.1–5.7 Gt CO_2 per year (Roe et al., 2019)]
4. Agrophoto-voltaics	CM: +++ CA: +++ B: 0 F: +++	Combination of photovoltaic systems and food production on the same land. Agrophotovoltaics can simultaneously save water, use sunlight for energy generation and provide shade for suitable crops or livestock.	+	+	Potential in semi-arid and arid regions and in rural regions in general (decentralized energy system)
5. Aquaponics	CM: + CA: ++ B: ++ F: +++	Combination of the technologies of recirculating systems for aquaculture and hydroponics in a closed recirculation system (Junge et al., 2017). Rice-fish farming is based on wet-rice systems with basin irrigation including fish farming.	+++	++	Aquaponics possible in locations that are otherwise rather unsuitable for agricultural use, such as (sub-)urban areas (on roofs, factory sites)
6. Biochar	CM: ++ CA: + B: + F: ++	Carbon-rich product produced by heating biomass (e.g. agricultural waste or by-products) in the absence of oxygen; among other things it can be incorporated into the soil for long-term carbon dioxide fixation (Teichmann, 2014).	+	++	[Conversion of biomass into hard-to-biodegrade (persistent) biochar 0.3–4.9 Gt CO_2 per year (Roe et al., 2019)]
7. Climate-friendly bio- and depot fertilizers	CM: ++ CA: ++ B: 0 F: ++	New green manufacturing processes for mineral fertilization and the production and use of biofertilizers from microorganisms reduce emissions and regenerate soils. In the case of depot fertilizers, organic residues are compressed with mineral fertilizers.	+	+	Techniques for improving the carbon footprint of mineral fertilizers. Reductions of up to 50% in the case of biofertilizers and depot fertilizers.
8. Climate-friendly organic farming	CM: + CA: +++ B: +++ F:+++	Closing the nutrient cycle by using the farm's own fertilizers and feeds. No application of mineral fertilizers or synthetic chemical pesticides. Humus is enriched (sink) and soil life preserved. The products are certified by farming associations. The product prices are higher and the yields somewhat lower than in conventional farming.	+++	+	More suitable for wealthier countries because of certification and higher prices for consumers. The equivalent in developing countries is agroecology.

9. (Soil) conserving agriculture	CM: ++ CA: +++ B: ++ F: +++	CO_2 is sequestered (but only in the upper soil layers) and soil protected by using no-till systems or minimal tillage, permanent ground cover and crop rotation. This also improves other soil properties, stops soil erosion and promotes soil life. Yields are usually higher to much higher than in conventional farming with ploughing.	+++ (with herbicide resistance technology)	+++	Only a multiple-benefit strategy without the use of broad-spectrum herbicides (e.g. glyphosate). Alternative methods of weed control are being sought for large-scale use.
10. Ecological intensification – example of rice	CM: +++ CA: + B: 0 F: +++	The system promises more output with less input and is therefore a form of precision agriculture. The cost of inputs can be drastically reduced with sustainable rice intensification (SRI). The roots develop better when planting distances are wider; nutrient exploitation is higher and therefore so are the yields (+ 20%).	+	+++	In all rice-growing areas ++, plus spill-over effects on probably all other arable crops (including cotton).
11. Cultivation of forgotten and underused crops	CM: 0 CA: + B: +++ F: +++	Cultivation mainly of fruit trees and vegetable crops, the distribution of which is declining in indigenous societies. Crops are usually easy to grow and their reintroduction offers multiple benefits (healthy food, adaptation to climate change, conservation of genetic resources).	+	++	In all regions of the world; many hundreds to thousands of cultivated species available worldwide.
12. Paludiculture – agriculture on peat soils	CM: +++ CA: 0 B: ++ F:++	Drained peatlands are rewetted and managed in such a way that they are preserved as CO_2 sinks in the long term, while at the same time producing high yields and preserving biodiversity.	+++	+	
13. Permaculture as a multifunctional market-gardening system	CM: 0 CA: ++ B: ++ F: ++	Intensive, diversified market-gardening system aimed at the maximum use of sunlight and therefore based on altitudinal zonation.	+	+	Especially as a market gardening system.
14. Sustainable precision agriculture	CM: ++ CA: + B: + or 0 F: +++	Inputs are efficiently applied via digital (and analogue) systems according to plants' needs and soil quality. Technology should be adapted to production and not vice versa (small-scale digital agriculture, pixel cropping; Gebbers and Adamchuk, 2010).	+++	+	In principle, the digital systems can be used worldwide.
15. (Peri-)urban agriculture	Whether the trilemma is balanced depends on the design.	Use of (peri-)urban space for intensive food production, especially vegetable crops via (1) small-scale urban gardening, (2) high-tech solutions, (3) with the aim of strengthening the link between rural and urban areas and greening urban fringe areas.	+	+	In the short term primarily supporting the nutrition transition, in the medium term using technological solutions.

the basis for food production and biodiversity conservation, and simultaneously promotes climate-change mitigation. Farmers should be involved as producers, researchers and experimenters in the development and shaping of innovative greening. Precision agriculture offers several opportunities for optimizing the use of production inputs and for expanding the possibilities of biodiversity conservation. In other words, "there is a chance that machines can adapt to a smaller-scale landscape and diversified agriculture in view of the increasingly urgent requirements of sustainability" (WBGU, 2019b:196).

Strengthen the integrated landscape approach and spatial planning

The integrated landscape approach aims to reconnect crop cultivation with animal husbandry, close nutrient cycles and create carbon sinks and/or protect natural carbon reservoirs. The WBGU recommends coupling crop and livestock production by gradually introducing limitations on livestock concentration in order to exclude overfertilization, avoid the use of external production inputs and promote diversified multifunctional production systems (Lampkin et al., 2015); absolute stock ceilings should be fixed for commercial livestock farming. Organic farming (Box 3.3-11) and aquaponics (Box 3.3-8) have an explicitly circular orientation. Furthermore, spatial and landscape planning should be geared more towards sustainability, using structural elements (e.g. hedges, copses, bodies of standing water) to help promote the conservation of biodiversity and ecosystem services in the cultural landscape. These elements help to specify and designate areas (e.g. erosion-prone slopes, areas vulnerable to erosion) where agroenvironmental measures are desired (von Haaren et al., 2019). People should be placed at the centre of such efforts and special attention paid to gender.

Box 3.3-16

Digitalization of agriculture: who benefits from agricultural data?

Digital technologies have already changed agriculture profoundly, especially in industrialized countries. However, in addition to the opportunities that come from increased productivity and efficiency, there are also risks, which are the subject of controversy, for example with regard to unevenly distributed access opportunities, expected rebound effects (von Ahlefeld, 2019) or path dependencies (HLPE, 2019:80). The increasing prevalence of precision agriculture is based on the use of big data, artificial intelligence and robotics, but also on platforms for bringing together networked data streams, devices and actors, and for communicating information and knowledge (WBGU, 2019b: Chapter 3, Sections 5.2.9, 5.2.10). Internationally, in addition to a 'digital divide' for developing countries there is a danger of intensified asymmetrical power relations between producers and citizens on the one hand and the agricultural industry on the other. The more the latter designs, owns and controls technologies, platforms and data, the greater the risk of current power asymmetries being magnified (HLPE, 2019:83). Questions of data protection, sovereignty and ownership raised in this context are key – both in Europe and in developing countries, where the risk of 'data colonialism' (Couldry and Mejias, 2018) in the agricultural sector is even higher given the weaker or non-existent data protection. When market power is concentrated in the data centres of large corporations, this reinforces the dependency relationships that already exist (HLPE, 2019:82). The key questions revolve around who controls the technology, its design, and access to information (WBGU, 2019b). Also in the agricultural sector, the need to answer these questions inevitably leads to a value-based debate between individualistic and common-good-oriented approaches (HLPE, 2019:83), given the 'proprietary markets' (Staab, 2019) of digital platforms (e.g. Amazon).

State agricultural platform – *quo vadis*?

Two debates are intertwined in the current German discourse on a state agricultural platform: on the one hand, quite recent debates on the role the state should play in actively providing digital infrastructure as part of basic public services, and, on the other, older discussions on the commercial use of shared data spaces. Depending on the field of application, there are tensions here regarding goals, values and functions, as well as the question of achieving the right balance between the common good and particular interests.

In line with the WBGU's plea (2019a, b) for public ICT, the discussion in the current context is whether the state should operate "as a major actor" in initiating and steering the development of digital platforms in order to be able to use platform-based "organizational potential for safeguarding the common good and providing public goods and services" in the interests of more "transparency, openness and cooperation" (ÖFIT, 2020:21). As databases and platforms have been insufficiently interconnected up to now, the Bundestag (2019:3f.) has discussed the "establishment of an agricultural master platform" aimed at "building a 'bridge'" to function "as a data hub and provide services for all farmers" while ensuring "open access and legal certainty for the agriculture of the future in Germany". Climate-change mitigation and environmental protection were initially addressed only on a secondary level and thus optionally – further research and development will be trend-setting in this respect.

In the Fraunhofer Cognitive Agriculture (COGNAC) lead project, cooperative research by eight Fraunhofer institutes aims to design and realize an "integrated platform for information-based agriculture", guided by the goal of "making the numerous stand-alone solutions consistently usable as a whole in order to maximize productivity and sustainability" (IESE, 2019b:4). However, the decisive factor for an assessment is likely to be to what extent the platform is implemented as a basic infrastructure oriented towards sustainability and the common good, and how this can be made innovatively compatible with the industrial origin of the concept without intensifying existing path dependencies. Following the idea of an Industrial Dataspace, which has been pursued since 2014, an 'Agricultural Dataspace' (ADS) – as "the totality of all components of a digital ecosystem that generate, store, manage or consume data" – could enable non-proprietary offers "to be placed in as many digital agriculture markets as possible" while providing non-discriminatory access to all actors and guaranteeing data sovereignty (IESE, 2019a:10). Given the already high concentration in the agricultural sector, depending on how it is implemented, such a platform would be an opportunity to prevent "platform providers from using the data collected to prescribe algorithm-based 'decision-making aids' and product offers to influence what farmers grow, which pesticides and fertilizers they use and what machines they deploy to cultivate their fields" (INKOTA, 2019:4).

Whether this opportunity will be taken when the European platform ecosystem GAIA-X is implemented is still open at present, but it appears questionable in view of initial outlines of the Agri-Gaia component. Although GAIA-X is supposed to be guided by seven principles (European data protection; openness and transparency; authenticity and trust; sovereignty and self-determination; free market access and European value creation; modularity and interoperability; user-friendliness), apart from the field of technical implementation (BMWi, 2020b) only the existing vision of industrial precision agriculture is depicted at actor level (Fig. 3.3-26).

The aim is to create an "AI ecosystem for the SME-oriented agricultural and food industry based on GAIA-X" as a business-to-business platform "which provides industry-specific adapted AI building blocks as easy-to-use modules and brings together users and developers of AI algorithms" and creates a "manufacturer-independent infrastructure for the exchange of data and algorithms" (BMWi, 2020b). Even if the technical principles of the platform were consistently implemented, the question would remain whom and what kind of agriculture they serve. However, this question has not been raised to date in the discourse on implementation, and certainly not in the outline of Agri-Gaia, which is currently still quite vague.

Blockchain in the agricultural sector

The use of blockchain (WBGU, 2019b: Section 3.3.5.5) is also increasingly being discussed in the agricultural sector, for example supposedly to "establish a common view of the respective subject area that is reliable and manipulation-proof" for land registers or supply chains (Rehak, 2018:54). But here, too, the primary challenges lie not only in the application of digital technology, but also in what societal, political and legal preparations need to be made beforehand. Nevertheless, in many cases the emphasis is only on possible application opportunities. The FAO (2019b:7), for example, sees so-called "smart contracts" – i.e. blockchain-based

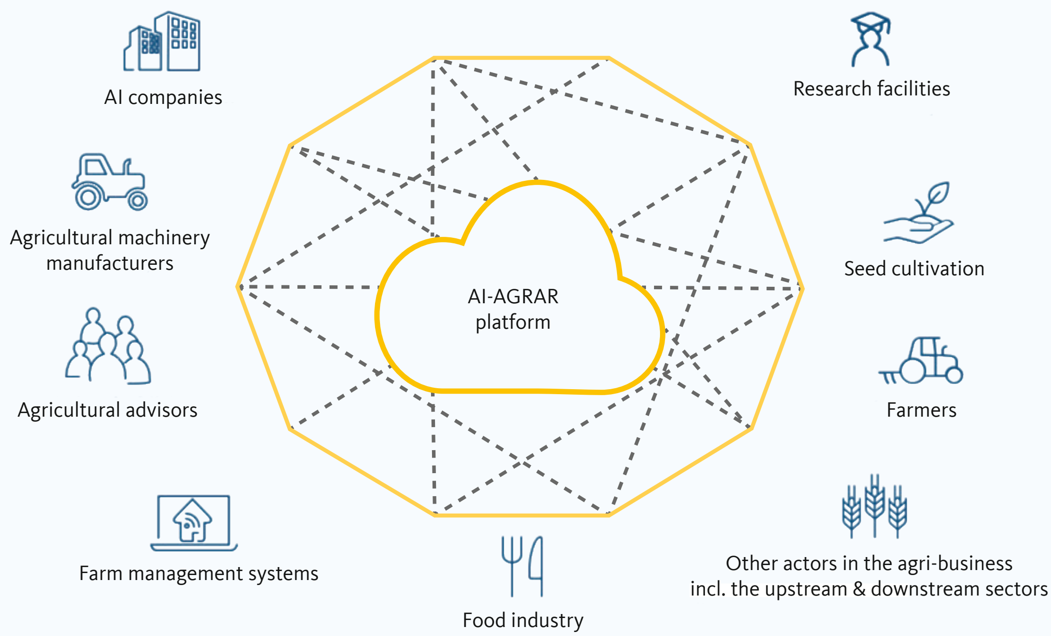


Figure 3.3-26
Structure of 'Agri-Gaia'.
Source: based on BMWi, 2020a

and rule-based self-executing contracts in combination with automated payment – as a "game changer" and as potentially "very effective" in the field of agricultural insurance and supply-chain transparency. However, the necessary input must be provided by data and sensors (e.g. in the event of a flood or drought). To this extent, the considerable need for infrastructure in view of the 'digital divide' represents an initial major challenge. Furthermore, the application example of the land register (GIZ, 2019b) shows that even in the most successful pilot project to date, 'Bitfury' in Georgia, it is not yet possible to deploy the system nationwide. Moreover, the Bitcoin blockchain used there is the most energy-intensive process by comparison (FAO, 2019b:3). Nevertheless, it has become clear that document availability, political will and necessary legal adjustments are key. The latter are preventing the broader scaling of a pilot project in Sweden, for example; and others in Honduras, Ghana and Rwanda have had limited success to date (GIZ, 2019a). Furthermore, addressing decentralization only technically inadequately captures power asymmetries because if the majority of computers involved were controlled by one only person or organization, power would be distributed technically but not factually (Rehak, 2018:57).

Current funding by the German Federal Ministry of Food and Agriculture on digitalization in agriculture
In addition to the already implemented online geodata infrastructure via the Geoportal GDI-BMEL, a remote-sensing programme of the German Federal Ministry of Food and Agriculture (BMEL, 2020c) also aims at more sustainable agricultural production, among other things. Remote sensing is essential for coordinating and implementing the integrated landscape approach advocated in this report to ensure permanent and governance-supporting monitoring (Box 4.1-1). In addition, 14 projects will be funded over the next three years as "digital experimental fields in agriculture" with a total of more than €50 million, which, according to Federal Minister Klöckner, should "also contribute to overall sustainability in environmental protection and nature conservation" (overview at BMEL, 2020d). However, there is no sign of a fundamental paradigm shift in most projects; instead, the primary aims are still efficiency enhancement and intensification. Depending on the reference system and in view of possible rebound effects, such aims do not necessarily promote sustainability. To this extent, on the one hand there is a need for a platform ecosystem for the agricultural sector that can be openly designed beyond existing paradigms; on the other, there is also a need to 'tread new ground' with digital support, e.g. by 'pixel cropping' (Box 3.3-15). There should be further research here with a view to timely scalability, especially under internationally heterogeneous conditions.

Further develop indicator systems and strengthen monitoring

The CAP-related indicator system should be revised and improved on the basis of scientific findings, and oriented towards the SDGs, the CBD and the Paris Agreement. Quantifiable indicators should be at the forefront to ensure that CAP instruments deliver the required results. These impact-oriented indicators are easier to monitor, i.e. need less bureaucracy (e.g. established biodiversity indicators such as the European meadow butterfly indicator, the field-bird index or the High Nature Value Farming indicator can be used; Herzon et al., 2018; van Swaay et al., 2019). At the same time, better monitoring of soil conditions and land-use changes is urgently needed (Dauber et al., 2012; Vlek, 2005). Early-warning systems must ensure that certain threshold values for nutrient imbalances in soils and land use are not exceeded. Digitalization should be deployed for global and comprehensive monitoring (WBGU, 2019b). This includes the development and application of new technologies for remote sensing with a focus on vegetation types and land use, or image recognition and assessment. However, digital tools should also be developed and tested for an *ad hoc* assessment in order to manage ecosystems more sustainably (WBGU, 2019b).

3.3.3.2 Recommendations for action in sub-Saharan Africa and for development cooperation

Channel funds for environmental measures through the Input Subsidy Programmes (ISPs)

Although the African Union's Comprehensive Africa Agriculture Development Programme (CAADP) provides the overarching framework for promoting diversified farming systems in sub-Saharan Africa, it is up to the individual states to implement these systems in practice. Sustainable land management (SLM) is the basis of productivity in diversified farming systems. However, resource-poor smallholders require subsidies to convert and rehabilitate the land. The WBGU recommends that these subsidies be provided by creating a second ISP pillar via the ministries of agriculture (Jayne et al., 2018b). Most sub-Saharan African states need international financing for this purpose from adaptation or environmental funds such as the Global Environmental Facility (GEF), which can cover these additional costs. Successful implementation in practice then requires a coherent approach by the respective agricultural and environmental ministries, because adaptation measures are the responsibility of the environment ministries, while subsidies for inputs are provided by the ministries of agriculture (Section 3.3.1.2). Interlinking the two sets of measures could thus not only save time, as no new funding channel would need to be established, but would also provide an opportunity to coordinate the two types of measures. It is important to make the payments in the form of e-vouchers, rather than in a non-monetary form, so that farmers have some freedom to decide how to spend the money in a way that is in line with their situation (Jayne et al., 2018b).

Supporting additional work to restore soils is a key success factor

In order to successfully finance soil restoration, it is essential to provide financial support to the smallholder farms not only for purchasing materials, such as seeds and equipment, but (also within the framework of cooperatives) to pay for the additional, sometimes extremely hard, work they need to do to restore the soil. Otherwise, the additional effort required, sometimes lasting for years, will be difficult to manage without a 'successful ground response', i.e. if based only on neighbourhood and kinship assistance (Adimassu et al., 2016). This type of payment could also be a cash transfer (with conditions) but bearing in mind the aim of food sovereignty within the next 5–10 years. Smallholder farmers need a lot of staying power, especially when soils are severely degraded and require costly restoration over several years before they finally become productive – and that can take 7–20 years (Schmidt et al., 2017; Bunning et al., 2016).

Shaping benefit-sharing systems between socio-cultural groups is fundamental for success and active peace work

Alongside smallholders, pastoralists are the most important stakeholders in the Sahel countries when it comes to land use. In most countries, they are under even greater land pressure than any other societal group. The development of new benefit-sharing regimes between the different socio-cultural groups – first and foremost arable farmers and pastoralists – could be moderated, for example, by development-cooperation experts, provided they are non-partisan. This would then also represent active peace work. Thus, in addition to village boundaries, migration routes would need to be part of the basis for implementing the landscape approach, and best practices for co-management would need to be jointly developed and contractually agreed with the knowledge and support of local or national authorities.

The WBGU recommends that, wherever possible, livestock farmers should be included in payments for ecological services with the help of a second ISP pillar, so that the customary discrimination against livestock farming compared to arable farming is brought to an end. Subsidizing sustainable pasture management presumably only makes sense if it is accompanied by a reduction in stocking densities (Section 3.3.1.2). At the same time, alternative sources of income for pastoralists would need to be jointly developed, possibly along meat or dairy value chains, so that they can also leave pastoralism. The 'green innovation centres' of German development cooperation could also play a supportive role in this regard (Bunning et al., 2016; Ostrom, 2000;

Shettima and Tar, 2008; Bunning et al., 2016; Wynants et al., 2019).

Provide reliable funding for the transformation of land use, but link it to increasing the absorptive capacity of recipient institutions

The funds pledged by the international community for adaptation to climate change (e.g. the Green Climate Fund) should be made available in full and in a timely manner. In view of the long periods of time soils need to regenerate, the overall costs will certainly be high until such time as yields can be realized again and an overall doubling is achieved. However, increases in funding should be accompanied by a corresponding increase in the absorptive capacity of recipient institutions (IPCC, 2019a). This means impartiality on the part of national experts and decision-makers, the acquisition of know-how, and transparency and/or security against corruption. Before concrete measures are implemented in the individual countries, overall self-responsibility should be strengthened in line with the African Union's master plan 'The Africa We Want' 2063 (African Union Commission, 2020; BMZ, 2020e).

Ending food losses

As discussed in the strategy for sub-Saharan Africa, food losses in the context of grain storage can be almost completely eliminated in a technically simple and inexpensive way (Section 3.3.2.3). The success of these measures could initially buy time until the difficult and time-consuming projects of land restoration, inter-ethnic peace-building and, ultimately, implementation of diversified farming and grazing systems can actually be accomplished.

3.3.3.3
Recommendations for action relating to trade

Boost sustainability in trade through certification

Sustainability in agricultural trade can be promoted by a range of certification programmes under which a product is awarded an eco-label if it exhibits certain certified product or process characteristics. In addition to certification according to environmental or sustainability criteria, protected geographical designations of origin are also an instrument for promoting the local production of sustainable products or certain traditional production methods. However, it must be ensured that sustainability aspects that are adapted to the local environment are taken into account (e.g. 'Dehesa de Extremadura', Box 3.3-5). Regional trade agreements should proactively adopt the development of guidelines for voluntary eco-labelling programmes from the planned Agreement on Climate Change, Trade and Sustainability (ACCTS).

Promote cooperation in supply chains

Approaches to cooperation in the field of supply-chain management should be expanded and fleshed out to promote fairness and sustainability in trade (Zengerling, 2020:37). In addition, resilience can be increased by shortening and unbundling international value chains in the agricultural sector and expanding intraregional trade – especially between African states. The repeated occurrence of acute pandemics and crises (COVID-19, SARS, Ebola, the 2008 food crisis) underlines the added value of more regional and diversified value chains.

Take into account the special role of developing countries

Economic partnership agreements (EPAs) between the EU and ACP countries aim in particular at poverty alleviation and sustainable development and can take into account the special role of developing countries in international trade law. In the context of further developing EPAs or other regional trade agreements, the contracting parties should reassess the possibility of extending protection for setting up and expanding sustainable infant industries or service sectors in developing countries and emerging economies in the face of European competition (Zengerling, 2020:56). Furthermore, when extending certification programmes, care should always be taken to design the programmes in such a way that not only sustainability criteria are followed, but that producers in developing countries also really benefit from participation via higher producer prices.

Strengthen resilience in agricultural trade

Resilience in agricultural trade can be increased by improving food security – especially in sub-Saharan Africa – via rising agricultural productivity, and by reducing dependence on imports. Furthermore, any expansion of aid-for-trade measures should specifically promote the establishment and expansion of sustainable production, service and consumption patterns in developing countries, leading to higher incomes from agricultural exports or – even better – processed agricultural products. Aid-for-trade funds should only flow into sustainable products or promote a sector transformation towards a sustainable economy (Zengerling, 2020:57). Where appropriate, the contracting parties could set up a new EPA fund to support, for example, the conservation of protected areas and sustainable forestry.

3.3.4
Research recommendations

3.3.4.1
Research recommendations for the EU

Promote research into the details of the CAP reform

Systems of output, impact and result indicators should be developed as a basis for the new CAP agenda. Although such information is much more complex to gather, it actually enables the achievement of biodiversity targets (Lakner, 2020). One way of promoting the conservation or restoration of biodiversity is to grant a public goods bonus (Section 3.3.3.1). However, clarification is still needed on some details, e.g. the specific list of measures, as well as on weighting, evaluation and monitoring (DVL, 2020). In addition, there are a number of alternative proposals that need to be subjected to comparative analysis (Section 3.3.2.2). The extent to which elements of the Dutch system of collective contractual nature conservation can also be applied in Germany and other EU countries should be examined.

Step up research on agroecological approaches and practices

Research and innovation policy should concentrate on developing agroecological approaches and agricultural production systems, not only on comparing and assessing them (Lampkin et al., 2015). What contribution do ecologically intensive approaches make to climate, biodiversity and water protection? What impact do agroecological approaches have on productivity? How can trade-offs with regard to productivity and environmental protection be minimized? How can acceptance of these approaches be increased among farmers and how can their broad impact be improved? Are there innovative incentive mechanisms for the adoption of diverse agroecological approaches and practices? What are the institutional requirements for collectively organized agroenvironmental protection and climate-change mitigation? How do diversified production systems affect food security and sovereignty in different countries in the short, medium and long term (Wanger et al., 2020)?

Initiate new methods, approaches and models for the agricultural sector

Today's change processes in the agricultural sector are complex, insufficiently interlinked and poorly understood. However, they affect important issues of inclusion, *Eigenart* and, ultimately, natural resources. Multi-agent models are proposed as a modelling framework; they make it possible to depict interactions between actors and their environment (Kirschke et al., 2007). Experiments and more comprehensive models, including agent-based models, can contribute towards understanding the causal effects of land-use changes (Dauber et al., 2012; Wanger et al., 2020). Spatial- and landscape-planning methods can be used to better understand the relationships between changes in biodiversity and economic values. Big Data can be generated via global research networks and the integration of different data sets (Wanger et al., 2020). In addition, research must be geared more towards citizens' needs (keyword: citizen science); transformation research that relies on, for example, real-world laboratories, living labs or experiments is an aspect of citizen science and should be encouraged (Frigerio et al., 2018; Bonn et al., 2016).

Use digitalization for sustainability

Digitalization has great potential, e.g. for promoting sustainability in land stewardship via precision agriculture (WBGU, 2019b:193ff.). However, innovations and technical improvements are needed to promote this potential. For example, smart machines should be developed that are adapted to field sizes or diversified production systems (WBGU, 2019b:195). Another research task would be to make available digitalized systems that are small and inexpensive enough to be used by resource-poor smallholders. It would have to be ensured that these innovations are oriented geared towards a circular economy and serve sustainability. The extent to which digitalization opens up new avenues for global and comprehensive monitoring should also be explored. New technologies for remote sensing with a focus on vegetation types and land use, or image recognition and assessment, should be developed and applied. Digital tools for *ad hoc* assessment and sustainable ecosystem management should also be developed (WBGU, 2019b).

3.3.4.2
Research recommendations on land use in sub-Saharan Africa

At the international level, there is a great wealth of research on sustainable land-use management (SLM), and the number of publications on land degradation, restoration, and sustainable land-management practices has increased exponentially since 2013 (Liniger et al., 2017; ICRISAT, 2020; Xie et al., 2020). Alongside the USA and China, Germany is one of the strongest players worldwide in this field (Xie et al., 2020), whereby research projects have become increasingly interdisciplinary in orientation in recent years, starting from projects dominated by the natural sciences. However, research activities in developed countries and emerging economies have hitherto strongly dominated those in developing countries (Xie et al., 2020). In order to also empower young academics in African countries, promoting the education of people in developing countries is at the heart of the research funding of the German Federal Ministry of Education and Research (BMBF, 2018, 2020b). For example, over the past ten years, the Ministry has co-funded two centres of excellence to support scientific research on land-use issues in sub-Saharan Africa, contributing to the doctoral studies of nearly 200 students (BMBF, 2018).

Include African practitioners and development cooperation in research projects

In addition to the including local academic potential, it would be equally important – as agroecological innovations show – to incorporate the experience of local practitioners and, together with them, identify research problems and develop solutions. Corresponding projects can also be carried out with the support of the Green Innovation Centres of German development cooperation. There is still potential here for boosting cooperation between researchers and efforts to implement the results (Section 3.3.2.3).

Complementary research on ‚soil memory'

Although SLM measures and effective techniques for soil recovery have evidently been thoroughly studied, there is a lack of understanding of the mechanisms involved in the so-called 'soil memory' (the heterosis effect) and ways of accelerating recovery and returning to earlier yields on degraded soils (Tittonell et al., 2016). Complementary research projects in this regard would therefore be very helpful (Targulian and Bronnikova, 2019).

Research on ecological intensification measures

There are still numerous gaps in research on identifying ecological intensification measures. Of particular interest are measures aiming at higher yields and synergies by designing entire landscapes only with knowledge and an efficient use of natural mechanisms, e.g. ecosystem services in the landscape, or by means of accurate time management, a more efficient use of sunlight, the uptake of nutrients through the roots, or efficient and temporally differentiated water use (Tittonell et al., 2016; Kleijn et al., 2018).

Experimental research into financing mechanisms for sustainable land management

The WBGU recommends focusing research on the financing mechanisms, modalities and channels in sub-Saharan Africa for implementing SLM, as well as on the greening of agricultural production methods. Such research projects can accompany pilot projects, but they can also be conducted on an experimental basis with the aim of determining the most successful formats and channels for funding and what impact the greening programme is having (FAO, 2015).

Determinants of the realization of diversified farming systems

The examples of diversified farming systems described in Section 3.3.2 are not new; many, like agroforestry or conservation agriculture, go back 30 years or more. Despite the numerous advantages of conservation agriculture, for example, and despite external support, their spread in sub-Saharan Africa is slow and not continuous. What, therefore, are the determinants of, or the barriers to implementation? Moreover, research into solution pathways for successful, widespread and sustained implementation would be of great benefit (Dougill et al., 2017).

3.3.4.3
Research recommendations on trade

Improve the methodology of sustainability analyses in agricultural trade

The methodologically not-yet-optimal *ex ante* evaluations of regional trade agreements should be further developed through research on the corresponding modelling methods and on sustainability-impact assessments (Zengerling, 2020:35). *Ex-ante* evaluations of the most important climate-relevant import and export flows at the regional and national level should also be identified (climate-change mitigation and adaptation). This includes identifying regionally important terrestrial ecosystems and economic drivers of land degradation. Also relevant is the development of proposals on what instruments should be used to address these drivers (Zengerling, 2020:36). Furthermore, there is a need to quantify the multiple factors that determine the nutrient flows in the context of trade, their causes and effects, their processes and interlinkages; this is crucial in order to ensure the sustainable use of nutrients and to conserve biodiversity while simultaneously reducing greenhouse-gas emissions.

Improving the effectiveness of certification and designations of origin

Research should be conducted into the extent to which the design and implementation of existing certification programmes and protected designations of origin can be improved to promote sustainability. New programmes should be developed (e.g. climate certificates for agricultural products) where necessary. Furthermore, the extent to which the expansion of supply-chain management can replace certification schemes should be studied. Supply-chain management also needs to be optimized. Laws on supply chains in other countries should be compared juridically, and experience and success with their application should be empirically researched. What standard of due diligence is effective to ensure compliance with human rights and the environmental standards of supplier companies? How can a German company make sure that foreign suppliers comply with the standards?

Strengthen resilience research

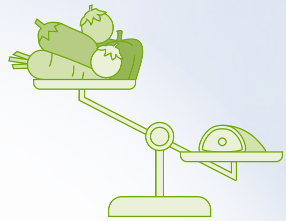
In agricultural trade, not only efficiency aspects need to be considered but also resilience issues. Climate-risk analyses should be promoted to gain a better understanding of the impact of shocks related to climate change, and to be able to take appropriate precautions on behalf of the affected farmers. How will the COVID-19 pandemic and climate change affect global supply chains in the medium and long term (outsourcing versus backsourcing)? To what extent are developing countries affected? What impact will shocks have on food security in developing countries? How can the resilience of the food system be strengthened?

Other animal foodstuffs:
meat, fish, eggs
89 g / day

Sample daily intake
per person in grams

250 g / day
Dairy products

985 g / day
Plant-based foods:
vegetables, grains, fruits,
nuts, vegetable fats, sugar



Vegetables have a much lower environmental impact than **animal products,** especially meat.

The **Planetary Health Diet** with vegetables, grains, fruits and nuts as its main ingredients offers a practical framework for sustainable dietary habits.

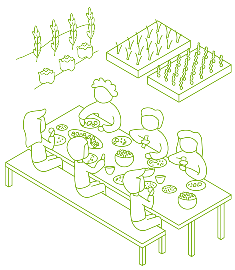
LEGEND

Trilemma

Multiple-benefit strategies

Governance

3.4
Drive forward the transformation of animal-product-heavy dietary habits in industrialized countries



The global food system threatens all three dimensions of the trilemma: above all, in industrialized countries and among the growing middle classes in developing countries, dietary habits that are heavy in animal products are exacerbating land-related problems connected to climate-change mitigation, biodiversity conservation and food security. A change in values away from factory farming and towards lower meat consumption has already begun in Europe. This incipient transformation can be given a decisive boost by resolutely changing framework conditions and setting new standards.

The food system, which encompasses all activities from food production to consumption, is one of the main drivers of the land-use trilemma (Section 2.2): because of industrial production practices, the food system has a negative impact on the environment through pollution and the consumption of natural resources (water, forests, soil, biodiversity); it also exacerbates climate change. It drives the loss of biodiversity (e.g. affecting the global nitrogen and phosphorus cycles) and simultaneously causes nutritional deficiencies, which, almost paradoxically, manifest themselves on the one hand in undernutrition for more than 690 million people and, on the other, in massive overnutrition for more than 1.9 billion people (WHO, 2020; Welthungerhilfe, 2019). The EAT-Lancet report (Willett et al., 2019) identifies these deficiencies and calls the associated dietary habits 'lose-lose-diets' because of their environmental and health-related shortcomings. With reference to the trilemma dimensions described above (Section 2.2), it would be more appropriate to speak of 'lose-lose-lose' dietary habits, since biodiversity, climate and food security are all threatened. The WBGU supports the call made in relevant reports (Willett et al., 2019; FOLU, 2019) to align global nutrition with the proposed Planetary Health Diet (PHD). Recent global assessment reports (e.g. FOLU, 2019: 69f.; IPCC, 2019b) cite a "lack of awareness" among consumers as an important barrier to food-system transformation. This refers to barriers that seem to be created by the consumers themselves, e.g. laziness, non-sustainable cultural preferences, or a lack of willingness to pay higher prices. It is therefore necessary to systematically examine the socio-cultural factors of this actor group's consumption patterns, their potential and contextual constraints (such as supply, pricing). On the one hand, consumers, especially in industrialized countries and the growing middle classes in developing countries and emerging economies, have great potential to advance the transformation of the food system, as is shown in some trends and niche activities. On the other hand, contextual conditions are powerful and hitherto not very beneficial, so that sustainable dietary habits (especially reducing consumption of animal products) are not given sufficient support. From a normative perspective (normative compass, WBGU, 2016a, 2019b; Box 2.3-1), two aspects are of particular importance. First, the transformation of dietary habits must begin in the industrialized countries, since western consumption patterns, which have already spread widely all over the globe, now threaten the natural life-support systems of the global population and will continue to do so in the future (compass dimension of 'inclusion'). Second, when shaping the transformation of dietary habits, it must be taken into account that dietary habits are cultural in origin and help to form people's identity (compass dimension of '*Eigenart*', which also takes the plurality of transformation paths into account).

In view of these considerations, the WBGU recommends creating corresponding (new) governmental and structural framework conditions in the industrialized countries in the short term, conditions which not only allow but also encourage consumers (for instance through new guidelines) to adopt win-win-win dietary habits that create space for successful climate-change mitigation and biodiversity conservation by freeing up areas of land without threatening food security. This idea can link up with trends and niche activities (Section 4.1; WBGU's understanding of transformation; WBGU, 2011).

3.4.1
Statement of the problem: the global food system

3.4.1.1
Definition and development of the food system

The food system comprises the totality of activities from the production to the consumption of food. This includes the services from upstream and downstream sectors of agriculture, as well as the environmental, societal and economic impacts of these activities (Gõmez et al., 2011). The climate and biodiversity crises (Section 2.2) are either greatly influenced by the food system or influence the system themselves (Ingram,

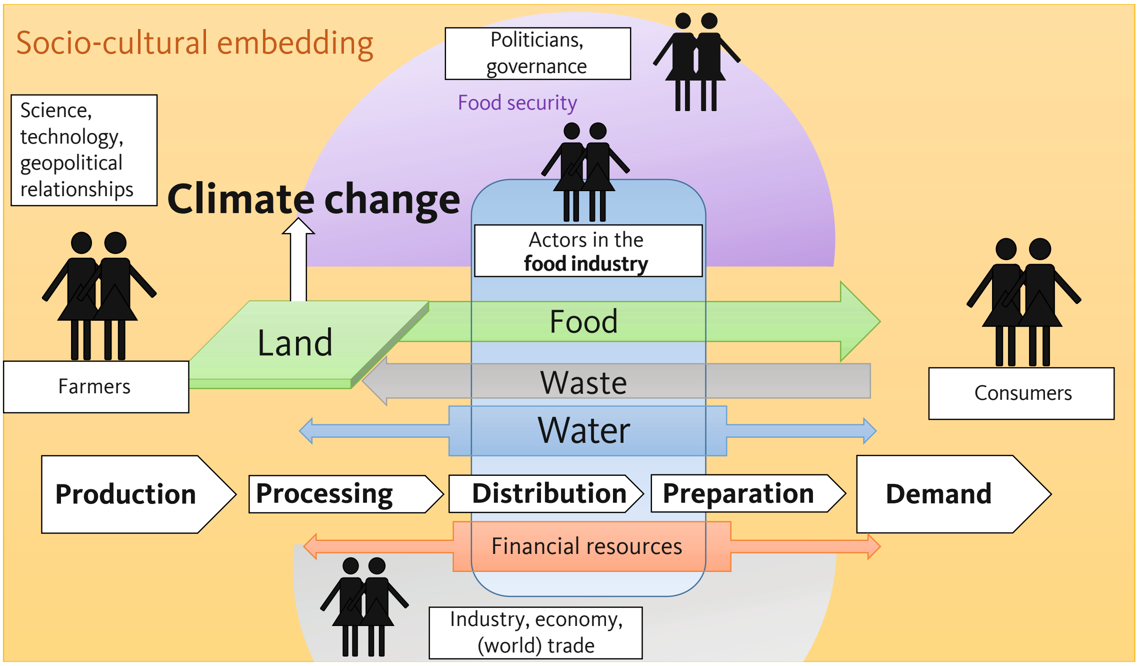


Figure 3.4-1
Schematic diagram of the food system.
Source: WBGU based on GOS, 2011, and Willet et al., 2019

2011). For example, global warming, water pollution, biodiversity loss (e.g. genetic diversity) and ongoing land degradation are becoming an ever-increasing risk to food-system resilience and to current and future food security (Schrode et al., 2019; Willet et al., 2019).

The activities of the food system can be assigned to individual stages of the value chains (Fig. 3.4-1). Land, labour and capital help produce products (e.g. grain, sugar and meat) in agriculture. These products reach consumers in a processed form via the processing industry and the retail trade. Processing and consumption generate waste products that can either pollute the environment or be recycled (e.g. by composting or use in biogas plants).

Historically, the food system in industrialized countries evolved from subsistence agriculture to the production of surpluses, which were initially sold regionally at weekly markets. Initially, only spices, coffee, tea, tobacco and sugar were traded internationally (Kriedte, 1994). Rising agricultural productivity, combined with new preservation methods and storage facilities, ultimately encouraged the mass production and processing of food and international trade. For example, the trade in agricultural products has boomed in recent decades (FAO, 2018h).

Since the 1950s, supermarkets with a growing range of products have increasingly become established in industrialized countries like Germany; their parent companies have concentrated over time, so that most of them now have strong transnational and international links. In developing countries, especially sub-Saharan Africa, there is talk of the supermarket revolution that has only just begun (Reardon et al., 2003). International environmental and food-safety standards and certification programmes are developed and implemented to ensure food safety along the value chains. In particular, these lay down private standards for food-quality characteristics, also in developing countries (Karki et al., 2016a). These standards often prevent smallholder farms from accessing markets, as they lack the financial resources for the investments needed to meet higher standards. At the same time, traditional outdoor markets are gradually being abolished. Producers that are vertically integrated into the new, more concentrated supply chains, e.g. via contract farming, often benefit, although intensified production systems have also contributed to environmental problems in some regions (Qaim, 2017). On the consumption side, the possible contribution to food security as a result of intensified production systems is emphasized, but there is also criticism of insufficient dietary diversity (Qaim, 2017). Moreover, it has been pointed out that the supermarket revolution, with its growing role in semi-prepared or ready-to-eat foods, may contribute to overweight and obesity (Qaim, 2017).

However, empirical evidence is still scarce in this area (Qaim, 2017; Gómez et al., 2011). Since the 1990s, the debate on the food system has broadened to include

Table 3.4-1
Deviation from target values in Germany.
Sources: DGE, 2015; Willet et al., 2019; Schrode et al., 2019; Sachs et al., 2018

Category	Actual value	Recommended target value	Reference
Health-promoting levels of fruit and vegetable consumption	259 g per capita per day	400 g per capita per day	DGE, 2015
		500 g per capita per day	Willet et al., 2019
Meat consumption	600 g per capita per week (women) or 1,000 g per capita per week (men)	300–600 g per capita per week	DGE, 2015
		300 g per capita per week	Willet et al., 2019
Obesity prevention (BMI ≥30)	22.3% of the adult population	≤10% of the adult population	Schrode et al., 2019 Sachs et al., 2018

consumption as well as production. Accordingly, the English-language literature has coined the term 'food and nutrition system' (Burchi et al., 2011) alongside 'food and nutrition security' (FAO, 1996b). In addition to ensuring availability, access and stability, the use of appropriate foodstuffs also plays a key role in food security. Food sovereignty is also increasingly seen as a condition of food security (Edelman, 2014). Food sovereignty is first and foremost the right of consumers to healthy food. Such foods reflect cultural diversity and are produced using sustainable methods. Food sovereignty promotes the right of consumers to control their food and nutrition (Nyéléni Declaration; La Via Campesina, 2007).

The new understanding of the food system thus not only involves the quality aspect, but also emphasizes consumers as key actors: "A resilient food and nutrition system involves people, as consumers, as the central focus" (Burchi et al., 2011). However, such a food system can only be created in combination with the sustainable management of agricultural production systems, a health-oriented food industry and corresponding consumption. It thus becomes a dynamic system characterized by diverse food chains, cycles, networks and contexts. This system consists of activities and processes that transform raw materials into foodstuffs and nutrients into health. Moreover, they are embedded in biophysical and socio-cultural contexts; the biophysical variables comprise climate, soil, water and biodiversity, while the socio-cultural factors include cultural values and traditions, knowledge and experience, and scientific findings, but also political and economic aspects such as geopolitical relations and markets or capital (Burchi et al., 2011).

3.4.1.2
Effects of the food system

The food system is responsible for massive breachings of the planetary guard rails relating to the nitrogen and phosphorus cycles, biodiversity, land-use changes and the climate (Meier, 2017; Willett et al., 2019). The current food system has met few, if any of the key sustainability targets, especially in the fields of the environment, animal welfare and health (Schrode et al., 2019). In Germany, for example, current figures on the 'protection of human health' deviate considerably from the target values (Tab. 3.4-1).

The current food system also has a negative impact on all three dimensions of the WBGU's normative compass (2016a, 2019b; Box 2.3-1). The compass dimension of 'sustaining the natural life-support systems' is threatened by a significant breaching of planetary guard rails (Chapter 2). Nevertheless, some 690 million people worldwide currently suffer from hunger and undernutrition (Willett et al., 2019; Section 3.3.1.2; Box 3.4-1), while a further 1.3 billion people are affected by malnutrition caused by micronutrient deficiencies ('hidden hunger'; FAO, 2019d).

At the same time, overweight and obesity constitute the second global malnutrition problem (Box 3.4-4). Both types of malnutrition – overweight/obesity and hunger/undernutrition – drive up the costs of human health. In addition, education and economic productivity are also severely affected by malnutrition. It is estimated that in Ecuador and Mexico, for example, the combined impact of the double burden of malnutrition causes a net loss in gross domestic product of 4.3% (overnutrition) and 2.3% (undernutrition) per year (ECLAC and WFP, 2017).

Furthermore, rationalization, specialization and concentration processes lead to an unsustainable development in the food system (Schrode et al., 2019). As a result, a large proportion of humanity does not have adequate access to a wide enough range of foods to pro-

Box 3.4-1

Indigenous peoples and dietary diversity

Indigenous Peoples and Local Communities (IPLCs) and ethnic or religious minorities are very frequently among the undernourished groups, having lost their access to land and traditional food sources. Indigenous peoples' territories cover approximately 22% of the world's surface area and contain a significant proportion of its biodiversity (ECLAC and WFP, 2017; Section 3.2.3.5). Traditional food systems of indigenous peoples often include the production of diverse crops with sustainable traditional agricultural practices that promote diversified land use without destroying the ecosystems, thus supporting adaptation to climate change. At the same time, they promote dietary diversity, as many of the neglected and underutilized species they cultivate are very rich in micronutrients and are functional foods (e.g. marula, which is native to southern and eastern Africa, is very rich in vitamin C). Indigenous peoples complement their wide range of foods with products that stem from forests and fishery and are thus adapted to the local environment (ECLAC and WFP, 2017: 100).

vide a balanced and healthy diet (FAO, 2019c; Willett et al., 2019). The current food system is able to provide more and more people with abundant quantities of affordable and safe foods. However, these are average calculations that do not adequately reflect the dimensions of food security (availability, access, food use and stability) described at the outset (Pingali, 2015; Krause et al., 2019).

3.4.1.3 Dietary habits

Culturally and regionally different dietary habits, also referred to as 'personal food systems' (Shepherd and Raats, 2006), develop within the food system. The EAT-Lancet report (Willett et al., 2019) refers to the current, dominant dietary habits as 'lose-lose' dietary habits because they meet neither health nor sustainability targets. Such diets are primarily characterized by a high caloric value, added sugar and salt, saturated fats, highly processed food with low fibre content, and the consumption of red meat (Willett et al., 2019; FOLU, 2019). Since these dietary habits, as part of the food system, not only threaten the climate and food security, but furthermore contribute indirectly to biodiversity loss, they could, in the WBGU's view, even be described as 'lose-lose-lose' dietary habits.

Via trade, the food system influences the quantity, quality, and therefore the availability and a stable supply of food (Walls et al., 2019). Dietary diversity, which is considered essential for human health, can of course be promoted and thus make a significant contribution to the compass dimension of *Eigenart* (Remans et al., 2014). At the same time, however, commercial enterprises promote dependence on food imports and the 'westernization' of dietary habits based on animal products and highly processed foods that are often rich in fat, sugar and salt. The term 'nutrition transition' (Popkin and Gordon-Larsen, 2004) is also used in this context. For example, it has been calculated that increasing prevalence rates of obesity among women in Mexico can be attributed to rising imports of food from the United States between 1988 and 2012 (Giuntella et al., 2020). Not only trade policies, but also increased foreign direct investment (FDI) in the food system, some of which is promoted under regional trade agreements, have an impact on the quality of food and thus on the population's health. For example, it has been found that FDI has led to increased consumption of sugary drinks (Baker et al., 2016). As the WBGU (2016a: 90f.) has argued, dietary habits in developing countries and emerging economies are changing primarily due to "easier access to ready-made high-calorie food ... [and] the effect of targeted marketing for highly processed products". Furthermore, a primary role is played by the social (also symbolic) significance of certain unsustainable consumption patterns that are associated with modernity and status (Hawkes, 2007). This counteracts an understanding of socio-cultural and spatial diversity.

The development of animal-product consumption

While the world population has doubled over the past 50 years, global meat production has tripled (Heinrich Böll Foundation, 2019b). It can be assumed that the demand for food will continue to accelerate in the future due to rising incomes and the associated purchasing power. From 2006 to 2050, this increase is expected to be around 70% (FAO, 2009), and as high as 85% for meat (Heinrich Böll Foundation, 2019b). However, consumption differs from one region to another (Fig. 3.4-2). In 2017, meat consumption was around 15 kg per person per year in countries such as India and some African states like Sierra Leone, Nigeria, Ethiopia, Uganda, Tanzania and Mozambique. This relatively low per-capita consumption can be explained on the one hand by the predominant vegetarian food culture in India, but it is also related to poverty and food insecurity in African states. In most industrialized countries (Fig. 3.4-2), meat consumption is well above the climate-compatible level. In the USA, for example, it aver-

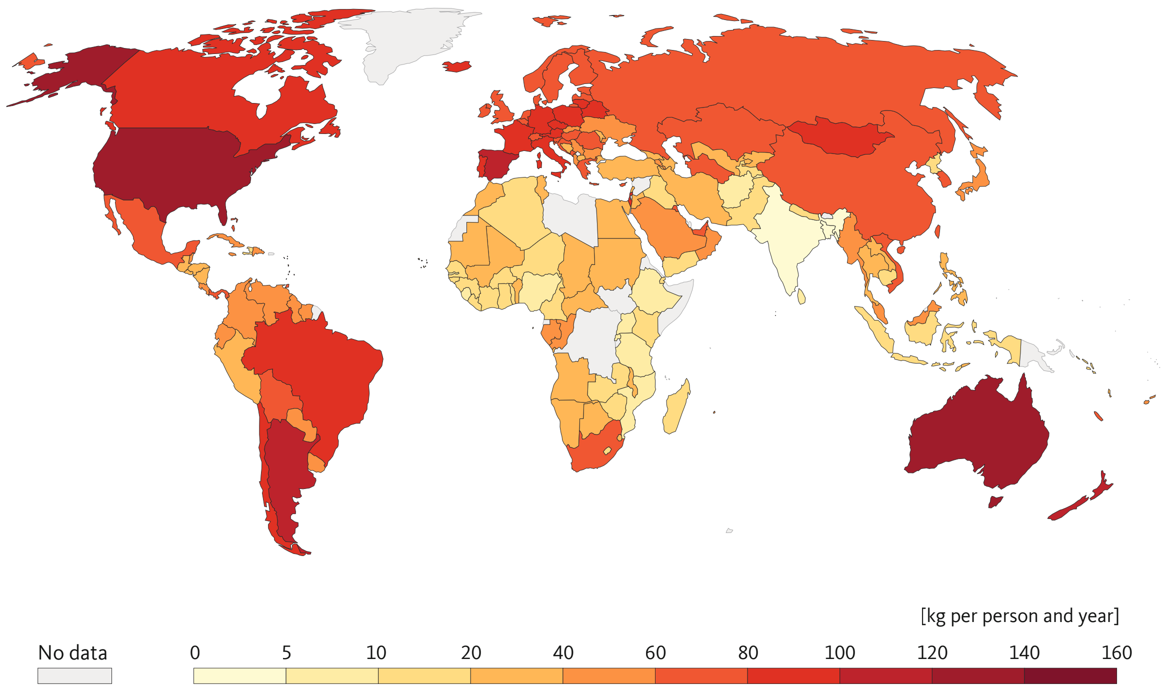


Figure 3.4-2
Global provision of meat in kg per person per year (2017).
Source: Our World in Data, 2019

ages over 140 kg of meat per person per year.

It is estimated that, compared to the last decade, around 200 million tonnes more meat and one billion tonnes more cereals will need to be produced every year by 2050 to meet future demand (FAO, 2009). The demand for animal products will increase not only in the industrialized countries, but also and especially in the emerging economies and developing countries, since an up-and-coming middle class is simultaneously driving up the demand for animal products there. Thus, the animal-product-heavy dietary habits of the industrialized nations are becoming more and more widespread in emerging economies and developing countries. This trend is being reinforced by growing affluence there, coupled with low food prices (Graham and Abrahamse, 2017; Steinfeld et al., 2006).

Effects of meat consumption

Animal husbandry has been a traditional element of agriculture worldwide for thousands of years. In integrated systems, there are synergies between crops and livestock, where manure is used as fertilizer to improve soil structure and as a source of fuel (IAASTD, 2009: 176). A large proportion of the pastureland used today is unsuitable for any other agricultural use than extensive grazing, especially in arid regions ('absolute grassland'; IAASTD, 2009: 37). Pasture-raised animal products are an important part of the local diet in these regions. However, only half of the land used globally as pasture (about 26% of the Earth's ice-free surface) consists of natural grassland; the other half has been converted from forests (IAASTD, 2009). From a global perspective, the share of livestock products from pastureland is negligible: about 72% (Greenpeace, 2019) of animal products in Europe and about 99% (Anthis, 2019) in the US currently stem from industrial factory farming. This form of meat production has led to a decoupling of crop cultivation from animal husbandry, with the result that animal feed has to be purchased in large quantities and liquid manure is spread in large concentrations on too small areas of agricultural land (Section 3.3.1.1).

Although total meat production (including grassland use) uses about 77% of global agricultural land, meat consumption supplies only 17% of global calorie needs (Heinrich Böll Foundation, 2019b). This comparatively unfavourable balance is mainly due to losses and inefficiencies in the conversion of feed into animal products (within the animals' bodies) and is repeated when the focus is on proteins, where the average loss rate is 82% (Alexander et al., 2017).

In the context of industrial animal fattening, there are also health risks for humans and animals from the use of growth-enhancing antibiotics and the resistances that develop as a result (multi-resistant germs; Box 3.4-2). To prevent and counteract disease and

Box 3.4-2

Factory farming and COVID-19

In the course of the COVID 19 pandemic, there have been cluster outbreaks of infection in slaughterhouses all over the world, leading to their closure (Terazono and Schipani, 2020). Emerging infectious diseases (EIDs) such as COVID-19 can (1) spread as a result of the working conditions in factory farms, (2) lead to a conflict between animal ethics and economic interests, and (3) are intensified by the way in which farm animals are kept and looked after.

1. The higher infection rates have been linked primarily to socially precarious working conditions, including "people working shoulder-to-shoulder with no [physical] distancing" (Dyal, 2020; Terazono and Schipani, 2020). In addition to outbreaks in German slaughterhouses, there have also been such COVID 19 hotspots in Canada, Spain, Ireland, Brazil, Australia and the USA. Low temperatures, high humidity and extensive ventilation systems in slaughterhouses could be good conditions for viruses to survive and spread. However, current research is insufficient to draw definitive conclusions (Asadi et al., 2020; Dyal, 2020; Beck et al., 2019). Preliminary results show that COVID-19 is also transmitted through the air (Lu et al., 2020). Ventilation systems could, on the one hand, be migration routes for the virus; on the other hand, the constant draughts in buildings could reduce the effectiveness of (social) distancing measures (Asadi et al., 2020). Exhaustion caused by the hard physical work in slaughterhouses reduces people's resistance to viral infections (as in other food industry plants, although the effect is exacerbated here by cool, enclosed spaces). Moreover, foreign workers are often employed who share the same housing units and means of transport in large numbers (Wolf, 2020; Piller and Lising, 2014; Lever and Milbourne, 2015).
2. Furthermore, the COVID-19 pandemic and the socio-political countermeasures are causing disruptions in the food sector's supply chains (Hobbs, 2020). Supply-chain disruptions or abrupt falls in demand can also cause a production bottleneck in the factory-farming system, leading to problems of animal ethics. This is because it means that animals that are not processed or transported have to be destroyed (Le Roy et al., 2005). Here, farm animals are seen as an economic resource, and their health and aspects of animal ethics are hardly a major concern. Their transport is a particular stress factor, e.g. due to heat and their spatial confinement (Minka and Ayo, 2009; Schwartzkopf-Genswein et al., 2012). Stress and physical exhaustion reduce the animals' resistance to pathogens (Espinosa et al., 2020). When a virus or disease occurs in the factory-farming system, in certain cases uninfected animals also have to be destroyed as a preventive measure, and the carcases are not subsequently used. Examples have included foot-and-mouth disease (Haydon et al., 2004; Manning et al., 2005) and BSE (Le Roy et al., 2005). In the latter case, cattle, which are herbivores, were given feed containing animal-product ingredients to increase productivity (BMEL, 2019a).
3. Factory farming provides a new habitat for viruses and potentially contagious parasites that can transmit diseases to human communities (Mennerat et al., 2010). Domesticated animals are carriers of most zoonotic viruses (Johnson et al., 2020) and can spread them to other livestock. Recurrent zoonoses increase the risk of zoonotic-disease transmission at the human-animal interface in factory farms (Johnson et al., 2020; Kilpatrick and Randolph, 2012; Karesh et al., 2012). The close proximity of the farm animals increases the incidence of zoonoses. More frequent transports of animals and animal products increase the likelihood of pathogens being spread (Espinosa et al., 2020). Factory farms in particular are not sufficiently protected from pathogens either at the entrances (e.g. from incoming animals from other breeding farms, hatcheries or livestock markets, and from feed and water deliveries) or at the exits (excreta, animals being transferred to other farms, markets or slaughterhouses) (Schmidinger, 2020). Viruses can also enter the environment via food products or manure – which normally makes a positive contribution to the circular economy (Graham et al., 2008; Leibler et al., 2009). Manure can be another source of infection, especially for wildlife (Schmidinger, 2020). Wildlife farms are especially problematic because, in addition to the problems of husbandry already mentioned, new, unresearched pathogens are introduced via the international trade in wild animals (Karesh and Cook, 2005; Daszak et al., 2000). Preventive antimicrobial and anti-parasitic treatments, e.g. through the widespread use of antibiotics in factory farming, play a crucial role in the development of resistance and newly emerging infectious diseases (Liverani et al., 2013).

The factory-farming system not only exacerbates the risk of EIDs, it has also been criticized for years over a number of health, animal-welfare and environmental issues. Past outbreaks of diseases such as BSE and swine or avian influenza show that the health of factory-farmed animals has an impact on human health. This is compounded by the clearing of rainforests to produce the enormous amounts of feed needed and to keep livestock on this land (Ruiz-Saenz et al., 2019). This forces resident wildlife to adapt to new habitats and leads to more frequent overlaps between humans, livestock and wild animals (Box 3.2-3). The factory-farming system again demonstrates the need for a holistic approach to health in the sense of 'planetary health' (Box 2.2-2), which regards animal, human and ecosystem health as positively interdependent influences. De Boer and van Ittersum (2018) have proposed a three-part circular-economy approach to food production that would be compatible with this: (1) plant-based food should be used exclusively for human consumption; (2) by-products are returned to this production, to processing and to consumption as far as possible through recycling; (3) livestock (not only mammals, but also fish and insects) are kept in order to process the residual by-products and to utilize the ecosystem services, e.g. for the preservation of pasture landscapes and the production of fertilizer.

achieve faster growth, around 131,000 tonnes of antibiotics were used in animals produced for human consumption in 2013 alone (Van Boeckel et al., 2017). This is about twice the amount that humans take themselves (Bbosa and Mwebaza, 2013). In a study carried out in 24 EU states, different types of multi-resistant pathogens or MRSA strains (methicillin-resistant *Staphylococcus aureus*) were found on average in every fourth pig farm (EFSA, 2009). In a subsequent investigation in Germany, MRSA was detected in pigsty dust in around 42% of the pig-breeding herds examined (BfR, 2009). Far lower resistance rates were found in organic broiler and dairy farms compared to conventionally managed farms (BfR et al., 2018). It is estimated that by 2050, approximately 10 million people worldwide will die each year because antibiotics have become ineffective (IACG, 2019). The EU is also aware of this problem. The Farm to Fork strategy proposes a 50% reduction in antimicrobials for livestock and aquaculture (EEAC, 2020).

3.4.1.4
Drivers of the deficiencies of the food system

The non-sustainable development of the food system is reinforced by various drivers. On the production side, this development is driven by agricultural policy and the concentration of power in agribusiness (e.g. CAP; Box 3.3-1); in the food industry and food trade, economic and societal path dependencies play a major role (Schrode et al., 2019). For example, the concentration of power within the food industry and retail sector meant that in 2017 the top ten food manufacturers dominated around 90% and the top four food retail chains around 85% of the total market (Inkota, 2020a, b). Based on this position of power, the private sector exerts more and more influence over consumers by specifically marketing processed foods (FOLU, 2019). Thus, on the one hand, the consumption of processed and highly processed foods is encouraged. On the other hand, incentives are given to buy large quantities of food, for example via discount promotions, which increases waste at the household level.

3.4.2
Transformation of the food system through a transformation of dietary habits

3.4.2.1
Potential on the demand side

In order to be able to transform the food system, global reports have already identified strategies along the entire value chain (from production to demand) that address the major drivers of the current development and can thus contribute to overcoming the problematic situation (Willett et al., 2019; FABLE, 2019). For example, in addition to efforts to decelerate population growth, there are general calls for stronger and coordinated governance between (ocean- and) land-based concerns (Willett et al., 2019), (FABLE, 2019). In addition, numerous strategies are mentioned on the production side of the food system (such as changing agricultural-policy priorities, sustainable intensification, greening of industrial agriculture, and a shift towards the production of high-quality products; Section 3.3). Great potential is also seen on the demand side (Willet et al., 2019; FABLE, 2019; FOLU, 2019). This relates to reducing food losses and waste and to changing dietary habits.

Potential through changes in food losses and waste

A 50% reduction in food losses or food waste along the value chain is considered relevant here (Willett et al., 2019; FABLE, 2019).

Losses that occur within the value chain from post-harvest to the retail trade (without including the latter) are referred to as food losses (Section 3.3). Losses in the retail trade (inclusive), catering and among consumers are referred to as food waste (FAO, 2020k). Reducing food losses and waste is seen as having a lot of potential; it is one of the five key aspects of the EU's Farm to Fork strategy. One aim is to reduce food waste by 50% by 2030 at the consumer and retail level. To this end, the prevention of food losses and waste is to be included, regulations on the best-before dates are to be revised, losses in production are to be examined more closely and avoidance potential researched (EU Commission, 2020d)

The problems involved in losses and waste differ between industrialized and developing countries (Section 3.3.2.3): the problem of losses is primarily a challenge to be solved in developing countries (Section 3.3). Food waste, on the other hand, occurs mainly in industrialized countries, particularly in the restaurant and catering sector and in private households (UN Environment, 2019; Box 3.4-3). The WBGU adds to this view the thought that, for reasons of equity and inclusion, clear priority should be given to minimizing food losses in developing countries (Section 3.3).

However, quantifying food losses and wastage remains a complex and partially unresolved problem (Parfitt et al., 2010). Different methods are used for quantification (e.g. measurement by weight, caloric value, GHG equivalents and lost inputs such as water or nutrients). Moreover, different forms of loss or waste are defined, and the two categories are often mixed (Corrado et al., 2019). In the EAT Lancet report (Willett et

Box 3.4-3

Food waste in private households as a potential field for transformation?

It is thought that in Germany alone about 61% of existing food waste originates in private households (Kranert et al., 2012). In addition to societal influencing factors, certain modes of consumer behaviour and habits are also relevant. These cover, for example, the planning of daily meals and associated food purchases, the actual act of preparation and consumption, and subsequently the storage and handling of leftovers from preparation and food that has passed its best-before date (Schmidt and Matthies, 2018). Measures promoting a reduction in food waste can be taken by teaching people about problems and actions in order to support the goals of sustainable consumption. However, corresponding action does not start at the last step – the disposal of food – but begins with the actual problem: the overconsumption of food. This occurs during purchasing, for example because of quantity discounts, planning deficits, predefined package sizes and, above all, because of today's increasingly dominant single-person households, where planning how to deal with leftovers is more difficult than in multi-person households. Thus, it initially sounds like a good idea to primarily target this wasteful overconsumption (also on the part of the producers and sellers). More relevant for sustainability, however, would be a targeted change in dietary habits, which, in addition to promoting eco-sufficiency, should also make informed consumption decisions possible (such as preference for regional and organically produced, seasonal products) (Schmidt and Matthies, 2018).

al., 2019), it becomes clear that no scenario exists that makes a ranking possible within planetary guard rails simply according to food-waste (and food-loss) avoidance in the food system. The current IPCC Special Report on Climate Change and Land Systems (IPCC, 2019a) also highlights the uncertainty of calculations of greenhouse-gas emissions from food waste, and the reported figures are rated as 'low-confidence'. Against this background, the WBGU finds it questionable that leading reports and programmes focus so much – and sometimes exclusively – on preventing food waste (e.g.: FABLE, 2019; WBAE and WBW, 2016). The WBGU regards this focus as problematic, as it remains unclear whether and to what extent the underlying overconsumption and overproduction would actually be changed by a reduction in the waste generated by consumers. Although the issue of waste addresses important aspects of food appreciation, it distracts from other strategies that offer greater and more clearly identifiable potential for defusing the trilemma (Garske et al., 2020).

Potential of changing non-sustainable dietary habits in industrialized countries

Recent reports, e.g. by the EAT-Lancet Commission (Willett et al., 2019), the FOLU Coalition (2019) or the 'From Farm to Fork' strategy (EU Commission, 2020d) address the potential that lies in the currently dominant 'lose-lose-lose' dietary habits. In this context, reducing the amount of animal products consumed is considered to have the greatest transformative potential (Drenckhahn et al., 2020; Röös et al., 2017, 2018); it also exceeds the potential of reduced food waste.

Such a transformation must begin in the industrialized countries, since the high level of meat consumption there deviates most from a climate-compatible level (Section 3.4.1.3). In addition, in developed countries about 20% of the world's population currently consumes about 40% of global food production (FAO, 2020a). It is therefore necessary to strive for changes in dietary habits in industrialized countries and accompany them with a reduction in the consumption of animal products (as is the case in vegan and vegetarian dietary habits; Fig. 3.4-3).

3.4.2.2 Objective: multiple benefits from the transformation of animal-product-heavy dietary habits in industrialized countries

The WBGU adopts the vision of the Planetary Health Diet (PHD) formulated in the EAT Lancet report (Willet et al., 2019) as a target for a multiple-benefit strategy. This healthy reference diet – scaled to the world's population – is consistent with adherence to planetary guard rails. It consists largely of vegetables, fruits, whole grains, pulses, nuts and unsaturated oils, contains a small to moderate amount of fish and poultry, and little or no red meat, processed meat, added sugars, refined grains or starchy vegetables. The PHD differs from the dominant dietary habits of industrialized countries (above all the consumption of red meat; Heinrich Böll Foundation, 2019b), mainly with regard to the main sources of protein, and propagates a considerably lower proportion of animal products but a higher proportion of pulses, for example, as a source of protein (Table 3.4-2).

The WBGU advocates exploring in greater detail the potential for changing dietary habits in industrialized countries, and revealing strategies for promoting the consumption of food with reduced animal-product content. The WBGU sees this as a first and important step towards tackling a long-term Great Transformation of the food system.

The WBGU adopts the call for a change in dietary habits in the industrialized countries and extends this

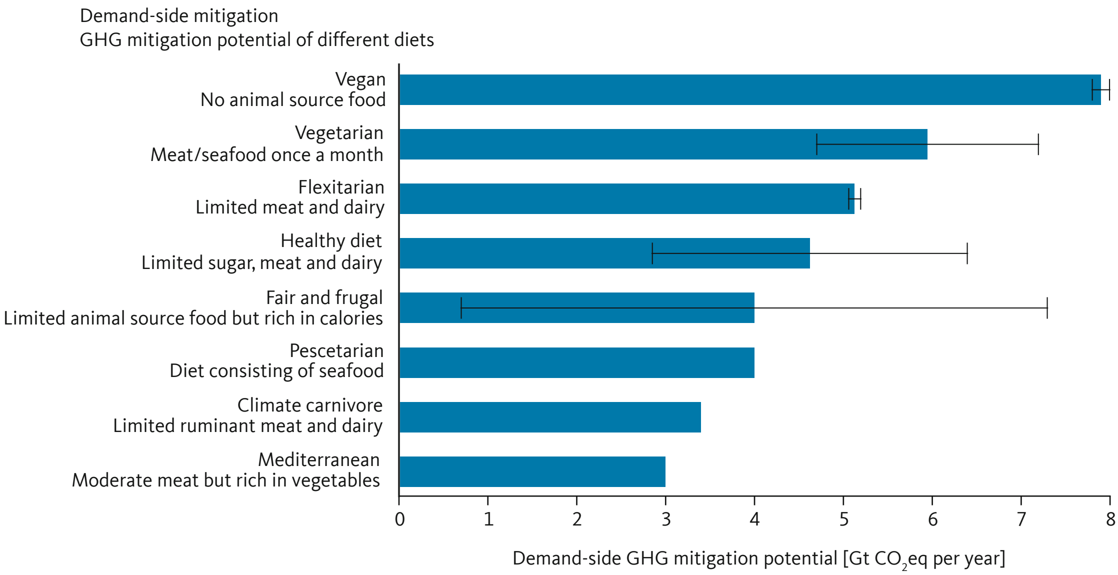


Figure 3.4-3
Potential of different dietary habits for avoiding GHG-emissions.
Source: IPCC, 2019a: 488

view to include a systematic examination of the socio-cultural contexts of consumption patterns. Thus, concrete, modifiable barriers and diverse resources for a successful transformation of dietary habits in industrialized countries can be identified, as well as starting points for implementation (Section 3.4.5).

3.4.3 A question of awareness? The diverse conditions determining how dietary habits develop and change

Recent global analyses (FOLU, 2019; IPCC, 2019b; IPBES, 2019b) cite multiple barriers to food-system transformation. Where these barriers concern consumers, a 'lack of awareness' is frequently mentioned – especially in the case of industrialized countries (FOLU, 2019: 69f.; IPCC, 2019b; IPBES, 2019b). This mindset on the part of consumers includes e.g. laziness, cultural preferences and unwillingness to pay higher prices. A systemic view, however, brings other aspects into focus, and these will be elaborated in the following sub-sections.

Clear trends towards sustainable consumption can already be identified today in the industrialized countries. For example, the demand for organic products and other sustainable alternatives (vegetarianism, veganism) has increased markedly within the EU in recent years (Vou, 2019; Section 3.4.3.4). The incipient change is accompanied and supported by a growing awareness of the production conditions for animal products (e.g. Blanc et al., 2020). In this context, knowledge about the origin of products and their environmental impacts is becoming increasingly available (both today and in the future) thanks to the possibilities opened up by digitalization (Box 3.4-12). The WBGU sees opportunities to link up with these trends and this potential in order to strengthen and expand the transformation that has already begun. The following section begins with a consideration of the global barriers to change (Section 3.4.3.1), the conditions under which individual dietary habits develop (Section 3.4.3.2) and their social embedding (Section 3.4.3.3), and goes on to deal with disruptions and innovations in nutritional biographies (Section 3.4.3.4), focusing in particular on the contextual conditions of food intake (Section 3.4.3.5), which up to now have not been very beneficial. This comprehensive view forms the basis for identifying starting points for strengthening the transformation of dietary habits (Section 3.4.4).

3.4.3.1 Dietary habits and corporate interests viewed globally

Globally, non-sustainable – and usually unhealthy – foodstuffs often become the cheapest option because global supply chains specialize in large quantities of this kind of food (FOLU, 2019). Another system barrier is that the supplier who can process food most cheaply (in mass production) prevails in the market. The quality of the products on offer suffers as a result. Further barriers and path dependencies that have hitherto inhibited

Table 3.4-2
Design of the Planetary Health Diet (PHD) according to Willet et al. (2019).
Source: WBGU based on BZfE, 2020 (©EAT Foundation)

Food group	Recommended amount [g per day] (in brackets: possible ranges)	Calorie intake [kcal per day]
Carbohydrates		
Whole grains	232	811
Starchy vegetables (potatoes, manioc)	50 (0–100)	39
Vegetables	300 (200–600)	78
Fruits	200 (100–300)	126
Protein sources		
Beef, lamb or pork	14 (0–28)	30
Poultry	29 (0–58)	62
Eggs	13 (0–25)	19
Fish	28 (0–100)	40
Pulses	75 (0–100)	284
Nuts	50 (0–75)	291
Dairy products (whole milk or products made from this amount)	250 (0–500)	153
Fats		
Unsaturated fats (olive, rapeseed, sunflower, soybean, peanut, grape-seed oils)	40 (20–80)	354
Saturated fats (palm oil, lard, suet)	11.8 (0–11.8)	96
Added sugar		
All sweeteners	31 (0–31)	120

a transformation of dietary habits cannot be described in general terms, but must be considered in a regionally differentiated manner (FOLU, 2019). In developing countries, additional barriers to a sustainable food system include unfavourable framework conditions, which are reflected above all in unreliable markets and infrastructures, but also an individual lack of educational opportunities, technologies and capacity. In industrialized countries, by contrast, the discussion on causes focuses on inconvenience, a lack of financial incentives in the absence of 'true' prices, a lack of awareness and the low priority assigned to sustainable diets.

Similarly, the cultural embedding of dietary habits is linked to barriers, above all to habits and a person's dietary biography (Section 3.4.3.2), but also to contextual conditions (which are often not focused on sustainability), such as guidelines (dietary guidelines; Section 3.4.3.5), accompanied by incoherent policies, cultural preferences (values, personal and social factors; Section 3.4.3.2) and aspects of affordability (resources; Section 3.4.3.2). When looking at industrialized countries, the market power of the food trade must not be ignored. It impacts both on agricultural producers and directly on consumption. Lobbying exerts direct influence on the context of available food – in most cases in favour of non-sustainable products and production methods (Sections 3.3., 3.4.2; Box 3.4-4). Furthermore, the food industry uses advertising to promote the consumption of unhealthy and unsustainable products. Apart from which, consumers can only consume what is on offer, although they have a certain amount of leeway in this regard depending on their individual purchasing power and access to information. Yet the decisive factors are the product specifications of producers and what is offered in markets and distribution. Adequate and transparent information can increase symmetry.

3.4.3.2 Influences on the development of dietary habits

According to current theories, eating habits are learned primarily via the foods we are offered in infancy and childhood, as well as via corresponding learning pro-

Box 3.4-4

Sugar: Driver of the number-one disease of civilization

Frequent consumption of highly processed foods containing refined sugars can lead to addiction-like health conditions. The habit of preferring high-sugar foods can become established in childhood and then contribute significantly to the development of obesity, now a global disease with dangerous consequences (Ahmed et al., 2013; Filgueiras et al., 2019). Together with other factors, obesity causes an increase in non-communicable diseases (NCDs) such as heart attack, stroke, cancer and diabetes, which are the number one diseases in this category with 16 million premature deaths per year. A sharp increase in obesity rates and NCDs is particularly evident in developing countries and emerging economies, above all in Africa and Asia (Spires et al., 2016; WHO, 2015). In the USA, Latin America and other parts of the world, the problem has been a matter of great concern for some time.

In developing countries and emerging economies, obesity typically occurs in conjunction with the development of a growing middle class and a convergence with the diets of people in industrialized countries. This 'nutrition transition' begins in the cities. Women tend to be particularly affected by the negative consequences – obesity and NCDs (Ntandou et al., 2009; Ziraba et al., 2009). This problem is also referred to as a 'double burden of malnutrition', i.e. the undersupply of micronutrients combined with an increased incidence of obesity and NDCs (Popkin et al., 2020). The direct costs of obesity to the healthcare system are estimated at up to €30 billion per year in Germany alone (Effertz et al., 2016).

A sugar tax could be a suitable instrument for counteracting this development. There is a positive example in Chile, where a tax combined with controls on advertising confectionery products has reduced consumption of these foods, but only among higher income segments of the population (Nakamura et al., 2018). The example of South Africa – where obesity is also a major problem, affecting 68% of women and 31% of men – is assessed more critically. According to the WHO (2016), an estimated 20,000 people between the ages of 30 and 69 die of diabetes each year in South Africa. The South African government therefore imposed a sugar tax in 2018, but its effectiveness has been limited to date. There are several possible reasons for this. First, the tax was set at a very low level (Bosire et al., 2019), so that its incentive effect has been small. At the same time, food companies have nevertheless conducted parallel marketing campaigns for sweet foods (Myers et al., 2017). For example, the sugar lobby claims that the responsibility of sugar for diseases such as obesity and diabetes has not been scientifically proven and has bribed professors to publish forged studies (Nestle, 2016). When the WHO lowered the recommended intake of sugar from free sugars to a maximum of 10% of daily caloric intake in its 2003 guidelines, the US Sugar Association (an influential food lobby group based in Washington, DC) put pressure on the US government to withdraw its financial support for the WHO unless it changed the regulations again (Owens, 2014).

cesses about what foods are safe (i.e. edible; Shepherd and Raats, 2006). As people move into different life stages, especially from adolescence to adulthood, such upheavals are regarded as barrier-lowering events that allow people to reflect on and try out new dietary habits (Astleithner and Brunner, 2007).

Figure 3.4-4 shows the different influences that impact on personal dietary habits. Looking at different cultures, a wide variation of biographically influenced eating habits can be observed, and thus a fundamental variation of what is 'edible'. For example, according to European food culture, insects or the butter tea served as a national drink in Tibet seem quite unpalatable. And even within Europe, frogs' legs, for example, which are treated as a delicacy in France, are viewed in different ways. Food cultures largely follow linguistic and national boundaries. For example, unique food cultures exist in each of the Mediterranean countries (rather than a common Mediterranean food culture) as well as in each of the Nordic countries (rather than a common Nordic food culture; Askegaard and Madsen, 1998; Thøgersen, 2010). Another factor that is relevant for biographical influences is what is regarded as a meal in a particular culture (Eichinger, 2018). In the western world, for example, it is the 'three-component meal', the classical version of which consists of a main dish with meat, a vegetable and a starchy side dish (e.g. potatoes, pasta), plus an optional dessert. Although dietary habits are shaped by socio-culturally embedded customs, they remain dynamic in the course of a lifespan and evolve over time under current influences (Sobal et al., 2006; Fig. 3.4-4). Individuality in a person's dietary habits is primarily determined by the priority given to values or personal factors (Bove et al., 2003) and by the variability with which certain foodstuffs (e.g. insect food) are rejected, often for emotional reasons (Box 3.4-5). By contrast, there are also certain invariant factors; for example, food intolerances (including allergies) can be difficult to overcome.

3.4.3.3 Food intake as a social situation

People also use eating together to regulate and build relationships (contexts and social factors, including meal cultures; Hamburger and Teherani-Krönner, 2014). In addition to the culture of family eating (nutritional biography), for example, different motives come into play in the choice of meals from out-of-home catering in everyday working life (in canteens, college cafeterias, restaurants, etc.). Thus, on the one hand, the need to save money is comparatively relevant when it comes to everyday product purchases such as food

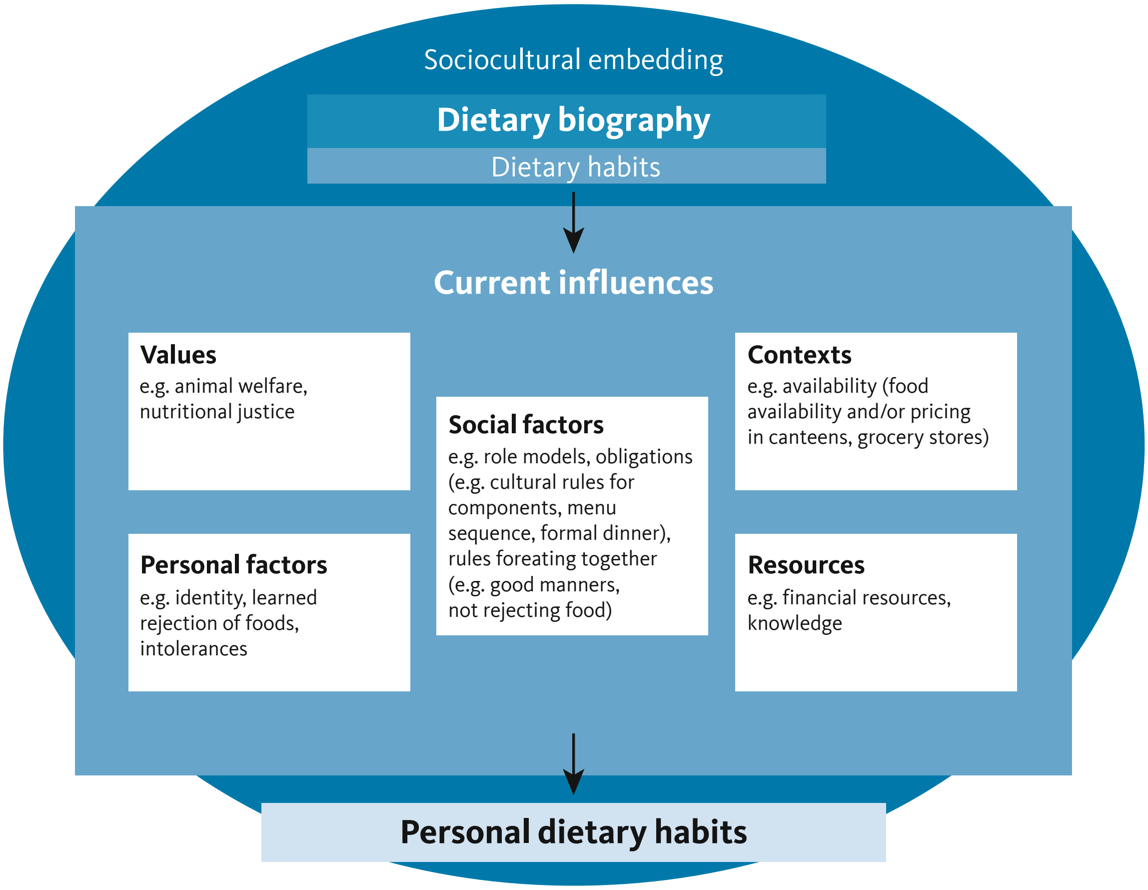


Figure 3.4-4
Model showing influences on personal dietary habits. The nutrition biography describes a person's socio-culturally embedded formation of eating habits during early childhood. Values represent socially appropriate modes of behaviour, but also normatively and culturally learned criteria for decisions, which develop into individual preferences, e.g. sustainable diets, but also ethical components (e.g. animal welfare). These are supplemented by personal factors consisting of physiological, psychological, emotional and relational aspects (components of identity and self-concept). Social factors describe cultural rules, for example. Contexts represent food-intake situations, which are characterized by the range on offer, advertising and food prices. Resources comprise financial means, transport and storage facilities but also knowledge (about the other costs of food, e.g. 'environmental costs'), and social capital (understood as help from others, advice, emotional support).
Source: WBGU, based on the Food Choice Process Model according to Furst et al., 1996

(Struve and Stehr, 2017). In other words, pricing has a considerable impact on meal choices. On the other hand, especially on special occasions such as public holidays, celebrations or publicly hosted meals, societal norms can be activated or shaped. Shared meals should be classified as special social situations whose materiality (e.g. components, compositions, sequences) reflect social relationships such as hierarchy, inclusion and also exclusion (Meyer, 2018). On these occasions, motives of thrift recede into the background, and the social craving for recognition, e.g. the need to show generosity, become more relevant.

3.4.3.4
Breaks in nutrition biographies, changing values in dietary habits

Basically, nutrition biographies are fairly stable; however, this stability can be undermined – for example by societal trends in nutrition. Such breaks in a person's nutrition biography are most common during the adolescent and young-adult phase in the context of identity-formation processes (this applies in particular to vegetarianism, veganism, etc.). Other favourable windows of opportunity are dietary changes after starting a family (e.g. switching to organic food) or due to illness or other so-called 'critical life events' (Jaeger-Erben, 2010). Although the majority of food choices follow a

Box 3.4-5

Integration of new foods: alternative sources of protein

The FAO (2019d) has identified new foods that can replace meat while providing similar protein intake and a consistent taste. Compared to conventional forms of livestock production, the land-use efficiency of insect diets, for example, is much better (Mulia and Doi, 2019). Such diets are already common in Asia, but there are also corresponding offers in Europe – e.g. buffalo worms.

A cross-cultural comparison showed that Chinese test subjects, whose original dietary culture includes insect-based products, rated them higher in terms of taste and nutritional value than German subjects in a comparative sample (Hartmann et al., 2015). It was also shown that a low level of fear of new or unfamiliar foods (food neophobia), positive expectations of the taste of insect-based products, high social-acceptance scores, and prior experience with this kind of diet were significant predictors. Compared to Chinese participants, German participants were more likely to choose insect-based products if they were processed (e.g. biscuits based on cricket flour), but would avoid 'raw' products. The authors conclude that the introduction of insects into Western diets would be particularly successful if they were incorporated into foods that are already familiar (Verbeke, 2015).

biographical and culturally determined framework in which habits and availability play the most important role, alternative diets have been emerging for decades, especially in industrialized countries. One example of an innovative way of eating that has already become an international movement is the Slow Food movement (Altuna et al., 2017). There are also current trends such as paleo or raw-food diets, 'clean eating' or various 'free-from' dietary habits (lactose-free, gluten-free, etc.; Schröder, 2016).

Various forms of vegetarianism or veganism are especially relevant and stable dietary trends from the sustainability perspective. These dietary styles are regarded as examples of 'political consumption' (Oosterveer et al., 2019), in which more profound aspects linked to identity and values become more significant as the basis for the choices made. Vegetarians and vegans overcome certain social norms through their diets and become members of a distinct social group; this leads to the development of a corresponding identity (Rosenfeld and Burrow, 2017; Box 3.4-6).

The number of vegetarians and vegans has grown in Europe in recent years. The percentage of the population espousing such diets varies between 3% and 11% from one European nation to another (Vou, 2019). However, there are not yet any comprehensive studies on the popularity of these lifestyles (EVU, 2020). A similar trend can be observed for other contexts of nutrition, in addition to private dietary habits: the range of vegetarian products available in supermarkets and in the retail sector is growing, so that sales of such products rose by about 30% in Germany between 2017 and 2018 (Czinkota, 2018). According to ProVeg International (2019), the number of vegan cookbooks is also rapidly increasing, and the number of vegan restaurants increased by 5% in 2017 compared to the previous year, and the trend is still upwards. ProVeg International (2019) goes on to describe that vegetarian and vegan meals were among the most frequently adopted trends in communal catering (regular catering for people in businesses, out-of-home markets and healthcare facilities) in 2018. This trend is also reflected in the current nutrition report (BMEL, 2020a). For example, respondents report purchasing vegetarian or vegan alternatives more often (49%). In addition, 55% of the respondents describe themselves as flexitarians, i.e. people who only consume meat occasionally. The example of vegetarianism and veganism shows that niche trends have already developed sufficient innovative power to find their way into broader areas of society, above all into markets. Thus, the number and also the relevance of such change agents is on the increase.

3.4.3.5 Context and resources as possible starting points for changing dietary habits

The model of influences that shape personal dietary habits (Fig. 3.4-4) can reveal areas that are potentially accessible to a societal shaping of dietary habits. Favourable starting points are contexts (e.g. supply, pricing) and resources (e.g. financial resources, knowledge), as they reveal both major deficits and opportunities for intervention.

Contexts: prices and supply

Today, the range of food available is greatly affected by systematically distorted prices. In food production, many environmental costs (externalities; Section 3.4.1) have hitherto been insufficiently priced into certain production methods and products. Existing subsidy systems (in the EU mainly the CAP; Box 3.3-1) contribute to this. In Europe, animal products, for example, can be offered at comparatively low prices. By contrast, sustainably produced foods and certified organic products are much more expensive than conventionally produced products. This is due to higher production costs resulting from higher labour inputs and the non-use of certain pesticides, fertilizers, farming methods, hus-

Box 3.4-6

Integration of vegetarianism and low-animal-product diets in different cultures

A sustainable diet is already an integral element of some cultures. For example, vegetarianism originated both in India and independently in ancient Greek culture (eastern Mediterranean region, southern Italy). It was practised in Europe from the 6th century onwards in the form of certain religious beliefs. The indigenous Tsimané people have also received special attention in the scientific discourse of recent years, as a particularly healthy and simultaneously sustainable lifestyle has been observed there. They have a conspicuously low-fat diet (only 14% of their energy comes from fat, and trans fats are not to be found in their diet at all); their diet has a very high carbohydrate content of 72% (including mostly high-fibre foods such as rice, cassava, nuts and fruit such as plantains) and their protein requirements are met with fish, less frequently with meat (Kaplan et al., 2017).

Historically, the rationale behind vegetarianism in Europe has been based on different approaches. In the early centuries, people abstained from eating meat mainly because philosophical currents valued animal life more highly (Haussleiter, 1935) and in order to support their own asceticism (Lutterbach, 1999). Finally, European vegetarians in the 18th century regarded eating meat as unnatural (Teuteberg, 1994). Veganism, which split from vegetarianism around this time, also contributed to a renewed deepening of the discourse about aspects related to health, animal welfare and also sustainability (Scholz, 2002).

bandry systems and feeds to protect the environment and ensure animal welfare (Section 3.3).

Moreover, the price difference between sustainable and less sustainable products in the retail sector results not only from different production costs, but also from different price mark-ups in the sector. Offers by wholesalers and retailers, canteens and restaurants, too, currently focus mainly on foods heavily based on animal products – although trends show unmistakably that this status quo could soon change. The operators of such companies and establishments and their motivation are caught in a field of tension: they are torn between having to reconcile the (presumed or real) interests of customers, their own pricing policy and other financial factors (preparation and therefore personnel costs).

Resource: knowledge

As long as externalities are not priced in, knowledge about these externalities must be provided. Food labels can play a role here. However, most food purchases follow habits (heuristics of previous purchases) because they are repetitive actions performed in familiar places. These tend to change little, even when consumers themselves report different purchase intentions (Ji and Wood, 2007). The assumption that consumers make rational decisions using all available knowledge is considered outdated in consumer research (e.g. Srnka and Schweitzer, 2000; Achilles, 2020). If consumers are to be empowered to make informed purchasing decisions, it is necessary to take a closer look at the effects of existing knowledge, trust and individual heuristics. Only in transitional phases ('critical life events'; Section 3.4.3.4) is information systematically collected in advance in order to make purchasing decisions (Jaeger-Erben, 2010). Furthermore, due to the broad availability of unhealthy – and in most cases unsustainably produced – food and a lack of qualified knowledge, consumers are often unable to make consumption choices that fit their desired lifestyle. This is systematically exploited by vendors such as supermarkets and food companies, among others, through advertising, product placement and cue stimuli to boost sales of certain products (van Kleef et al., 2005; Just and Gabrielyan, 2018). It is therefore important to give consumers appropriate orientation. This is done to some extent by the state by means of labels, but also with nutritional guidelines. In addition, a wide range of civil-society actors, associations and initiatives provide information on sustainable diets (e.g. EcoYou, Eat Smarter, green food groups, local associations such as Eostre Organics).

However, the information available to date does not solve the problem of the adequate provision of information; rather, information is processed from a specific perspective.

There is currently confusion among consumers in view of the wide range of available labels, especially in the field of sustainability (Gwozdz et al., 2020). Another factor that reinforces this confusion is the plethora of diffuse environmental terms used (such as 'natural' or 'organic'). Studies indicate that consumers regard many of these terms as synonymous or even identical, which makes it more difficult to choose 'truly' sustainable products (Gwozdz et al., 2020).

A project run by the Max Rubner Institute (MRI, 2019) has attempted to make it easier for consumers to make more favourable product choices from a nutritional-physiological point of view. The aim was to develop labelling systems that "give consumers a clear and simple orientation for comparing products within the same product group [...], so that preference can be given to products rated more favourably than to products rated less favourably' (MRI, 2019: 5f.). However,

Box 3.4-7

Example of Germany: DGE guidelines focus on health, not sustainability

The German Nutrition Society (DGE) is the central institution in Germany which, in cooperation with the Federal Ministry of Food, Agriculture and Consumer Protection (BMEL) and the Schule Plus Essen initiative (schuleplusessen.de), lays down nutritional guidelines for day-care centres, schools, commercial canteens and hospitals.

The DEG lists four dimensions relating to sustainability: ecology, society, economy and health. However, each institution is explicitly free to decide "which aspects of sustainability are implemented". Within the guidelines, different aspects are assigned to these dimensions, for example the provision of predominantly 'ovo-lacto-vegetarian menu lines' (ecology), limiting waste to 'unavoidable leftovers' (ecology) or 'preferential selection of products with short transport distances' (economy). However, sustainability in the sense of resolving the trilemma has no influence on DGE certification. In the recommendations across all age groups, higher amounts of both meat and fish and animal products are recommended than those provided for in the PHD, for example.

Different information more relevant for sustainability goals can be found in the 'Quality Management Guidelines for Serving and Preparation Kitchens in All-Day Schools and Day Care Centres', which calls for a menu that is as low in meat content as possible, with vegetables or salad served daily and fruit served two to three times a week; or, for example, in the recommendations of the Research Institute for Child Nutrition.

the target definition used here was based on nutritional physiology; it was not related to sustainability. Developing an equivalent for healthy and sustainable food would be desirable, but it is a formidable challenge. Approaches already exist for meals, such as calculating the CO_2 content (e.g. climatarians), and approaches can also be found for taking other indicators, such as water consumption, into account (Section 3.4.1). However, such values can hardly be calculated for individual foodstuffs, so that a comparison with other products – and a classification of which product is the most sustainable by comparison – does not appear possible at present.

Dietary guidelines as special resources

If entire dietary habits are taken into consideration in addition to specific product purchases, guidelines on nutrition issued by institutions or the state are effective instruments. On the one hand, they make knowledge available; on the other, they convey cultural nutrition norms because they are referred to in a variety of contexts. As such, they are propagated in many ways and used in particular in public institutions and communal catering. These are also places where dietary habits are formed (e.g. schools and day-care centres). Moreover, food is consumed here in a social community, which provides a particularly effective framework for developing norms and corresponding discourses on food cultures.

Historically, the first dietary guideline was probably the recommendation to use lemon juice on sea voyages to curb scurvy (EUFIC, 2009). After World War II, dietary recommendations were published and propagated to encourage an optimum intake of nutrients. An awareness of the overnutrition problem emerged from the 1970s onwards, so that recommendations were revamped accordingly, especially in industrialized countries (Prochazka, 2012). Not until the International Conference on Nutrition in Rome in 1992 was a targeted action plan adopted for providing information on nutrition; this was followed in 1996 by the first FAO and WHO guidelines (FAO and WHO, 1998), which still form the basis for a wide range of nutrition recommendations today. It can be assumed that these nutritional recommendations are reflected in corresponding practices, for example when menus are drawn up in catering facilities. However, little empirical knowledge exists to date about how strong these relationships really are. Up to now, guidelines have focused primarily on the health aspect of nutritional design, while sustainability criteria have been given secondary importance.

Food pyramids are probably the best known form of such guidelines. The first better-known food pyramid was developed by the United States Department of Agriculture (USDA) and has been continuously adapted ever since. The recommendations it contains are not uncontroversial, so that – alongside the USA and the WHO – more than a dozen countries (and corresponding organizations) in Europe alone have published their own versions (EUFIC, 2009).

Furthermore, just over 80 countries have produced a Food Based Dietary Guideline (FBDG; Fischer and Garnett, 2016; Box 3.4-7). A report by Oxford University's Food Climate Research Network draws attention to the fact that a country's national dietary guidelines have great potential for addressing consumption patterns (Jones et al., 2019). It can be assumed that sustainable nutrition guidelines represent an incentive to follow the recommendations precisely because of the currently high level of public interest in the relation between nutrition, the environment and the food system (Springmann et al., 2016). Officially, however, only four countries (Brazil, Germany, Qatar and Sweden) refer to healthy and sustainable diets (Fischer and Gar-

Box 3.4-8

Health and sustainability of national and global dietary guidelines: a sample study

Dietary guidelines not only influence national food choices, they also have significant global implications, especially when consumption patterns are recommended that conflict with the chances of achieving global climate goals (Blackstone et al., 2018; Ritchie et al., 2018; Behrens et al., 2017). However, up to now there has been a lack of systematic analysis into the way international dietary guidelines impact on health and sustainability on the one hand, and how they fit with global policy goals and the establishment of healthy and sustainable diets on the other. Springmann et al (2020) provide such an analysis in the British Medical Journal. For comparison, the authors also analysed the impact of following the WHO's global dietary recommendations and those of the EAT-Lancet Commission PHD.

The study included across-the-board guidelines from 85 countries. The health and environmental impacts of these guidelines were assessed using a comparative risk assessment of deaths from chronic diseases and a number of country-specific ecological footprints (GHG emissions plus the use of freshwater, cropland and fertilizers). The health and sustainability impacts of each guideline were assessed by modelling their adoption at both national and global levels and comparing impacts with global health and environmental goals (including the Noncommunicable Disease Action Plan, the Paris Climate Agreement, the Aichi Biodiversity Targets relating to land use, the Sustainable Development Goals and the planetary guard rails relating to freshwater use and fertilizer application).

Since their establishment, most national guidelines (83 out of 85) have been inconsistent with at least one of the global health and environmental objectives. About a third are incompatible with the NCD Action Plan and most (57 to 74 out of 85) are incompatible with the Paris Climate Agreement and other environmental goals. By comparison, following WHO recommendations would involve similar health and environmental changes, while alignment with the PHD would involve a 34% bigger reduction in premature mortality, a more than three times greater reduction in GHG emissions, and overall achievement of global health and environmental goals.

Providing clearer guidelines on limiting the consumption of animal products, particularly beef and dairy products, was seen as having the greatest potential for increasing the environmental sustainability of dietary guidelines, while increasing consumption of whole grains, fruit and vegetables, nuts, seeds and pulses, reducing consumption of red and processed meats, and emphasizing the importance of balanced energy intake and weight were associated with the most additional health benefits.

nett, 2016). As a result, although sustainability goals are addressed, such guidelines still recommend the consumption of animal products and meat.

To sum up, the formative international guidelines focus primarily on health, hygiene and quality standards, with sustainability-related aspects given secondary importance, if any. The lack of references to sustainability in nutrition guidelines is criticized internationally. For example, New Zealand's Eating and Activity Guidelines have been judged to be non-sustainable, and the inclusion of sustainability features has been firmly supported by agricultural, environmental and health professionals (Jones et al., 2019). Even dietary guidelines with a 'holistic' approach, like those in Sweden or Canada, which were intended to address both health and environmental concerns, prioritize health goals in cases of conflict (i.e. when it seems that both goals cannot be pursued at once; Bergman et al., 2019; Kirkpatrick et al., 2019). However, the FAO's recommendation (2010b) emphasizes: "Food-based dietary guidelines and policies should give due consideration to sustainability when setting goals aimed at healthy nutrition." A recent study (Springmann et al., 2020) has shown that current international guidelines cannot adequately serve either health- or sustainability-related goals – especially not in terms of the necessary lowering of animal-product content (Box 3.4-8). The apparent playing-off of health against sustainability is detrimental to the transformation towards sustainable dietary habits and should, in the WBGU's view, be redirected towards transformative benefits.

Communal catering as a special context

Above all, institutions of communal catering at schools, universities, day-care centres, kindergartens and hospitals are direct addressees of guidelines. Places of communal catering are usually visited weekly, sometimes daily, whereas other places (such as system catering) are used much less frequently (BMEL, 2019b). The reference to guidelines – and thus their potential to shape dietary habits – is particularly relevant here, as kindergarten children, pupils, students, patients and employees usually have few or no alternatives and therefore (have to) choose the food on offer in-house. In addition, there are likely to be at least weak links to the guidelines in other areas of food supply. For example, the assortment of goods in the wholesale and retail food trade will partly follow these guidelines.

3.4.3.6 Conclusion: normative orientation towards sustainability in community catering as a special trigger for transformation

The WBGU identifies, above all, three deficits in the current way dietary habits are shaped by society: (1) a lack of 'true' prices that take environmental externali-

Box 3.4-9

Comparing the public outcry over veggie day with study results

The history of the Veggie Day proposal began as part of the political debate leading up to the 2013 federal election in Germany. It revolved around a recommendation made by the Green party (Bündnis 90/Die Grünen) to introduce a Veggie Day in public canteens to reduce meat consumption in Germany, causing a lively public debate during the election campaign.

In the course of the debate, studies were commissioned by some newspapers to investigate the amount of acceptance for a 'meat-free day in canteen kitchens'. Some of the results seem to contradict the outcry and reported resistance (Table 3.4-3).

Table 3.4-3
Study examples from the 2013 Veggie Day debate.
Sources: FOCUS, 2013; Stern, 2013; ZEIT Online, 2013

Study example	Sample	Result
Emnid, commissioned by FOCUS magazine	n = 1,003 representatively selected German citizens aged 14 and over	53% supported Veggie-Day (72% approval among 14- to 29-year-olds); 44% oppose Veggie-Day, mainly men
Forsa, commissioned by STERN magazine	n = 1,003 representatively selected German citizens, drawn by a computer-controlled random sample	50% approved of Veggie-Day (above-average number of women with 61% and supporters of the Greens with 70%), 48% of all respondents rejected Veggie-Day, especially men (60%) as well as supporters of the CDU/CSU (60%) and FDP (61%)
YouGov, commissioned by the ZEIT newspaper	n = 1,038 participants of the YouGov panel (online survey)	45% would approve of a Veggie Day, 43% rejected such a regulation; here, too, the proposal was supported predominantly by women (57%); support among men was only 33%

ties into account, (2) the absence of a broad range of sustainable products, and especially (3) a lack of normative attractiveness of sustainable diets, since current discourses are dominated by outdated guidelines. These deficits are currently making it difficult to transform dietary habits. Guidelines are currently not exploiting their transformative potential to implement win-win-win dietary habits in communal catering (Section 3.4.2).

Gearing the range of food on offer to the PHD offers a profitable solution. A low-animal-product diet on this basis is not only more cost-effective, it can also be reconciled with a wide range of different nutritional needs. As the 'lowest common denominator', the PHD supports the aim of a sustainable diet that can be applied differently in many cultures. Such an orientation makes sense, especially in places where diversity is both desired and appreciated, as it would not discriminate against or disadvantage anyone. By contrast, offering meals that are primarily based on animal products excludes followers of certain religious communities, as it does people who cannot eat animal products for health reasons (e.g. certain forms of treatment require people to avoid red meat) or because they have an intolerance (e.g. lactose intolerance). The main range of meals on offer in canteens should therefore be oriented towards the PHD and thus be as sustainable and inclusive as possible. Especially in educational institutions such as universities, schools and day-care centres, it is particularly appropriate to also focus on such a culturally diverse and compatible, sustainable diet. A significant reduction in the supply of animal products could recognize and make possible diverse dietary habits (and needs) – establishing them as an inclusive normal case.

3.4.4 Starting points for encouraging the transformation of dietary habits

3.4.4.1 Control coupled with room for manoeuvre so as to respect *Eigenart*

Approaches to controlling the field of nutrition involve entering a sensitive area where value-related topics such as personal health, political convictions and cultural specificities are particularly relevant. The WBGU therefore considers massive interventions, e.g. by issuing bans, to be an inappropriate course of action.

Among animal products, meat, for example, is especially symbolically charged, as it is considered a status symbol in most societies (Westhoek et al., 2011) and can express human superiority (including hierarchical aspects and constructs such as masculinity, strength and power; Çoker and van der Linden, 2020). Exerting direct influence over the consumption of animal products, for example through bans or general restrictions on supply, therefore risks being perceived by citizens as a loss of their freedom, which can lead to resistance to change (reactance theory; Font and Hindley, 2017). The Veggie Day motion tabled in the Bundestag by the German Green party (Bündnis 90/Die Grünen) in 2013 was a prominent example in the German media of resistance to an attempt to curb meat consumption. Fears of patronization were activated in a media-effective way among certain groups of the population, and this was reflected in a corresponding press echo. An interesting observation here is that reactant statements were provoked, even though a large proportion of the population (especially young people and women; Table 3.4-3) would even prefer vegetarian food or a Veggie Day (Box 3.4-9).

The lesson that can be drawn from experience with the Veggie Day motion is that deliberate restrictions of individual dietary habits by regulations are negatively received, especially if they are patronizingly justified, for example, with the aim of protecting consumers' health (Linz, 2017). Such regulations can also conflict with the consideration of diversity, personal rights and *Eigenart*. As outlined by the WBGU's normative compass (Box 2.3-1; WBGU, 2016a, 2019b), *Eigenart* is understood as the appreciation of diversity as a significant resource for the success of the transformation. *Eigenart* explicitly means recognizing difference, i.e. respecting the diversity of cultural expressions (WBGU, 2016a), which can also be found in different dietary habits. Thus, the cultural influence of dietary habits, including, for example, traditional holiday meals characterized by a meat component, celebratory feasts or similar features, should be recognized. *Eigenart* also plays an important role at the individual level. A personal dietary style is strongly related to one's personal identity and characterized by special needs, so that individual decisions and choices are significant in this area. Exerting any influence on dietary habits therefore takes place in an area of tension between the recognition of personal autonomy and cultural diversity on the one hand, and the simultaneous need to lay down a framework in the sense of the common good on the other. It is therefore helpful to have well-founded terms of reference that are explicitly oriented towards sustainability (e.g. clear nutritional guidelines), clear frameworks for the range of food on offer (such as the provision of animal-product-free alternatives) and prices (in the sense of taking externalities into account) without completely eliminating animal products from the menu.

3.4.4.2 Transformation via true prices and sustainable supply

In order to promote a change in dietary habits, the first step is to make sustainable foods both easier to purchase and more readily available, i.e. to target prices and supply. Currently, conventionally produced foods are too cheap, putting sustainably produced food and consumption habits at a disadvantage (Section 3.4.3.5). The effects of this are evident not only in the food trade, but also in the organization of communal catering. For example, managements of student dining halls interviewed in a study (Hachmann et al., 2019) indicated that few active attempts at discounting were currently being undertaken to make animal-product-free or environmentally friendly meals more attractive. However, should costs reverse in the future (in the sense of higher prices for non-sustainable products), individual canteens indicated that they would be prepared to offer correspondingly fewer animal products in order to be able to maintain a fair price structure.

Meat-reduced, vegetarian or vegan dishes should furthermore be made available in sufficient quantities and better positioned in order to prioritize sustainable offers. For example, doubling the proportion of vegetarian meals offered in cafeterias increased vegetarian sales by 41% to 79% (Garnett et al., 2019). In the sense of a 'lowest common denominator' (Section 3.4.3.6), a sustainable range of products should also offer an adequate range for those who cannot switch to other products due to various restrictions in their diet.

3.4.4.3 Multiple nuclei of transformation

In addition to the possibility of transforming contextual conditions, a variety of initiatives already exist (mostly from civil society) that relate food appreciation to sustainable diets and advance both goals (Sections 3.4.3.4, 4.1), e.g. initiatives for individual and collective gardening (e.g. Ackerhelden, Regrowing, Leaf to Root, Microgreens, Indoor Farming). Here, too, the WBGU sees great potential for transformation (Box 3.4-10; WBGU, 2016a: 318f.).

Various studies have mentioned the positive effects of such initiatives. The most relevant effect from a transformative perspective is a growing appreciation of food (Pudel and Westenhöfer, 2003; Artmann and Sartison, 2018), as this can be seen as a first and important step towards a change in dietary habits. It seems reasonable to assume that this appreciation can give rise to an attitude that values food and counteracts food waste and overconsumption. In this sense, the WBGU suspects that such initiatives also have the potential to develop a greater awareness within the community of

Box 3.4-10

Examples of socio-technical innovations that increase appreciation of food

Inhabitants of eco-settlements or eco-villages and members of sustainable communities usually have a more differentiated knowledge of sustainable nutrition. For example, the grass-roots democratic community of the Tempelhof eco-settlement in northern Baden-Württemberg near Kressberg has existed since 2010 on about 30 hectares of village land with 150 inhabitants. It is part of a global network of eco-villages, the Global Ecovillage Network, and there are numerous other villages in Europe alone (Global Ecovillage Network, 2020).

A prominent local example of a successful urban gardening project is the Prinzessinnengärten, founded in Berlin's Kreuzberg district. Since 2009, residents have been transforming a former wasteland into a kitchen garden for urban agriculture. Its special feature is that it acts as a mobile garden. For example, the 'sheds' are made from containers, and the crops are planted in recycled bakery crates, Tetra Packs or rice sacks, so that the garden can be moved at any time. In 2020, parts of the Prinzessinnengärten were thus moved to the St. Jacobi cemetery in Hermannstrasse, Neukölln, while the original gardens at Moritzplatz were being reconstructed (Prinzessinnengarten Kollektiv Berlin, 2020).

Approaches like the IP-Garten tap into the transformative potential in another way that is profitable for the land. The idea is to make cultivation areas in infrastructurally weak regions accessible to the needs of urban dwellers, who, with online support, can provide for themselves through their own gardening (IPGarten, 2020).

Similarly successful are the 'Ackerhelden', a young company from Essen that was founded in 2012 (Ackerhelden, 2020). They offer certified organic and pre-planted areas of land for tenants to plant and harvest, with the aim of "bringing people back closer, both regionally and emotionally, to what they eat every day". A positive role is also played by the social aspect of connecting people of all cultures by working, communicating, relaxing and spending leisure time together.

In addition to the demand side, there are also innovative, sustainable company forms on the production side, such as solidarity farms and organic farms. Another well-known movement in Germany is 'Wir haben es satt!' (We've had enough!), in which farmers, supported by environmental, nature- and animal-protection associations, take a critical stance against the agricultural industry and factory farming. Every year, the movement demonstrates during the Green Week in Berlin (Wir haben es satt!, 2019).

The 'Sounds For Nature – Guide for Sustainable Outdoor Events' offers a positive example of sustainable nutrition guidelines (Behr et al., 2013). This guide follows principles such as using food from organic farming that should be produced and processed nearby ('as close as possible') and contain as few animal products as possible. Depending on the season or availability, organizers should also consider whether conventional but regional products should be given preference over imported organic food. Alcohol, extremely fatty or salty foods, and sweets should be reduced or offered only in small portions.

the environmental costs of products (above all via the CO_2 footprint, but also in relation to biodiversity aspects) and could have an awareness-raising effect (Box 3.4-11). These awareness-raising innovations are framed by other positive effects, such as an increase in knowledge and education (Hutchinson et al., 2015; Savoie-Roskos et al., 2017), an increase in the quality of life (Adevi and Mårtensson, 2013; Egli et al., 2016; Soga et al., 2017; van Lier et al., 2017; Artmann and Sartison, 2018) and a positive impact for biodiversity conservation in urban areas (Isaac et al., 2018; Palliwoda et al., 2017).

3.4.4.4 Transformation potential from strengthening knowledge resources (labels and guidelines)

In addition to initiatives that drive transformations forward, the WBGU focuses on strategies that convey knowledge for orientation, i.e. that link up with personal resources for a healthy and sustainable diet. Two effective sets of instruments are available for this purpose: comprehensive product information suitable for consumers and nutrition guidelines (Section 3.4.3.5). Nutrition guidelines have a special position in this context, as they fulfil a normative function and provide information on which diets are 'desirable' for society as a whole, i.e. which make sense in view of their impacts. On the one hand, their orientation towards sustainability makes it possible to directly influence dietary habits, for example when the guidelines are discussed in educational institutions. On the other hand, they can have a normative effect in communal catering, i.e. provide orientation.

In addition, knowledge transfer at product level is equally relevant. However, the use of product labels only makes sense if they can be properly understood by consumers. Labels play a key role here in taking into account and integrating different information needs – but greatly risk being misunderstood and leading to wrong decisions. For example, product labels can hardly be used to provide adequate orientation for a person who needs information aimed at protecting the climate and biodiversity, nor can a label at the product level address overconsumption. Here, the WBGU sees a need for research into an appropriate form of information transfer on the diverse environmental and health impacts in the area of food consumption, so that in future the transformation potential inherent in consciously solidarity-based consumption (Section 4.1) can be effectively exploited (Sections 3.4.5, 4.1). Harnessing the opportunities offered by digitalization (Box 3.4-12) opens up great potential here.

Box 3.4-11

Food sharing as a prominent example of a societal initiative to avoid food waste

Food-sharing initiatives aim to change food systems and address the huge waste of food (e.g. food banks or social supermarkets; Michelini et al., 2018; Davies et al., 2017). Numerous digital options exist, such as the opportunity to use online platforms to offer free food and for networking, which has contributed to the emergence of food-sharing organizations (Michelini et al., 2018). This form of donating food (in the sense of communal sharing without any costs incurred by the end consumer; sharing leads only to joint consumption within society; Belk, 2007) continues historically enshrined cultural practices. However, the new food-sharing initiatives are moving beyond the family setting to which sharing has often been confined and are aiming for community use on a society-wide scale (Gollnhofer et al., 2016). This idea originally developed from the food-rescue movement of 'dumpster diving' (collecting discarded food from containers at supermarkets; Schanes and Stagl, 2019; Rombach and Bitsch, 2015). Today, Food-sharing e.V., one of the first platforms, has more than 200,000 users in Germany, Switzerland, Austria and other countries within Europe (Foodsharing, 2019b). In addition, over 25,000 volunteers and more than 3,000 businesses are involved, through whom "7.8 million kg of food has already been saved from waste to date" (Foodsharing, 2019a).

Box 3.4-12

Harness digitalization for sustainable nutrition

Although, in addition to start-ups and NGOs, public institutions too have already developed initial digital solutions to support sustainable consumption in the food sector, there is still no authority that can securely enable transparency along product and supply chains. Similarly, there is no reliable and widespread certification in most areas. In this respect, corresponding apps are an initial, helpful, but by no means sufficient condition for promoting sustainable dietary habits on the consumption side. Moreover, providing information only digitally via apps would again be a system that excludes people who do not use smartphones (WBGU, 2019b: 158). Smartphone apps can be used for a variety of purposes in the context of sustainable dietary habits, for example:

- the nutriCARD App from the BMBF-funded Competence Cluster for Nutrition and Cardiovascular Health, which was made public in 2019, "already shows the Nutri-Score [nutritional quality of a foodstuff] of all known products" (baggid.com/nutriscore);
- the free 'seasonal calendar app' (bzfe.de/content/appsaisonkalender-3131.html) from the Federal Centre for Nutrition (BZfE) provides purchasing advice on approx. 80 types of fruit and vegetables, stating how much of each is imported (as %) compared with domestic produce;
- a consumer-orientation app such as codecheck.info uses (advertising-financed) bar-code scanners to help consumers find "healthy and sustainable products [based on] independent expert reviews of millions of products from the cosmetics, nutrition and household sectors";
- a consumer-protection app such as ToxFox enables a product check, "which helps consumers to check cosmetics and everyday products for harmful substances" (bund.net/themen/chemie/toxfox/);
- apps like 'Too good to go' (toogoodtogo.de) address the problem of food waste and make it possible (in this case commission-financed) to pick up leftover food and groceries before closing time in restaurants and supermarkets for a low price.

3.4.4.5 Transformation approaches in community catering: making the most of multiple transformation potential

Instruments that not only transform prices and offers, but also impart knowledge and norms, would not only further promote the transformation of dietary habits that has already begun, but also honour *Eigenart*. As a particularly relevant field of action, the WBGU has identified places where nutrition biographies are shaped and which therefore offer special potential for the dissemination of new dietary habits: the restaurant and catering sector, especially communal catering.

A new nutrition guideline in line with the PHD should be the basis for making sustainable dietary habits in community catering possible. In addition, there is plenty of scope for action, particularly in the compilation of school, day-care and kindergarten meals, as well as in workplace, university and college canteens and in restaurants. In this context especially, it makes sense to use 'nudging methods' in addition to prioritizing sustainable products in the product range and creating corresponding incentives to purchase. According to Reisch (2015), the term nudging means "gently encouraging people to make certain decisions or exhibit certain behaviours – decisions that people would themselves take if they were fully informed or could translate their intentions into behaviour. However, they are – systematically – prevented from doing so by human 'biases' and 'heuristics', which are described in detail in psychology. As a concept of political governance, 'nudging' is another name for 'behaviour-based regula-

Box 3.4-13

Determining CO_2 scores in canteens: an example

As reported by the Süddeutsche Zeitung on 21 February 2020, since January 2020 meals at the Infineon canteen in Munich have been labelled to show their CO_2 value. Employees can access this information via an app. The measure was accompanied by corresponding information offers and information stands.

The data for determining the CO_2 values comes from the Eaternity Scores, a database that continuously receives information on the latest research results, rates recipes – and would also make it possible to rate products from the supermarket. CO_2 costs generated by production and transport are also included.

This procedure is a novelty in communal catering. It also enables consumers to compare the climate compatibility of foods for which such an assessment is not easy – such as pizza or pasta dishes.

A month after the launch, the feedback was positive: guests showed a high level of interest and thought was given to expanding the range of vegetarian and vegan food on offer. Even so, no one has to give up meat completely.

tion', which links up with people's actual behaviour and their systematic behavioural 'mistakes'." In terms of environmental psychological understanding, nudges are considered a "manipulation of choice" (Hansen and Jespersen, 2017) in the sense of changing the situation via behavioural costs. However, nudges also convey what is justified by society as being appropriate or desirable (such as sustainability goals).

A recent review (Vecchio and Cavallo, 2019) shows that in terms of attitudes towards such nudging, a greater amount of trust in public institutions correlates with greater support for such interventions (Sunstein et al., 2019). Such nudging towards sustainable nutritional offers is usually successful and is also positively received by those 'affected'. This has been shown in catering, for example where conference participants were offered vegetarian catering as a standard (simultaneously setting a norm) and reacted to this positively (Hansen et al., 2019). Similarly, it has been shown for restaurants that vegetarian dishes are chosen more often when they are highlighted as the dish of the day (Saulais et al., 2019). Positive examples already exist in the field of workplace, university and college canteens where consumption of sustainable meals has been successfully promoted by a corresponding change in the range of products on offer. On the one hand, the range was extended so that not only 'meat-substitute dishes', but tasty and visually appealing vegetable dishes made from fresh, simple ingredients were sold. On the other hand, vegan dishes or dishes with reduced meat portions could be chosen if desired, and in some places completely vegetarian or vegan university and college canteens have been opened (Hachmann et al., 2019; also Sustainable Canteen Programme of the EU).

Taking up current ideas on food labels, in the case of groups of people where there is no risk of inclusion becoming restricted, digital 'solutions' (Box 3.4-12) could be used to improve access to information via QR codes or apps. One example of the successful application of such technical possibilities can be found in Johannes Steffen's approach in the Infineon canteen in Munich (Box 3.4-13).

3.4.5 Recommendations for action

The food system offers a many starting points for addressing deficiencies (Section 3.4.1). The fact that approx. 77% of the world's agricultural land is used for livestock production (Section 3.4.1.3), which meets only 17% of global calorie requirements is evidence of an imbalance in land use that is detrimental to combating the trilemma; it also goes hand in hand with dietary habits worldwide that are increasingly heavy in animal products – also in the growing middle classes of developing countries and emerging economies. A transformation of these lose-lose-lose dietary habits towards a low-animal-product diet, combined with a shift towards more diversified production systems (Section 3.3), is possible without restricting the diversity of global dietary practices. A transformation would furthermore have multiple benefits for the Sustainable Development Goals, especially SDG 1 (no poverty), SDG 2 (no hunger), SDG 3 (health and well-being) and SDG 12 (sustainable consumption and prosperity). In its thoughts on how to achieve a transformation of dietary habits, the WBGU is guided by a differentiating model of personal dietary habits (Fig. 3.4-4). In addition to changing product ranges and prices (see also the recommendations in Section 3.3.3), the WBGU advocates giving targeted support to the societal trend away from animal-product-heavy dietary habits. Starting points here are (1) a normative orientation through precisely targeted nutrition guidelines, (2) backing the diverse existing initiatives on alternative ways of dealing with food, and (3) improving the basis and dissemination of knowledge on the environmental externalities of animal products. In particular, (4) the context of community catering in day-care centres, schools and universities should be used to promote new nutritional norms, since this is where nutritional biographies are shaped.

3.4.5.1
Consistently make sustainable nutrition the norm with guidelines that are in line with the Planetary Health Diet

Recommend dietary guidelines targeting sustainability

The Planetary Health Diet (PHD; Willet et al., 2019) represents a science-based guideline for future sustainable and healthy dietary habits. The PHD's guiding principle is that some daily meals should be based on reduced amounts of animal products, especially red and processed meat (Fig. 3.4-4). This should be a fundamental principle of new nutrition guidelines and be represented externally (Section 3.4.3.5). The WBGU recommends that relevant actors (in Germany: BMEL, BMU, BZfE and DGE, the Council for Consumer Affairs, nutrition councils) should recognize the PHD as a common guideline and recommend it, e.g. on their respective websites. One suitable framework could be forums such as the one hosted by BZfE in 2020 on the topic of 'Eating is changing – nutrition within the planetary guard rails', which explicitly discussed access for everyone to healthy food from a sustainable food system based on the PHD. At the international level, the topic of PHD-compliant guidelines should be taken up at the UN Food Systems Summit in 2021.

Offer meals based on the Planetary Health Diet in communal catering

Because of their special role-model function, a nutrition guideline based on the PHD should be used as the basis for menus in all forms of public communal catering and further developed through corresponding transformative research (Section 3.4.6). As a transitional measure, existing recommendations should be used, such as the practical handbook from the BMBF-funded Nahgast research project (Speck et al., 2020).

Enforce the principle of sustainable procurement in publicly funded catering

A sustainably produced menu following the PHD should be established as standard for all publicly funded catering (conference catering, buffets at public events). Following the PHD principles, if variety is limited (e.g. if there is only one standard dish) or there is uncertainty about the strength of demand for vegan food, preference should be given to a vegan meal as it is compatible with multiple dietary restrictions (e.g. lactose intolerance, kosher, halal) and, as a multiculturally compatible diet, it is a safe option. This can also be an opportunity to set up vegan dishes as an attractive new norm and to give citizens an opportunity to have (new) experiences in their food choices.

3.4.5.2
Support the trend towards a low-animal-product diet and gear nutrition biographies towards sustainability

Publicize and support the diverse initiatives targeting the goal of sustainable diets

Sustainability-oriented civil-society initiatives that aim at a transformation towards sustainably produced products and a low-animal-product diet (self-harvest gardens, food coops, producer-consumer communities, solidarity agriculture, EcoYou, Green Food groups, Slow Food movement, urban gardening, food sharing, the Food Recovery Network, the Vegan Society; Section 3.4.4.3) should be networked and promoted – also by the state (Sections 4.1.2, 4.1.3) – e.g. by initiating umbrella organizations, organizing forums, launching media campaigns or awarding prizes. Networking activities can also be initiated via transformative research programmes (Section 3.4.6).

Sustainably shape nutrition biographies at an early stage in order to further support the change in societal values that is already taking place

Especially in educational institutions (kindergartens, schools), PHD-based dietary guidelines should, in the short term, not only apply in communal catering but also be included in the curricula. A separate subject, such as 'healthy and sustainable nutrition', could be introduced in primary schools. Knowledge of sustainable food production and sustainable, PHD-oriented cooking habits could also be (re-)introduced into the education system through cooking courses and school gardening. In a similar way to the Digital Pact, funds could be made available for this by the German Federal Government. Existing international student-exchange programmes and school partnerships could also be used to teach this educational content transnationally; at the same time, the diversity of food cultures for sustainable meals could be experienced.

3.4.5.3
Encourage consumers to practise sustainable dietary habits

Promote the pricing-in of environmental externalities and cut subsidies

At present, product prices do not reflect the societal costs of nutrition, and corresponding choices are not available, so that sustainable solidarity-based dietary habits are not encouraged among consumers. Following the recommendations in Sections 3.3.3.1 and 4.2.6, the pricing-in of environmental externalities should be promoted to reflect 'true' prices in the range of foodstuffs.

Promote the development of a consumer-oriented information system for labelling environmental externalities

The WBGU recommends developing a consumer-friendly information system that makes environmental externalities transparent. This can be done in a variety of ways, for example by public authorities actively informing civil society, by granting information rights, marking product packaging or using labels. The latter already exists in some cases; however, the labels are not always intended to reveal environmental externalities. Information offers should bear in mind that the integrated knowledge made available by labels cannot meet the requirements of all consumers, since individual people's dietary habits can be oriented towards different target systems (health, weight loss, promoting organic farming, etc.; Section 3.4.3.5). The WBGU recommends developing an information platform and corresponding apps in cooperation with civil-society actors that can form the basis for information related both to a variety of target systems (e.g. a PHD-compliant diet, exclusion of negative telecouplings of imported agricultural products, with a minimal CO_2 footprint, low-fat, low-calorie, vegetarian, vegan) and to a person's overall personal diet. Such information systems should be certified by independent bodies, e.g. according to transparency criteria, and in line with overarching societal objectives (health, sustainability). The development of such information systems should be initiated via transformative research programmes (Section 3.4.6).

Introduce a ‚sustainable food supply‘ certificate

A 'sustainable food supply' certificate should be introduced for the retail trade. Such a certificate could, for example, prove compliance with the basic principles of the PHD or show that at least 50% of the food is offered with well-researched information on environmental externalities. Such a certification system should be developed in a transformative research project (Section 3.4.6) by private initiatives and supported by government institutions (such as BMU, UBA, BMEL). The latter could subsequently issue the certificate.

Introduce and promote a ‚sustainable catering‘ certificate EU-wide

The trend towards vegetarian and vegan restaurants (Section 3.4.4.3) should be promoted: either already active initiatives (e.g. Green Table) and state institutions (BZfE, perhaps also BMU, BMEL, BMWI) or a combination of the two groups of actors should develop and introduce an overarching 'sustainable catering' certificate documenting that a PHD-compliant turnover target is achieved and also that information on the environmental externalities of each dish is provided.

Launch initiatives: place warnings on advertising for unhealthy foods

Overconsumption of animal products, especially processed meat, is also harmful to health. The same applies to other food categories such as products that are rich in sugar or fat. A societal discourse should be initiated on the extent to which advertising for such products should include informational or even evaluative references – e.g. a traffic-light label – which adequately inform consumers about health risks.

3.4.5.4
Promote 'healthy trade' nationally and internationally

In addition to the recommendations made in Sections 3.3.3 and 4.2.6, international trade should take the following calls for action into account, as they are particularly relevant to nutrition.

International trade and investment agreements should take into account their impact on the population‘s diet

The effects of international trade and investment agreements on the respective populations can be many and varied and should therefore be carefully examined (Section 3.4.5.3). The principles for responsible investment in the agricultural and food system developed by the Committee on World Food Security (CFS) strengthen food security and the right to adequate nutrition and should be rigorously implemented. This applies in particular to multi- or bilateral trade agreements which offer investors particularly strong protection (Baldwin, 2011). For example, the implementation of the Principles for Responsible Investment in Agriculture and Food Systems should also be examined (CFS, 2014).

Use trade as a driver for achieving sustainable and healthy nutrition

The agricultural trade enables the provision of a secure supply of diverse, sustainably produced agricultural products, especially for urban populations. In addition, trade also has indirect effects in that income is generated, for example through the commercialization and export of agricultural products, which in turn make a major contribution to food security for the rural population. Trade also makes a diversified supply of fruit and vegetables possible. Aid-for-trade measures and other ways of establishing and expanding sustainable consumption patterns can further promote this in a targeted manner (Zengerling, 2020).

3.4.6
Research recommendations:

A wide range of initiatives relating to both nutrition and sustainability have developed in recent years, and a consciously sustainable diet is increasingly considered important (Section 3.4.4.3). Against this background, the WBGU recommends involving and strengthening change agents in the sense of transformative research (WBGU, 2011, 2016a) in order to drive forward the transformation that is already beginning. The possibilities of establishing new information services and their implementation in the form of 'real-world laboratories' (i.e. local networking of actors on specific transformation requirements) should feature prominently in research programmes.

To accompany the implementation of the recommendations for action (Section 3.4.5), the WBGU sees a need for further research on the (broad) effectiveness and enforcement of international dietary guidelines.

Across the board, research into the multiple links between changing agricultural systems and nutrition is a new field of interdisciplinary research that combines agricultural, nutritional, economic and social-science perspectives (Qaim, 2017). Accordingly, existing research programmes in the field of nutrition should be supplemented by adding aspects of consumer psychology and nutrition sociology that take into account people's willingness to pay and other barriers (especially lack of knowledge and misconceptions), as well as trends towards solidarity-based consumption. It would also be useful to boost environmental-science research accompanying the wide range of nutrition-related initiatives.

3.4.6.1
Transformative research aimed at strengthening sustainable dietary habits

Promote sustainable dietary habits with real-world laboratories at educational institutions

Particularly in educational institutions, i.e. places where nutritional biographies are shaped, either new PHD-based nutrition guidelines or the PHD itself should guide the food choices. Concepts for this could be developed and tested at universities and schools in the form of real-world laboratories. Together with canteen operators, educational institutions could involve other actors, such as regional livestock farmers or ESD teachers. Educational institutions offer considerable diffusion potential, so that experience with barriers and potential would be easily transferable and a considerable transformational effect can be expected. The findings from these initial real-world laboratories should be made available to other transformation actors, for example via a specialist conference on sustainable school catering (involving the National Quality Centre for Nutrition in Daycare and Schools, NQZ, and the Competence Centre for Sustainable Procurement, KNB) or the BMEL action plan INFORM.

Transformatively explore the potential of sustainable offers in the catering industry

Together with actors from the catering industry (such as the German Restaurant and Hotel Association DEHOGA) and civil society, transformative research should be conducted into how offers can be further developed in line with the PHD and what information services can meaningfully support guests. In addition to practices and concepts, the outcome of transformative research could also be a certificate for catering establishments that promotes sustainable nutrition through information and the range of meals on offer (Section 3.4.5.3). This could be linked to the FONA 'Sustainable Management' funding or the BMBF's 'Transformations to Sustainability'.

Encourage the transformative development of needs-based information services on sustainable consumption

Product labels do not fully reflect individual needs for information and orientation. This applies both to health-related labels, such as the NutriScore, and to labels that aim to provide information on environmental externalities (the EU organic label, for example, does not provide any information on CO_2 equivalents in production or on water consumption). It might be helpful to set up online information portals, where users can choose individual criteria for finding information according to their needs and are offered corresponding product recommendations. Such information systems should be developed in a research programme involving a wide range of stakeholders (such as consumer-protection organizations, actors in the field of healthy nutrition, culturally sensitive nutrition and sustainability initiatives, as well as producers and retailers). In line with the EU's 'From Farm to Fork' strategy, not only nutrition scores or indications of origin should be included but also information relevant to climate protection and biodiversity conservation. Research projects could seek to answer the question of how existing information services can be further developed so that consumers can receive product recommendations in line with their individual information needs. Civil-society stakeholders (Section 3.4.3.5) could be empowered to provide such information on portals. Furthermore, the development of standards for such information portals should also be promoted. The German Federal Government's clarity-of-labelling ('Siegelklarheit') initiative should be included and, where appropriate, the results of the BMEL-funded Foodomics project (at GALAB) can be taken up. A similar approach is taken by the WBAE report's recommendation to create a corresponding open-access database in the form of a "federal sustainability key" (WBAE, 2020). The WBAE sees this as a basis for developing a "digital ecosystem of more sustainable food" (WBAE, 2020: Section 8.10.3), with which "consumers can understand better, more easily and more quickly the criteria and data that form the basis of the digital applications' recommendations and assessments".

Engage in transformative research into sustainable prospects for meat and milk

Using participatory research methods, concepts for a sustainable future for animal husbandry and animal-food production should be explored and discussed with actors operating in meat and milk production, also involving the retail trade and consumer initiatives. The aim could be to lay the foundations for a citizens' report (Dienel, 1997) on the subject of 'future prospects for meat and milk'.

3.4.6.2
Extend existing research programmes in the field of nutrition to include sustainability aspects

The BMBF's Nutrition Research Competence Cluster and the EU programme 'A Healthy Diet for a Healthy Life' are prominent in the field of nutrition research, but focus almost exclusively on the health aspect. The WBGU recommends adding sustainability aspects. Stakeholders such as the BMEL, BMU, BZfE or DIfE should be involved in this process.

Research the effects of political consumption and alternative forms of nutrition

The emergence of a wide range of initiatives in the field of sustainable nutrition (Ackerhelden, Too Good To Go, etc.) is also an expression of political consumption and indicates that nutrition as a form of expression is particularly important. Implications (collective effectiveness, experience of self-efficacy, diffusion potential) should be studied in a social-science research programme that looks into the effects on individual quality of life and societal impacts. In particular, research programmes should identify structural barriers to the practice of relevant individual dietary habits (veganism, vegetarianism) which deviate from the dominant animal-product-heavy diet and systematically study the effects of obstacles to the practice of chosen dietary habits.

Research the effect of and reference to dietary guidelines

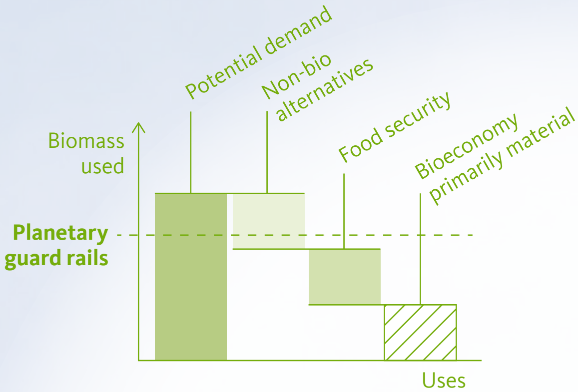
The main target groups of international and national nutrition guidelines are schools, day-care centres and hospitals (places of communal catering). However, it is largely unknown to what extent different nutritional locations or even individual institutions or associations (e.g. workplace, college and university canteens) actually conform to the guidelines in practice. A corresponding review aimed at more accurately assessing the effectiveness of dietary guidelines would also be helpful in view of a reorientation towards the PHD.

Optimize methodology for quantifying food waste (and its potential)

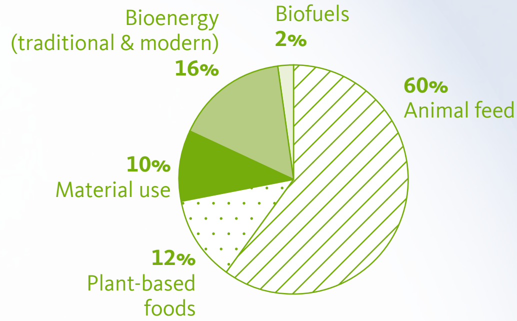
Quantifying food waste is currently a methodological problem (Section 3.4.2). This should be taken into account in future research projects, especially since prominent sustainability strategies are based on reducing food waste. By building on this, the potential for reducing food waste in households and commerce, particularly in industrialized countries, could be determined more reliably. Initial results, among others, are available in the BMBF-funded study REFOWAS in the context of schools (Elsen, 2019; Waskow and Niepagenkemper, 2019).

Initiate international research collaborations on the future of nutrition

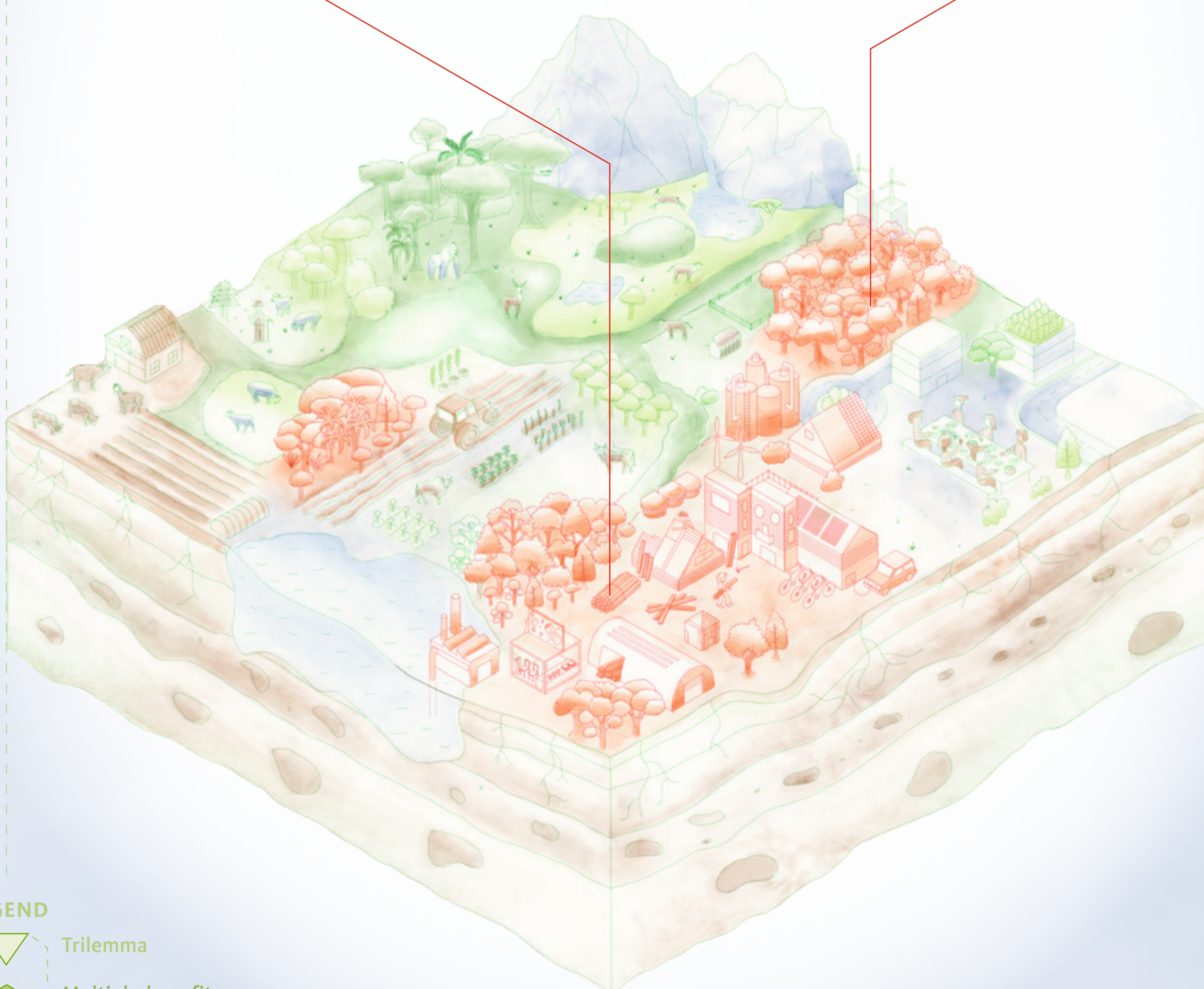
Existing research activities on sustainable nutrition should be systemically oriented, i.e. towards the effects on all the dimensions of the trilemma. An example of this is the scenario approach of the Oxford Martin Programme on the Future of Food (Box 3.4-8). The health and sustainability impacts not only of guidelines but also of diverse cultural and, in particular, dominant dietary habits should be analysed and evaluated. A corresponding research programme and collaborations should be initiated.

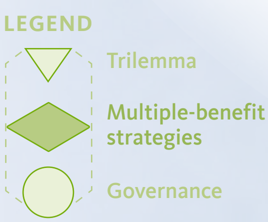


Sustainable bio-economy **prioritizes food, material uses** such as timber construction and the circular economy. Alternatives to the use of biomass, e.g. for energy and fuels, should be fully exploited.



Global demand for biomass
2018, by sector.
Total: 12.3 bn tonnes of dry matter





3.5 Shape the bioeconomy responsibly and promote timber-based construction

The use of biomass for materials or for generating energy in a bioeconomy offers options for replacing emissions-intensive processes and fossil resources, e.g. by more timber-based than cement-based construction. However, the growing demand for land for biomass production is intensifying competition with food security and biodiversity conservation. In order to shape a bioeconomy based on sustainable land use, a limiting framework for supply and demand is needed, within which selected applications can then be strengthened.

The bioeconomy beyond the food sector – i.e. using land to produce biogenic resources and their use in energy generation or as materials (e.g. biofuels, plastics) – is receiving increasing attention from policy-makers, business and the public in both industrialized and developing countries in the search for new sources of raw materials and areas of growth (Lewandowski, 2017; Bioökonomierat, 2015a, b, 2018a, b; FAO, 2016c, 2018b; European Commission, 2017; IAC, 2018; IEA, 2018; Hausknost et al., 2017). The bioeconomy is defined in Germany's updated bioeconomy strategy as "the production, exploitation and use of biological resources, processes and systems to provide products, processes and services across all economic sectors within the framework of a future-oriented economy" (Bundesregierung, 2020). In the WBGU's view, the concept should be supplemented by the aspect of the responsible stewardship of terrestrial and marine ecosystems. By 2018, about 50 nations had already incorporated the bioeconomy into policy programmes. Some European and other countries (Bioökonomierat, 2018a) as well as the EU (EU Commission, 2018a) have launched explicit bioeconomy strategies. Although sustainability is often the motivation behind these approaches, the implications for land use, biodiversity and food security mostly receive inadequate attention (e.g. in the strategies documented by the Bioökonomierat, 2018a, as well as in the bioeconomy discourse as a whole; Box 3.5-1). Biodiversity, for example in parts of Africa, is seen rather as a potential that can be increasingly exploited in the future (e.g. for medicinal substances). Although, in view of the finite nature of mineral resources and the harmfulness to the climate of fossil raw materials, the use of biomass offers alternative, sometimes innovative solutions, its extended use for energy and materials has a considerable impact on land use in many parts of the world. This is because biomass use competes with food security and biodiversity conservation, thus touching on all dimensions of the WBGU's normative compass (Box 2.3-1) and threatening to exacerbate spatial or development-related asymmetries. While demand for biomass for material or energy uses is growing, especially in the global North, the resulting land-use competition and rising prices for agricultural goods and food are threatening the food security of lower-income population groups, primarily in the global South (as illustrated by the 'food versus fuel' debate about growing biomass for fuel rather than food; Dietz et al., 2016; Persson, 2015). This is linked to conflicts between influential national and global actors (especially large landowners, biomass-processing companies) and local stakeholders (e.g. smallholders, rural population).

It is therefore important to give the bioeconomy a clear-cut framework which, alongside principles of responsible biomass use, first and foremost defines limits, because there is not enough land available to completely replace fossil resources with biogenic resources without jeopardizing the trilemma dimensions of food security and biodiversity (Smith, 2018). Only when such interrelationships are taken into consideration can the bioeconomy contribute to the Great Transformation towards Sustainability. To some extent, the concept of the bioeconomy itself offers approaches to dealing with the scarcity of sustainably produced biomass, as it covers not only the use of biogenic resources but also biotechnologies and innovations for a more sustainable use of natural raw materials (Kircher et al., 2020) and the application of ecological principles, such as the use of material cycles (Bugge et al., 2016; IAC, 2018).

After an analytical part (Section 3.5.1), a set of goals for a sustainable bioeconomy is developed and the fields of action relevant to its realization are identified (Section 3.5.2). Because the aim is to use biomass primarily in areas where, as an alternative to conventional technologies, it can make an important contribution to climate-change mitigation and biodiversity conservation as well as to food security, thereby defusing the land-use trilemma, we introduce sustainable construction with wood as a multiple-benefit strategy and demonstrate its high impact potential (Section 3.5.3). The construction sector's potential for contributing to tighter climate targets has also recently been emphasized at the EU level (von der Leyen, 2020). Recommendations for action and research follow in Sections 3.5.4 and 3.5.5.

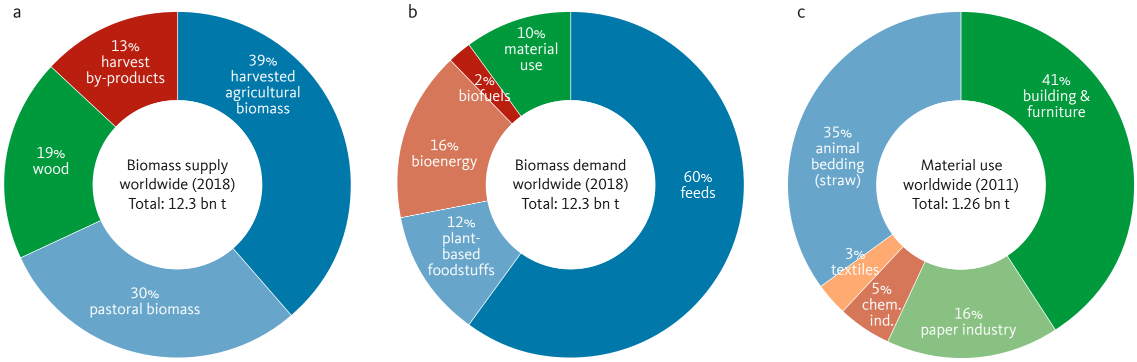


Figure 3.5-1
Biomass supply and demand worldwide in 2018 by source and sector; breakdown of material use by sector for 2011 (total material use remained stable up to 2018). Bamboo accounts for about 13% of demand for construction and furniture. Quantities are for dry matter.
Sources: Carus et al., 2020; Piotrowski et al., 2015: Fig. 35 and Appendix III.1

3.5.1
Problems and potential of the increased use of biological resources

Worldwide, about 50% of the supply of biomass comes from agricultural land and 30% from pasture land. Animal feed accounts for 60% and plant-based foodstuffs for 12% of demand; just over a quarter of biomass is used for energy (primarily traditional bioenergy) or materials (Fig. 3.5-1 a, b). Aquatic biomass sources have hitherto been insignificant in terms of quantity: approx. 0.2 billion t of aquatic biomass are consumed per year (of which 15% are algae; FAO, 2017b); this compares with 12.3 billion t of dry matter from land-based production (Carus et al., 2020).

In the transition from fossil resources or high-emission processes to climate-friendly alternatives, biogenic resources are increasingly needed for material and carbon-sequestrating uses (in 2018, only about 10% of biomass was used for material purposes, and only about 6–7% after subtracting biomass used as animal bedding; Fig. 3.5-1b, c), and for selected energy purposes, depending on the scenario (Box 3.5-3). The importance of timber and agricultural by-products is likely to increase as a result (19% and 13% of the harvested volume respectively, Fig. 3.5-1 a). How much additional biomass would have to be harvested to expand the bioeconomy also depends inter alia on savings in traditional bioenergy or on changes in dietary habits (in order to reduce the high level of demand for animal feed; Section 3.4). Another factor is the extent to which non-bio-based technologies and demand reduction can help avoid the large-scale use of modern bioenergy and biofuels, including in combination with carbon capture and storage (CCS; IPCC, 2018).

Current land use is already marked by sustainability problems, and the resource potential for a bioeconomy within planetary guard rails is limited. The prevailing production methods of industrial agriculture are not sustainable because they involve high inputs of chemicals, water and energy and consequently result in degraded soils, and because the existing framework conditions favour large farms and crowd out smaller ones (Bartz et al., 2015; Section 3.3). 'Land grabbing' in particular, i.e. expansive land use (usually in developing countries) by foreign or domestic state actors, often serves to provide resources for material or energy uses (Ashukem, 2020; Bartz et al., 2015; Box 3.3-7). Smallholders in developing countries, by contrast, frequently lack the means for biomass production beyond their own needs. Above all in the semi-arid zones of developing countries and emerging economies, agriculture beyond food supply is hardly possible, as it is already stressing regional water budgets to the limit, a situation that is being exacerbated by climate change (Dusseldorp and Sauter, 2011). In forestry, monocultures or logging on erosion-prone hillsides create considerable sustainability problems (Raev, 2002). This impairs the local and global climate, biodiversity conservation, the nitrogen, phosphorus and water cycles, and groundwater protection, which is especially important for wetlands (Felton et al., 2016; Chapter 2, Sections 3.1-3.3). Further ecological restrictions are also needed, e.g. harvest residues should partly remain on the fields or in the forests. Under these conditions and also bearing in mind increasing pressure from population growth and the consequences of climate change, it is doubtful whether the amount of biomass harvested per capita can be maintained or increased(as discussed for the example of wood in Warman, 2014; Yousefpour et al., 2019). Nevertheless, the bioeconomy also offers options in developing countries, e.g. in sub-humid or humid regions, if it is prudently integrated into existing land-use systems. For example, it offers new opportunities for residue use (Awasthi et al., 2020; Thorenz et al., 2018; Fletcher et al., 2017), and land less suitable for food crops can be used to grow other types of biomass for material and energy use, creating additional income opportunities as well as infrastructure and technology spillover effects (Virchow et al., 2017: 227). For example, agave crops grow on dry soils, energy crops such as oilseeds even thrive on land unsuitable for food crops (albeit with lower yields; Segerstedt and Bobert, 2013), and building up biomass-processing facilities promotes technological learning effects (Lynd and Woods, 2011).

Because land and sustainably produced biomass are generally scarce, their use should be prioritized in line with sustainability goals, with food security and biodiversity conservation being given priority. Even with diets that are less reliant on animal products and reduced food losses and food waste (Sections 2.2.2, 3.3.2.3, 3.4.2.1), continued growth in the world's population would mean that biomass and land requirements for food would decline only slowly, if at all (Bringezu and Schütz, 2008; Gerten et al., 2020; Godfray et al., 2010; Rahmann and Oppermann, 2010; Ponitka and Thrän, 2015). If reduced feed or food production really does 'free up' land, priority should in many cases be given to long-term ecosystem stabilization rather than to short-term raw-material production (which is impossible in the long term without stable ecosystems; Section 3.1), depending on the type of land (grassland or arable land) and the biodiversity potential.

If more biogenic resources are required for non-food-related use, this could on the one hand exacerbate sustainability conflicts. For example, the widespread use of cheap palm oil in various industries (Vijay et al., 2016) and the promotion of bioenergy (including biofuels) in the EU and Germany (Cotula et al., 2008) have contributed on a relevant scale to deforestation, water scarcity and rising food prices in developing countries and emerging economies (Dehue et al., 2007; FAO, 2010a: 40; German et al., 2011; van der Hilst et al., 2013). The 'food-versus-fuel' debate, triggered by the 2007 food-price crisis (Muscat et al., 2020) and reinforced by the biofuel blending quotas set out in the European Renewable Energy Directive (EU, 2009a, 2018a), continues to reverberate to this day in the public perception and in policy debates on the bioeconomy (FAO, 2010a; UBA, 2019b).

On the other hand, using biomass to reduce CO_2 emissions to zero and to sequester carbon is in some cases unavoidable. CO_2 emissions arise when fossil raw materials are used to generate energy, in cement production, during manufacturing processes that use fossil source materials (e.g. in the production of plastics or nitrogen fertilizers), and as a result of land-use changes (Fig. 2.2-3). Renewable alternatives to biomass use are available for most energy applications, e.g. electricity from wind power or photovoltaics (PV) and hydrogen produced with it. For aviation or shipping fuels and material applications, however, there are in some cases hardly any alternatives, e.g. for base chemicals and in the construction industry (Section 3.5.2.2). Timber-based construction, durable biogenic products and bioenergy with CCS are among the few options available for sequestering atmospheric carbon over the longer term (Sections 3.1.1, 3.5.3; Box 3.5-3).

Expanding the bioeconomy also has further potential, which to some extent goes beyond climate-change mitigation:

- product and process innovations thanks to new biogenic materials and biotechnologies, although the assessment and the orientation of these innovations are still the subject of critical discussions (Box 3.5-1),
- more secure national or regional supplies of raw materials (reducing dependence on international supplies), regionalization of material cycles (Box 3.5-2),
- new, sustainable opportunities for employment and related training, especially in rural areas, and
- incentives for more sustainable consumption patterns due to the societal visibility of new bio-based products, which promote a more conscious use of resources and support socio-cultural transformation.

In the overall picture, a technical 1:1 substitution of fossil and other resources associated with emissions by biogenic raw materials is impossible, as there is not enough biomass available. This is shown by a comparison between estimated global biomass potential on the one hand and the scale of technically possible (not necessarily economically viable) uses in selected key sectors on the other (Fig. 3.5-2), e.g. bioenergy with CCS (BECCS) which has sometimes inspired high expectations for climate-change mitigation, biofuels in aviation, and bioplastics. Precautions should therefore be taken to ensure that ambitious climate protection, e.g. a high CO_2 price in the energy sector, does not cause the related use of biomass to increase beyond sustainable levels or at the expense of other, more important applications.

The key concern is that the bioeconomy should contribute to decarbonization in suitable sectors, while avoiding the risks of excessive biomass use and thus combining the bioeconomy with less land-intensive

Box 3.5-1

Innovations in bioeconomy: potential and criticism

The innovation potential of the bioeconomy is today associated with many hopes and expectations, but also with fears. It is therefore necessary to look more closely at whether its use is appropriate in each case. The extended application possibilities of biomass are currently being systematically studied. The German Biomass Research Centre DBFZ, for example, is developing biotechnological processes and testing areas of application (dbfz.de). Among other things, the BMBF supports business innovations (e.g. 'KMU-innovativ: Bioökonomie' (Innovative SMEs: Bioeconomy); BMBF, 2020a). As studies show, numerous materials and valuable substances can be produced from large-volume bulk raw materials (e.g. natural fibres, natural oils), small-volume but high-value components (e.g. terpenes) and urban biowaste. However, only 20 out of more than 100 bio-based materials analysed are considered to be economically and technically promising and could soon be used on a larger scale (EU Commission, 2018b; Table 3.5-1). On the other hand, because the basic materials are widely available worldwide, they make regionalized bioeconomy value chains possible in many industrialized and developing countries. Biotechnology, bioengineering and genetic engineering also offer options for bioeconomic process and product innovations (Chapotin and Wolt, 2007; Kircher et al., 2020; Kitney and Fremont, 2017), but this will not be explored in depth here, also in view of the sustainability risks of modern genetic engineering (CRISPR; Knott and Doudna, 2018).

An international Delphi study points to future-relevant, systemic fields of innovation combining diverse elements (Bioökonomierat, no date). It sees potential in artificial photosynthesis (production of carbohydrates or starch from water, CO_2 and sunlight), which could take some of the pressure off land use and act as a carbon sink, as shown by current research on artificial chloroplasts (Miller et al., 2020). Other innovative bioeconomy approaches include the use of biomass from sustainable aquacultures for food and commodity production, 'biorefineries 4.0' that generate energy, food and chemical base substances from waste materials by enzymatic biotransformation, and new (online) education and training approaches to continuously provide information about options for sustainable biomass production and use (Bioökonomierat, no date; de Lorenzo and Schmidt, 2018). In combination with integrated land use, biological principles could also be integrated into urban development, whereby the vision of a 'bioprincipled city' could be constructively linked with 'smart city' ideas (WBGU, 2019b; Section 5.2.7) via digital monitoring and control technologies. This urban model combines a regionalized circular economy and the cascade use of bio-based base substances, energy and water (Box 3.5-2) with biotechnologies to avoid emissions and support recycling, with urban agricultural production, optimizing buildings and neighbourhoods according to bioprinciples, and green spaces for ecosystem services (Bioökonomierat, no date). However, the multifaceted innovation potential of the bioeconomy faces a considerable amount of vagueness in the discourse, culminating in the thoughtless 'hype' that also characterizes the discussion on digitalization (WBGU, 2019b). According to an analysis by the UBA (2019b), three trends are shaping the German discourse on the bioeconomy (affirmative, pragmatic, critical), classifying the topic somewhere between a 'key industry of the future' and 'a new way of exploiting nature'. In a similar way to digitalization (WBGU, 2019a, b), the issues behind this are, on the one hand, ethical questions of the relationship between humans and nature, the shaping of future socio-technical systems and their ecological impacts. On the other hand, possible solutions touch on legal issues such as reinforcing the precautionary principle. Political questions are also raised, e.g. whether the controversial industry-driven bioeconomy needs to be democratized by giving farmers and civil society more participation. All sub-discourses rely on sustainability arguments but are based on different interpretations (from weak to strong sustainability); they involve practical implications for overarching goals (such as giving priority to climate-change mitigation, emphasizing economic growth and competitiveness, etc.), the relationship between humans and nature, and distribution fairness (international and intergenerational). The polarization of the bioeconomy discourse is based not only on conflicts of interest, but also on conflicts of goals and values, according to the UBA study (2019b: 118); it states that, instead of negotiation processes, both protected 'Chatham House' dialogue formats and an open, socio-political debate with the involvement of citizens could be practicable. Furthermore, capacity and resources would need to be more equally distributed between the representatives of the sub-discourses, because critical and pragmatic discourses are currently at a disadvantage.

The example of 'terra0' (Seidler et al., 2016) shows how interdisciplinary research projects in particular can contribute to an objective debate in science, business, politics and civil society by interlinking bioeconomy and digitalization. This art project, developed in the 'Digital Class' at the Berlin University of the Arts, investigates whether forests can be managed digitally. To this end, a hypothetical scenario describes a forest that uses automated decision-making processes, blockchain and smart contracts (Box 3.3-16) to analyse its inventory, sell licenses and thus accumulate capital 'itself'. It led to a considerable media response and inspired the interdisciplinary BMBF-funded joint research project called 'terra1', which seeks a constructive societal debate "on the future design of the bioeconomy using the example of digitalization in the wood-based bioeconomy on the basis of innovative participation formats" (terra1, no date). An "algorithm-supported, multi-criteria approach to participatory decision-making" makes it possible for experts and the public to discuss ideas from multiple perspectives in the course of a "ForestLab online dialogue" and to collectively develop them further (zebralog, no date).

The initial feedback suggests that there are key problems here, too, that need to be addressed before developing and applying digital solutions or that transcend them. For example, the people involved are to be taught digital skills through education. Yet it has been shown by discourse analysis that conflicts of values and goals cannot be directly negotiated, nor can they be processed in a meaningfully machine-readable way – they must be decided, not computed (Królikowski et al., 2017). For example, even the input for automated 'decision-making' requires political decisions that can only be meaningfully made democratically by humans. In the view of the project management, even if blockchain is used as the process, it is not really necessary; but there is a need for a public discourse and further research to improve its energy demands.

Table 3.5-1
The 20 currently developed bio-based materials with the best business prospects over the next 5–10 years.
Source: own compilation based on EU Commission, 2018b:5

Biomass category	Currently developed bio-based materials	Main fields of application (selection)
Lignin (cementing substance in the cell structure of wood)	› Lignin-based carbon nanofibres › Organic BTX aromatic compounds › Lignin bio-oil › High-purity lignin › Bio-based phenol and alkylphenols › Lignin-based phenolic resins	Carbon materials, automotive parts, tools, special chemical products, material reinforcement, fuels, adhesives and composites, textiles, sports equipment
Plant fibres	› Natural-fibre-reinforced lignin composites › Microfibrillated cellulose › Natural-fibre-reinforced thermoplastic biopolymer plastic › Natural-fibre-reinforced bio resins › Composite nonwovens	Nonwoven binders, plastic reinforcement, insulation foam, paper reinforcement, filters, hygiene articles, antimicrobial films for bone reconstruction, aircraft or car parts, lightweight components, various consumer goods for homes and gardens
Renewable oils and fats	› Bio-lubricants › Polyhydroxy fatty acids › Bio-based polyamides	Automotive industry, construction industry, electronics industry, food industry, medical technology, cosmetics
Polyelectrolytes (macromolecules containing groups capable of dissociation)	› Antibacterial biosurfactants › Biotechnological chitosans	Agriculture, pharmaceuticals, cosmetics, textile industry, food industry, biomedicine
Terpenes (organic aroma- or flavour-bearing compounds)	› Limonene-based machine polymers	Machinery, footwear, tires, coatings, insulation, medical products
Natural rubber	› Guayule rubber	Truck and aircraft tyres, car parts, medical products
Urban biowaste	› Polyhydroxy fatty acids › Volatile fatty acid mixtures	Packaging materials, fibres, biomedical cosmetics, plastics, paints and aromas/flavouring, foodstuffs

CO_2-saving approaches. Ominous future scenarios involving high levels of biomass use (as e.g. in Piotrowski et al., 2015) can be prevented if most of the corresponding demand can be met by other renewable energies or with lower resource consumption – or avoided completely. Such alternatives could become more cost-effective or attractive simply because biomass will become scarcer and thus more expensive. However, this assumes that the external costs of biomass use (e.g. impairment of biodiversity) are adequately internalized or prevented, and that regulations apply internationally, so that they cannot be undermined by foreign trade. In general, the demand for primary materials can be reduced by more economical use, improved product and material efficiency, non-destructive recycling and more durable products (Gutowski et al., 2013; Allwood et al., 2010). However, with constant or perhaps increasing output, even electricity from renewable sources, increased energy efficiency and higher recycling rates in many industrial sectors (steel, cement, plastics, paper, aluminium) will not be enough to achieve ambitious climate targets.

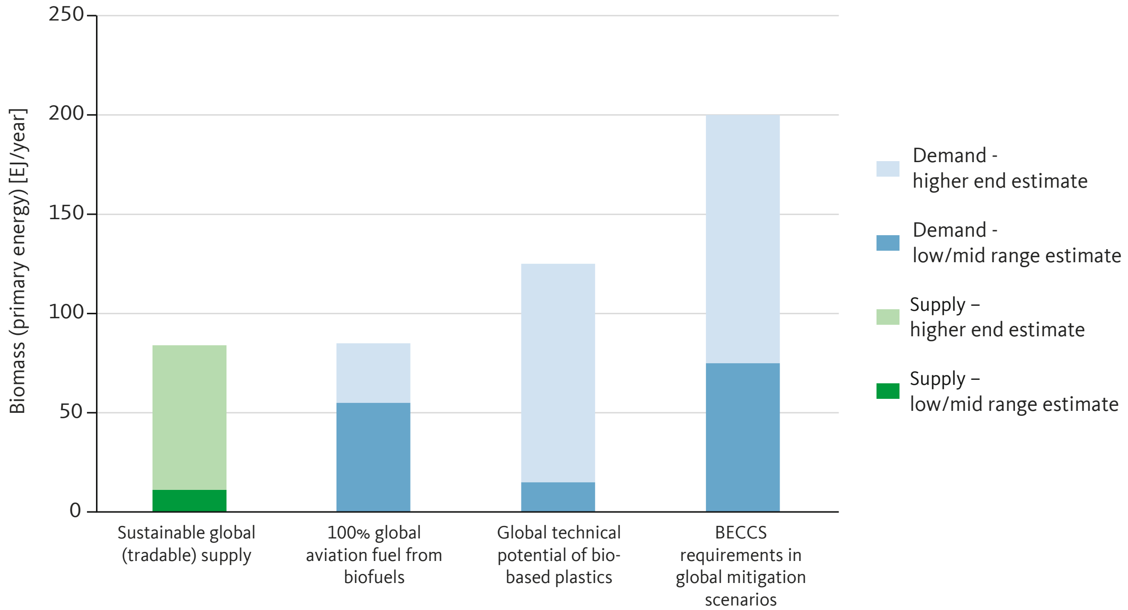


Figure 3.5-2
Global sustainable supply of biomass and demand potential for key end uses in 2050. On the supply side, the sustainably produced biomass (minus food) available on international markets is estimated; the low figure is below that of today (about 23 EJ per year) and assumes, among other things, strong population growth and meat consumption, but little innovation and sustainability governance (the reverse applies for the high estimate). The demand margins result, inter alia, from uncertainties in conversion efficiency (fuels), deployment options and resource efficiency (plastics), and different IPCC climate-change scenarios for 1.5°C or 2°C limitation targets (BECCS).
Source: CCC, 2018: Figs. 4.3 and 5.1

3.5.2 Vision and important fields of action for a sustainable bioeconomy

3.5.2.1 Vision of a sustainable bioeconomy

The problems and areas of potential that have been outlined suggest the following vision for a sustainable bioeconomy – in the sense of orientation markers for the recommendations presented later. The vision consistently takes account of the overarching requirements of sustainable land stewardship (Section 2.3).

1. *The amount of biomass used for materials and energy is within planetary guard rails and takes the high priority of food and biodiversity into account:* Climate and biodiversity, intact ecosystems, water and material cycles and fertile soils are protected by coordinated regulatory and incentive-based instruments (Chapter 2, Sections 3.1–3.3). Sustainable management secures the food supply for the world's population and limits both the quantity of additional biomass that can be produced or harvested for the bioeconomy, and what methods may be used (Fig. 3.5-3).
2. *Fair economic production structures and distribution mechanisms are established:* Stable, local opportunities to access and use food, which are necessary for food security (Gross et al., 2000), are not jeopardized by the economic incentives of additional biomass use; rather, they are actually strengthened where possible (e.g. because the valorization of agricultural by-products diversifies and supplements local sources of income without displacing food production). The higher land revenues resulting from the bioeconomy are skimmed off and the tax revenues used to solve global and local distribution issues and to create incentives for local actors to conserve ecosystems, biodiversity and soils. Basic foodstuffs are affordable for all population groups; the land rights and economic, social and political inclusion of indigenous and local population groups are respected.
3. *Biomass is used where there are no climate-friendly alternatives for avoiding CO_2 emissions and storing carbon:* In order to avoid CO_2-emitting processes and fossil raw materials in all sectors (as an energy source and as a source material from which carbon compounds are released into the atmosphere), scarce biomass is used as a priority where its material properties are particularly important for substituting fossil raw materials, or where it is effective as a long-term carbon store. Otherwise, non-bio-based

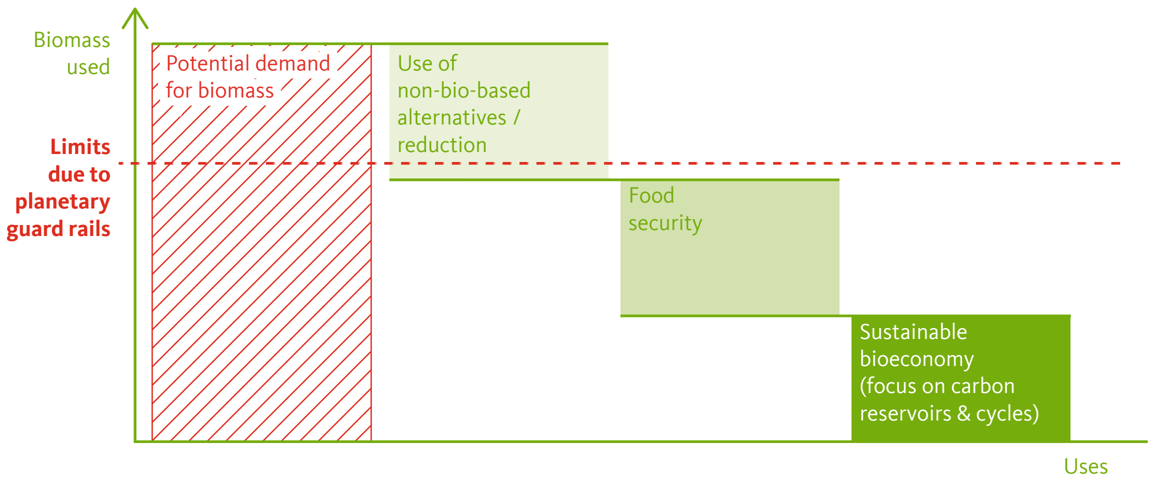


Figure 3.5-3
Biomass available for material uses and for generating energy within the framework of a sustainable, circular bioeconomy in accordance with the WBGU's vision (in particular elements 1, 3 and 4; schematic, proportions inconclusive).
Source: WBGU, graphics: Ellery Studio

climate-friendly alternatives are used to reduce the demand for biomass, which are already often economically more favourable today (Box 3.5-3; Fig. 3.5-3).

4. *Innovations and circular-economy approaches increase efficiency and useful life:* Due to the limited supply of biogenic primary raw materials (and possibly due to corresponding prices), their 'range' is optimized. Extracted biomass is used in various applications and (high-value) forms in cycles and cascades (Box 3.5-2), first materially, which also increases the size of the carbon store, and only thereafter for energy generation (where appropriate in combination with CCS). Residues from the bioeconomy are returned to the natural cycles where this is essential for their conservation and restoration (e.g. phosphorus from bioenergy residues). In addition, the material efficiency as well as the use and capacity utilization of material goods are improved by ongoing innovations.
5. *Local diversity is harnessed and used to boost resilience:* The bioeconomy contributes to the maintenance of cultural diversity and to the inclusion of the rural population (Box 2.3-1) by making use of local knowledge and traditions, supporting rural areas economically, especially via timber-based construction (Purkus et al., 2020), and making urban and rural areas more resilient through their functional interaction. The economic diversification made possible by the bioeconomy and the extended sources of income also increase resilience, in conjunction with the use of region-specific and social innovations, consolidated local production systems and the closure of local material cycles. This also reduces climate-damaging transports (priced according to their externalities).
6. *The adaptively developing, sustainable bioeconomy is embedded into a larger, inclusive transformation process:* The bioeconomy contributes to the Great Transformation towards Sustainability via participatory processes that help resolve conflicts of use and provide new ideas (Chapter 4; WBGU, 2011). This is particularly important if non-bio-based alternatives in the energy sector and efficiency improvements are not sufficient to completely replace fossil raw materials and climate-damaging processes. Then, biomass use can only be kept within sustainable limits if energy and material consumption are reduced by socio-institutional innovations, especially in industrialized countries and for selected goods (Box 3.5-2 on advanced circular-economy strategies).

Bioeconomy principles are also formulated, for example, by the International Sustainable Bioeconomy Working Group (FAO, 2019f). By comparison, the WBGU emphasizes the prioritization of resource-conserving, long-term carbon-storing material applications over energy applications; the limits of biomass use; a comprehensive concept of integrated technical and ecological cycles; and embedding the bioeconomy into a broader transformation towards sustainability which is required for a new, responsible land stewardship.

Box 3.5-2

Circular economy and circular bioeconomy

The global growth in the consumption of resources (Circle Economy, 2020), the ecological damage associated with resource extraction and disposal, and new digital support options (WBGU, 2019b) make the circular economy the key to more efficient use of both mineral and biogenic resources. For example, in the EU – in addition to many activities by member states (Ecopreneur.eu, 2019) and e.g. the Circular Economy Initiative in Germany – the new Circular Economy Action Plan (European Commission, 2020e) is a core element for implementing the European Green Deal (European Commission, 2019c) and aims, among other things, to decouple economic growth from resource consumption. Specifically for bio-based raw materials, the EU's bioeconomy strategy aims to "focus attention on sustainability and the circular economy" (European Commission, 2018a: 1). Internationally e.g. the USA, Japan, South Korea (Ghisellini et al., 2016, Herrador et al., 2020) and above all China (Mathews and Tan, 2016; Zhu et al., 2019; Pesce et al., 2020) are also pursuing ambitious circular-economy strategies.

The circular-economy concept emerged increasingly from the 1970s onwards as an alternative to the 'linear' economy (take-make-consume-dispose)); it was initially applied with '3R' approaches (reduce, reuse, recycle) primarily to waste management. Preventive approaches inspired by industrial ecology (Ayres, 1989) emphasized technical innovations, small-scale material cycles and economic opportunities. Today, broader supply chains and more stakeholders (consumers, NGOs, governments) are usually systemically included, and adapted business models and social innovations are also involved (Reike et al., 2018; Prieto-Sandoval et al., 2018). The circular economy is defined as a situation where "the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized" [European Commission, 2015c:2]. Operationalizations of the circular economy (Kirchherr et al., 2017; Reike et al., 2018) differ, among other things, in their emphasis on different 'value retention' options (items R0-R9 in Fig. 3.5-4; Potting et al., 2017).

In practice, mainly approaches of traditional waste management, such as material recycling (R8) or energy recovery (R9), have hitherto been given hard targets (Reike et al., 2018) and implemented on the basis of new technologies (Fig. 3.5-4 right), in the bioeconomy e.g. for compostable plastics (Potting et al., 2017). Nevertheless, resource consumption continues to rise because options based on product, business-model and social innovations have been underused up to now (Potting et al., 2017; Reike et al., 2018). In particular, options that are close to the customer and aim to use products sparingly (R0-R2), extend lifespans (R3, R4) and thus reduce the quantity of products required (Reike et al., 2018) threaten existing business models and create potential for conflict. In the WBGU's view, however, precisely such strategies are needed to reduce overall resource requirements and in this way to also limit demand for biomass (Section 3.5.2, points 1 and 6).

Specifically to ensure the sustainable use of biogenic resources, in addition to applying general circular-economy approaches (in the sense of a 'bio-based circular economy'), these strategies should be extended and/or priorities set towards a sustainably circular bioeconomy (Hetemäki et al., 2017; Antikainen et al., 2017; EEA, 2018; Carus and Dammer, 2018; D'Amato et al., 2017, 2020; Stegmann et al., 2020), e.g. for carbon storage and including nutrient cycles. The 'range' of efficient biomass use can be significantly increased by means of cascade use in which "a biogenic raw material is processed into a bio-based final product and this final product is used at least once more either for material or energy purposes" (UBA, 2017a:27). By gearing technical innovations and product designs towards the circular economy, more durable and less polluting biogenic materials and products can be kept in cycles for longer or used in cascades. At the end of their use, they can be separated and reused where appropriate or, even as waste, can still be used as fertilizers and chemicals (Hetemäki et al., 2017:14; Antikainen et al., 2017: 109; Carus and Dammer, 2018; Stegmann et al., 2020). In this context, the use of biodegradable plastics for example, with their particular challenges for collection, sorting and recycling, should also be weighed up (EEA, 2018:36). Integrated biorefineries can process various biological raw and waste materials relatively completely and efficiently into fodder, materials, chemicals and fuels, thus opening up new usage cycles. Today, however, they are used primarily for biofuel production (Temmes and Peck, 2020).

To ensure that these technologies not only make the use of biogenic resources more efficient (and potentially promote rebound effects; Zink and Geyer, 2017) but also reduce resource consumption, the WBGU recommends setting the following priorities. First, the bioeconomy as a whole should be given a framework that promotes circularity:

1. *Political momentum for the circular economy should be used to lay down explicit, ambitious targets for absolute reductions in the consumption of resources in general and biomass in particular:* The new EU circular-economy strategy has set the target of doubling the percentage of materials in circular uses by 2030 – in 2017 it was 8.6% (Circle Economy, 2020) – and of reducing the EU's "consumption footprint" [European Commission, 2020e: 2]. Germany's sustainability strategy (Bundesregierung, 2018) contains only the target of raising resource productivity by 1.6% per year. Given the acute ecological crisis (Chapter 2), neither of these objectives is ambitious enough. Concrete EU and German targets for reducing absolute resource consumption with sub-targets for biomass would initiate societal and economic processes for a timely transformation beyond detailed targets and support measures for the circular economy.
2. *Lay down specifications for the sustainable production of biomass used*: Incentives and regulations on sustainability for all traded biomass (Sections 4.2, 4.3) make biogenic resources scarcer. This creates incentives for efficiency gains through circular use (incl. product-as-a-service business models, reprocessing, sharing economy) and by prioritizing longer material recycling over energy recovery, which also binds more carbon. To ensure that investments and the design of durable products are adapted in good time, sustainability targets should follow a clear path of increasing ambition that remains reliable in the long term (Section 4.2).

Additional policy measures should specifically reduce barriers to circular approaches (e.g. information asymmetries, barriers to market entry, externalities and public goods). The new EU circular-economy strategy (European Commission, 2020e) already contains many important measures, e.g. on eco-design, consumer information, monitoring of raw-material and product flows, and sector-specific approaches. The WBGU recommends emphasizing or adding the following topics, among others:

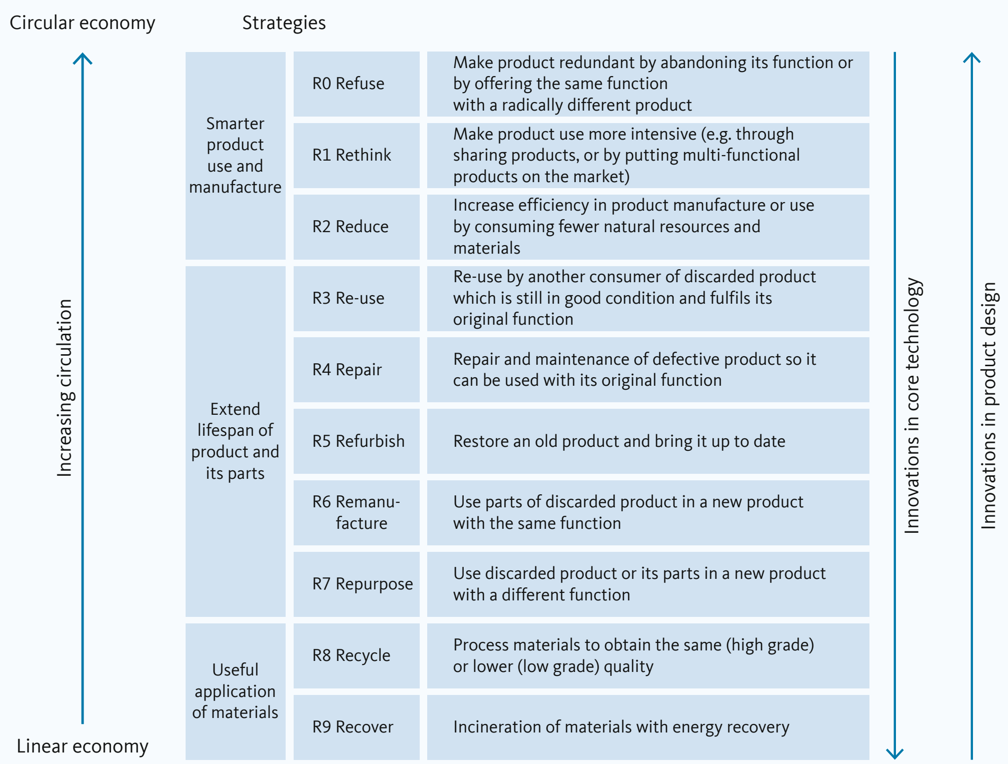


Figure 3.5-4
Possible strategies for operationalizing the circular economy (value retention options R0–R9) and associated innovation needs (right).
Source: Potting et al., 2017

3. *Conflicts of interest between existing and new business models* should be made explicit and discussed transparently in the context of promoting (circular-economy) innovations to reduce the amount of products.
4. *Social costs should be internalized comprehensively along the product life cycle*: The fact that this has been neglected up to now has favoured 'linear' business models. Consumer protection should be incorporated by obligations relating to design, liability, guarantees and information (eco-design, extended producer responsibility e.g. including differentiated payment obligations, reparability, availability of spare parts).
5. *Strengthen markets for secondary raw materials and products:* Actor coordination along cycles should be improved, e.g. using digital platforms, since the recovery, reuse and recycling of products and materials requires a lot of cooperation (Potting et al., 2017; Antikainen et al., 2017: 109). Meaningful measures include, for example – for manufacturers – design specifications on the separability of materials, and – for (large-scale) consumers and disposal companies – specifications on sorting and quality standards that have been agreed with secondary users. Public procurement should, for example, give preference as far as possible to recycled products and sharing models.

3.5.2.2
Important fields of action for a sustainable bioeconomy

Before Sections 3.5.4 and 3.5.5 formulate recommendations for the implementation of a sustainable bioeconomy, it is necessary to identify from among the energy, material and carbon-storage applications those which have most potential and low or manageable risks with respect to climate-change mitigation, biodiversity and nutrition, which can contribute to societal transformation and which therefore seem especially worthy of support. Above all, sustainable construction with wood is in line with the above-mentioned vision. Following brief assessments of bioenergy, BECCS (Box 3.5-3) and bioplastics (Box 3.5-4), it is singled out as a promising multiple-benefit strategy of the bioeconomy (Section 3.5.3).

As already briefly discussed, in view of the scarcity of biomass, in order to select the most important bioeconomy sectors it is essential to avoid biomass uses for which climate-friendly technical alternatives exist. This applies both to some industrial applications and to most energy-related applications, for which the material properties of biomass are irrelevant. Energy-related emissions account for almost two-thirds of global GHG emissions (one-third for heating; Bajželj et al., 2013). To reduce pressure on land, other options can first be exhausted before using bioenergy (BE): for example, it is important to first increase energy efficiency, insulate buildings, and change mobility behaviour to reduce the demand for energy (IPCC, 2014a, 2018; Grubler et al., 2018). For electricity generation, wind power and PV are often cheaper and up to a hundred times more land-efficient than BE (EASAC, 2019). Heat for households and industry can be provided by solar and geothermal energy on an electricity base, including heat pumps and hydrogen or possibly methane generated with electricity (Götz et al., 2016). For land-based transport, the focus should be on shifting transport away from roads, on efficient and shared means of transport, and on extensive electrification instead of biofuels (SRU, 2017: Chapter 4; Connolly et al., 2014; Kreyenberg et al., 2015). The most important need for substitution as regards current uses of BE, in terms of quantity and for health and environmental reasons, relates to traditional cooking and heating, above all using wood (Box 3.5-3). Where electrification is not yet possible or efficient because of the energy density required, energy sources such as hydrogen or synthetic fuels can be used, e.g. in aviation and shipping. Batteries, hydrogen, power-to-gas technologies and pumped storage power plants make it possible to balance up a volatile electricity supply from wind and solar energy. While bioenergy can be used as a bridging technology for such energy sources or as a flexible energy source (Reid et al., 2020; Bogdanov et al., 2019), this should be done responsibly and sustainably, primarily using waste and residual materials (acatech, 2019; Box 3.5-3) at the end of biomass-use cascades (Box 3.5-2). In combination with CCS, BE can then also contribute to the removal of CO_2 from the atmosphere, as one of several approaches to creating new sinks (Section 3.1). However, the realistic potential of BECCS that can be sustainably reconciled with biodiversity and food security is much lower than what would be required in some scenarios where energy or resource consumption would continue to grow (IPCC, 2018: scenarios P3, P4; Roe et al., 2019). They should therefore be the subject of further research regarding their overall impacts and accompanied by risk management, rather than being at the centre of climate-change-mitigation strategies (Sections 3.1.4, 3.1.5; Box 3.5-3).

There are also alternatives to some material uses of fossil resources: parts of the petrochemical industry, such as nitrogen fertilizer production, can be converted from fossil base substances to electrolytically produced hydrogen instead of biogas. The chemical industry is the biggest industrial consumer of oil and gas – yet half of this is used for material purposes rather than for generating energy (so that the associated CO_2 emissions from use or disposal are attributed to other sectors, such as agriculture or waste management; IEA, 2019). The production of 18 (out of several thousand) chemicals accounts for 80% of the chemical industry's energy consumption and 75% of its GHG emissions (IEA, 2013), including, above all, the production of nitrogen fertilizers (with ammonia) and synthetic rubber and plastics (including ethylene, propylene). In the production of nitrogen fertilizer, the biggest lever is the low-emission supply of hydrogen for the Haber-Bosch process for synthesizing ammonia, which is currently obtained from fossil sources with high process emissions and a lot of CO_2-intensive energy (Xu et al., 2019). In the future, the electrolysis of water using renewable energy, for example, can be used here (Capdevila-Cortada, 2019); as a non-land-based strategy, it likewise takes pressure off land use.

In other chemical and further industrial applications, however, there are (as yet) no practicable alternatives to using biomass as a substitute for fossil raw materials and emissions-intensive processes. Accordingly, the demand for biomass should first be reduced by demand-side measures and the reach of the raw materials increased by circular or cascade use and efficiency improvements. This applies to substituting fossil and mineral base substances and avoiding emissions, especially in the extractive, construction and, in some cases, chemical industries. Otherwise, it will not be possible to fully meet the demand for biomass to replace fossil raw materials (and, if necessary, to compensate for emissions).

About a third of global GHG emissions is attributed to industry (Bajželj et al., 2013), mainly to the basic materials industries: chemicals (6.1%), steel (5.9%), cement (5.5%), non-ferrous metals (2%) and paper (1.8%). The construction industry, as the largest consumer (of cement, about half of global steel production, other metals and chemical products; Moynihan and Allwood, 2012), accounts for about 14% of total emissions and 44% of industrial emissions (Bajželj et al., 2013), or 5.7 Gt CO_2 in absolute terms (including the service life of buildings; Huang et al., 2018). In the future, population growth (to over 9 billion by 2050) and urbanization will further increase construction activity (WBGU, 2016a). The corresponding provision of conventional building materials by 2050 will account for the equivalent of the CO_2 budget for limiting climate change to 1.5°C or for one third of the budget for 2°C (Müller et al., 2013; IPCC, 2018). The scope for reducing emissions in the steel and cement sectors is limited, and they are only partially avoidable with CCS. However, bio-based building materials (especially timber) offer significant GHG-reduction potential by substituting GHG-intensive materials; they can also sequester carbon – up to 20 Gt CO_2 over the next 30 years (Churkina et al., 2020). Unfortunately, the quantity of wood required for this amounts to today's entire global harvest. Sustainable construction with wood is therefore regarded as a multiple-benefit strategy if the biomass required is reduced and sustainably produced through circular and cascade use (Section 3.5.3).

An analysis of bio-based plastics (Box 3.5-4) confirms that recycling and avoidance strategies for all types of plastic (bio-based and conventional) should be the focus in the medium term, since bio-plastics offer comparatively little potential for climate-change mitigation. The same applies to other industrial sectors like paper or textiles, which are already predominantly bio-based. Here, a reduction in consumption should be combined with the application of all the principles of the circular economy (Box 3.5-2), in order to lower the pressure on land and on water consumption by reducing the need for primary raw materials.

3.5.3 Timber-based construction as a multi-benefit strategy

Due to rising populations and urbanization, a global increase in construction activity is also expected to accompany urban growth (WBGU, 2016a). The use of land for continued settlement construction in many areas of the world creates conflicts with sustainable land use and calls for a responsible, sufficiency-oriented use of the required land. Moreover, the construction sector is responsible for 14% of global GHG emissions, mainly as a result of cement production and the use of steel (Bajželj et al., 2013). In addition, conventional construction has other environmental and social consequences, such as the use of sand (Box 3.5-6) or the increasing uniformity of inner cities (WBGU, 2016a). The most important climate-friendly alternative is to replace cement- and steel-based construction with timber-based construction. In this way, not only are material-related GHG emissions avoided, but carbon is also stored long-term. However, this increases the demand for wood, which can have a positive or negative effect on land use. The extent to which sustainable construction (Bauer et al., 2013) with wood in combination with other biogenic or climate-friendly materials and technologies can contribute to climate-change mitigation, food security and the conservation of biodiversity depends on the technical application possibilities, environmental impacts and the quantities of biomass that are potentially required and actually available; this establishes links between the construction industry, land use and forestry. During implementation, it is also important to bear in mind that the construction sector is strongly shaped by culture, "with significant institutional and technological lock-in in local building practices" (Leskinen et al., 2018). Ambitious timber-construction strategies imply a transformation of urban architecture, value chains and the actors involved, and make it necessary to break up path dependencies in the construction industry. This has consequences for practice, for which barriers to implementation are analysed, instruments are identified and recommendations for action and research are made in the following.

The most important sustainability contribution of timber-based construction is to climate-change mitigation (Purkus et al., 2020). This is also the focus here. However, positive effects are also possible for the other two trilemma dimensions of food security and biodiversity conservation. For example, the additional demand for wood diversifies the income options for smallholders, and economically justified reforestation can provide more near-natural habitats for native animals and plants, provided that the timber cultivation is sustainable and near-natural. Timber-based construction is therefore a multiple-benefit strategy if biomass consumption by the bioeconomy as a whole is limited (Section 3.5.2.1) and forestry is sustainable.

However, it is no less important to exploit GHG savings potential in conventional construction (Box 3.5-5) wherever possible. Depending on the speed with which sustainable construction can be established, the amount of wood that is available from sustainable forestry, the limited amount of usable forest land that is available and the demand for buildings, there will still be conventional construction in the coming decades. Timber-based construction is not equally suitable for every region, and sustainable construction methods have not yet been found for all construction tasks. Renewable energy, energy efficiency, different or reused materials and, where appropriate, CCS should therefore be used to also rapidly reduce GHG emissions from conventional construction methods.

3.5.3.1 Potential of timber-based construction as a supplement and alternative to conventional construction methods

While non-bio-based approaches can only partially reduce the construction industry's GHG emissions (Box 3.5-5), timber-based construction has multiple benefits and great overall potential for climate mitigation, also from a global perspective. Timber-based construction not only helps avoid the emissions of cement and steel production, it also stores carbon long-term. Most of the

Box 3.5-3

Bioenergy and BECCS

Energy-related applications are the second-largest consumer of biomass after food (Fig. 3.5-1). Bioenergy (BE) covers 13% of primary energy consumption worldwide (70% of the renewable share), and about half in Africa. Solid fuels like wood are the main energy source (86%), and direct heat generation is the most important end use (72%, 2017 data; WBA, 2019). Inefficient traditional use of BE for cooking and heating dominates, especially in developing countries and emerging economies, contributing to respiratory diseases and ecosystem degradation. In addition, there are many forms of modern BE, e.g. liquid biofuels (7% of the biomass used for energy; WBA, 2019). Again, the type and extent of biomass harvesting is not always sustainable. Climate-change-mitigation strategies that rely on an excessive expansion of BE, with or without CCS, risk exacerbating other problems (WBGU, 2009). A dual strategy is therefore necessary: many of today's BE uses should be reduced or adapted, and climate-change-mitigation strategies should be chosen that do not require much BE(CCS).

Traditional BE use is particularly important for poorer populations in rural regions of developing countries and emerging economies (Chum et al., 2011; WBGU, 2005, 2009), where 2.8 billion people use solid fuels for cooking (Bonjour et al., 2013), heating or lighting. In many countries, above all those in sub-Saharan Africa, over 90% of household energy consumption is based on biomass. Wood, charcoal, crop waste and dung are widely and cheaply available, unlike access to modern fuels or electricity (Legros et al., 2009), and are related to cooking habits (Masera et al., 2015). However, the energy efficiency of traditional BE use is low at 10-20% (Chum et al., 2011), and causes considerable damage to health and the environment: it consumes 55% of the global timber harvest (90% in Africa, 66% in Asia), of which up to a third is unsustainable (above all in South Asia and East Africa) and contributes to forest degradation, deforestation and CO_2 emissions (Bailis et al., 2015; Masera et al., 2015). Bailis et al. (2015) estimate related emissions in 2009 at 1.0-1.2 Gt CO_2e. This figure includes both long-lived GHGs and short-lived gases and aerosols such as soot from incomplete combustion, whose climate impact is only partially comparable to CO_2. Smoke and fumes in residential areas cause approximately 3.9 million premature deaths every year (Smith et al., 2014b). Combatting energy poverty, i.e. the "lack of sufficient access to energy services in order to meet basic needs, that are affordable, reliable, high-quality and safe, and cause no undue health or environmental impacts" (WBGU, 2009:363), is essential for poverty reduction, a prerequisite for achieving the SDGs, and is being championed internationally, for example by the Safe Access to Fuel and Energy (SAFE) Humanitarian Working Group and the Global Alliance on Clean Cookstoves. However, the spread of improved combustion technologies, pre-processed biofuels and solar stoves, or access to electricity, have to date only sporadically led to a significant fall in biomass consumption. Rather, new and old technologies are frequently used in parallel (Masera et al., 2015), and sometimes more efficient stoves are wrongly or little used (Hanna et al., 2016). Recent research emphasizes the importance of locally adapted, low-maintenance stoves which should be widely available via robust supply chains and affordable (if necessary through subsidies; Pattanayak et al., 2019; Bensch and Peters, 2019; Jeuland et al., 2020).

Modern BE includes more efficient technical processes for producing heat, electricity, liquid and gaseous fuels. It uses secondary wood-based energy sources (e.g. wood pellets, wood chips, inter alia from short-rotation plantations), crop biomass (e.g. maize, sugar cane, palm oil, rapeseed, fast-growing grasses), agricultural residues or biogenic municipal and industrial waste (Chum et al., 2011). Modern BE use has a markedly lower primary-energy share than traditional BE; e.g. only 1.1 EJ of heat is generated centrally (of which 87% in Europe), but 40 EJ directly. However, use is growing steadily thanks to the many, flexible conversion technologies also available for waste and residual materials, the correspondingly broad availability of raw materials and to political support. In the transport sector, liquid biofuels (70% of which are produced in the USA and Brazil) cover about 3% of energy demand (3.5 EJ), mainly in road transport, almost three times as much as electricity. When it comes to electricity generation, BE's share is higher than PV's at about 2% (2.1 EJ), but less than that of hydro and wind power (all data for 2017, WBA, 2019). International trade in BE accounts for only about 2% of total consumption, but is growing significantly (Junginger, 2018). The EU is the main importer, already importing a third of its wood-pellet needs, 7% of its biodiesel and 4% of its ethanol (Proskurina et al., 2019). However, the growing consumption of biomass by modern BE is associated with ecosystem degradation, land-use changes and the displacement of food production (Muscat et al., 2020). In some areas, this has already led to adjustments in support instruments such as the Renewable Energy Directive (RED II; EU, 2018a). This now ties its promotion of BE – and in the transport sector the amount by which BE counts towards renewable-energy (RE) expansion targets – to criteria relating to GHG reduction, land use and sustainable production at the product and export-country level; it also restricts BE that is based on food and feed crops (Box 4.2-2; ICCT, 2018). However, the Directive should be further developed to prevent indirect effects between biomass types, the areas of land used, trade flows and other sectors of the bioeconomy (Sections 4.2.5.1, 4.3.3).

The importance of modern BE could nevertheless grow in the future in the context of climate-change-mitigation strategies. Its flexibility in the choice of fuel and deployment in different sectors, its storage capability and the relatively high energy density of liquid biofuels make BE a substitute for fossil fuels and a building block of an RE-based energy system (Rogelj et al., 2018; Reid et al., 2020). In combination with CCS, BE can remove CO_2 from the atmosphere over long periods (Section 3.1.1). In model calculations that determine cost-optimized decarbonization pathways for a given climate target, BE, when available, is predominantly combined with CCS. However, BE use is high even without CCS (Bauer et al., 2018; Box 2.1 in Rogelj et al., 2018) or is even increasing (Hilaire et al., 2019). In an IPCC assessment of 85 scenarios limiting climate warming to 1.5°C, the median primary-energy supply from biomass in 2050 will be 154 EJ (26%), 2.5 times the supply in 2020 (61 EJ or 10%; Rogelj et al., 2018: Table 2.6); the figure ranges considerably between 40 and 311 EJ depending on the availability, efficiency and cost of BE-conversion technologies and non-bio-based alternatives, biomass availability and demand trends. Up to 140 Gt of CO_2 could be stored by BECCS by 2050 (Rogelj et al., 2018: 135). 2.8 million km² of land – an area larger than Argentina – would be required for BE crops in a scenario generating 121 EJ of primary energy from BE in 2050 (IPCC, 2018: Fig. SPM.3b); it would also involve considerable land-use changes (Rogelj et al., 2018; Roe et al., 2019).

However, when interpreting these results, it is crucial to consider the assumptions that lie behind the model calculations. First, hopes of a rapid 'freeing up' of biomass and areas of land from traditional BE for more efficient, modern use have not yet materialized (Masera et al., 2015). Even if this were to change, the use of biomass and land would first have to be reduced to sustainable levels in many places (Section 2.1), rather than being diverted to modern BE uses. Second, it is to be feared that food production and ecosystem conservation will not prevail against strong climate-change-driven demand for BE and that indirect effects on land use cannot be avoided (WBGU, 2009). A large-scale expansion of agriculture and forestry, as well as water and fertilizer use for BE are associated with high ecological and social externalities, especially in developing countries and emerging economies (Roe et al., 2019; Section 3.1-3.3). Third, the CO_2-reduction potential of BE and BECCS might be lower than expected. Even large resource inputs do not necessarily increase biomass yields, and there are limits to these inputs (Creutzig, 2016). The necessary large BECCS plants and storage sites might not be feasible for technical, economic or political reasons (acceptance of CCS). In addition, agriculture and biomass processing cause emissions and climate-related biophysical changes, and CCS requires energy (Roe et al., 2019). Other methods for removing CO_2 from the atmosphere might not be sufficient to compensate for unexpectedly low BECCS effects, and each of them will also entail specific risks (Minx et al., 2018; Section 3.1.1). Fourth, climate-change-mitigation strategies that rely on high negative emissions in the future distract from the technological developments, political decisions and societal transformations that are needed now for a less risky path with faster emission reductions ('moral hazard'; Anderson and Peters, 2016; Section 3.1.1.3).

Paths with significantly less BE and BECCS are possible: IPCC scenarios – and other scenarios at the lower end of the range for BE given by the IPCC which, in some cases, do not use BECCS at all to achieve a 2°C or even 1.5°C target – require a big reduction in energy demand, a massive expansion of photovoltaic and wind power, changes in dietary habits and moderate population growth. Some of them rely on algae-based BECCS or other NETs (van Vuuren et al., 2018; Obersteiner et al., 2018; Grubler et al., 2018; Bogdanov et al., 2019; Roe et al., 2019; IPCC, 2018: scenario P1). Roe et al. (2019) outline a 'land-sector roadmap for 2050' according to which land-based measures could contribute about 30% of the necessary emission reductions (15 Gt CO_2 eq per year), including 1.1 Gt CO_2 per year from BECCS on 34–180 Mha of land. This would primarily come from biomass cultivation on 'marginal land' near CCS storage sites (Turner et al., 2018) in the US, China, Russia and Canada. Overall, however, there is no uniform definition of marginal land. In a broader sense, this is land that is unsuitable for food production but is frequently used for grazing, including ecologically valuable and biodiversity-rich biomes such as grassland ecosystems with a very high soil carbon content. Here it is necessary, where appropriate, for internationally binding standards to be established (e.g. by UN-Energy or within the framework of the Global Bioenergy Partnership) and to carefully weigh up, on a region-specific basis, in which cases it is possible to use marginal land sustainably.

In view of the risks and existing alternative strategies, the WBGU believes that expanding the use of biomass for energy generation (with or without CCS) should not be seen as a central pillar of climate-change-mitigation strategies; rather, it should be seen in terms of risk limitation by restricting it to certain types and applications of biomass. Instead, decarbonization pathways that require less BE or BECCS should be investigated and pursued. In accordance with the characteristics of a sustainable bioeconomy (Section 3.5.2), the following orientation would make sense:

- *Tighten and extend sustainability requirements for biomass*: In the short term, when implementing EU RED II into national law, the EU member states should use their available scope to tighten up regulations (Transport & Environment, 2020; Box 4.2-2) in parallel with strengthening and tightening up the EU Timber Regulation (Box 3.5-8). In the medium term, a consistent system of incentives and mandatory sustainability requirements should be developed for all biomass traded in the EU at the product and export-country level with more specific climate-oriented, ecological (e.g. water, soil, biodiversity) and social criteria (Sections 4.2.6, 4.3.3). In this context, the focus on waste and residual materials should be maintained for BE, and criteria for avoiding induced land-use changes (e.g. caused via high energy prices due to rising CO_2 prices) should be tightened and made mandatory.
- *Research and take into account distribution effects of BE policy:* The effects of BE policy on food and land prices as well as for 2.8 billion traditional biomass users and small bioenergy producers should be anticipated and addressed by complementary policy instruments (Sections 3.5.4.2, 4.2.5.3).
- *Exploit non-bio-based technologies for new and existing uses:* In addition to further research and expansion of 'classical RE', electrification and alternative modern energy sources such as hydrogen, greater attention should be paid to overcoming energy poverty (SDG 7) in developing countries and to more efficient, cleaner traditional BE (Section 3.5.4.2). Better cooking devices could, for example, reduce GHG emissions by up to 0.8 Gt CO_2 eq per year and achieve considerable health effects (Roe et al., 2019).
- *Increase range and reduce residual emissions in key BE applications,* e.g. by means of demand-reduction measures and application-side efficiency improvements in conversion technologies where BE is needed for a transition period, and prioritize the material use of biomass in cycles and cascades. However, this applies to the entire bioeconomy (Section 3.5.4.2)
- *Hold BE users accountable for ecosystem conservation,* e.g. when recycling BE residues (above all mineral nutrients such as phosphorus from BE residues; Tan and Lagerkvist, 2011; Lin et al., 2015) and for maintaining the water balance.

Box 3.5-4

Decarbonization of plastics production without massive use of biomass

Initial situation and technical possibilities for decarbonization

The manufacture and disposal of plastics causes 3.8% of global GHG emissions, and this could quadruple by 2050 (Zheng and Suh, 2019: baseline scenario). The energy-intensive manufacturing phase accounts for 91% of the emissions, so that the use of renewable energies could make a substantial contribution to reducing emissions from plastics manufacturing. Further emissions occur during the combustion or decomposition of the carbon-containing plastic. Global fossil-based plastics production is estimated at 407 Mt (in 2015; Geyer et al., 2017); mainly in China (36%), EU (17%) and NAFTA (14%; 2018 data; CEFIC, 2019). Table 3.5-2 shows the distribution of production and disposal.

Bio-based plastics can be produced from various raw materials such as sugar, starch, vegetable oils or cellulose (Behnsen et al., 2018: 28). These can be biodegradable, but durable plastics that do not differ chemically from fossil-based plastics and can be used in exactly the same way are also possible; however, they also have the same environmental impact. Current estimates of bioplastics production range between 2 and 7 Mt depending on definition (European Bioplastics, 2019; Geyer et al., 2017; Chinthapalli et al., 2019). This would correspond to an agricultural land share of 0.02-0.07% and around 4% respectively if today's amounts of conventional plastic were to be completely replaced (extrapolation based on European Bioplastics, 2019).

Replacing fossil base substances with bio-based ones can improve the emissions balance and store carbon. Plastic that is in use removes only a small amount of CO_2 from the atmosphere in the long term (Table 3.5-2): only 5% of bio-based plastic is used for building and construction, 12% in the automotive and transport sectors, the rest for much shorter-lived products. Landfill disposal is of greater (but still minor) importance. The extent to which CO_2 is sequestered after use depends on waste recovery (recycling, energy recovery, landfill disposal and, where appropriate, decomposition), but the overall effect is also small (Hill, 2018).

However, in addition to bio-based plastics and the use of renewable energy, there are further ways of reducing emissions in the production and use of plastics:

1. *Efficiency gains in the manufacturing phase:* globally, current best-practice technologies could reduce emissions by 21% (Allwood et al., 2010).
2. *Carbon capture and use (CCU):* fossil carbon as a base material can in principle be replaced by CO_2, e.g. from power generation, industrial chemical processes such as burning lime for cement, or direct air capture (Section 3.1.1), but this requires further R&D. Some see a lot of potential here – Carus and Raschka (2018) believe about 300 Mt of CO_2-based plastic can be produced per year, i.e. almost 80% of today's production. In the case of plastics production using CO_2 from bioenergy, however, the effects on biomass and land use are analogous to those of directly bio-based plastics (which are the focus here). In addition, it should be noted that CCU only delays the release of CO_2 into the atmosphere, so that the climate effect depends on the lifetime and end-of-life use of the plastic products produced, and the material use of industrial CO_2 flows competes with CO_2 removal by CCS (Box 3.5-3); furthermore, CCU applications consume a lot of energy (acatech, 2018), which should be met from renewable sources.
3. *Recycling:* collecting waste plastic is still not very effective (the global recycling rate is 18%; Geyer et al., 2017) and the quality of recycled plastic is limited due to the mixture of different types of plastic and additives. In order to reduce mixing, biodegradable plastic also has to be sorted in an elaborate process (Soroudi and Jakubowicz, 2013). Conservative estimates consider a global recycling rate of 28% to be realistic (Gutowski et al., 2013); in Europe, an average of 32%, in some countries around 40% of plastic waste is recycled (PlasticsEurope, 2019; only part of this becomes recyclate; Heinrich Böll Stiftung and BUND, 2019). However, due to low prices for fossil base substances, there is currently little incentive for further improvement and innovation, or for building the necessary infrastructure (Zheng and Suh, 2019).
4. *Other circular economy strategies:* reuse (without liquefaction) to reduce the amount of plastic for disposal (e.g. reusable bottles); substitution of used plastic by lower-emission alternatives; reduction of the plastic content in products 'by design'; reduced demand for products

Table 3.5-2
Global (primary) plastics production and plastic waste in 2015 by industrial sector.
Source: Geyer et al., 2017: Table S5 (SI)

Sector	Primary production 2015 [Mt]	Share [%]	Primary waste generation 2015 [Mt]	Share [%]
Packaging	146	36	141	47
Construction	65	16	13	4
Textiles	59	14	42	14
Consumer goods	42	10	37	12
Transport / Vehicles	27	7	17	6
Electrics / Electronics	18	4	13	4
Industry / Machinery	3	1	1	0
Others	47	12	38	13
Total	**407**	**100**	**302**	**100**

with plastic uses, e.g. avoidance of products with non-returnable packaging, sharing models (Box 3.5-2).

Overall impact, quantification and core problems

Among the options mentioned, only replacing fossil base materials by bio-based ones is directly related to land use. Zheng and Suh (2019) compare this to RE deployment, recycling and reduced demand growth. Their model calculations show that a complete switch to RE can reduce emissions by 62% in 2050 relative to a baseline. Full recycling can achieve a 25% reduction, and both together 77% (or about 10% less than in 2015). Further GHG emission reductions could be achieved by reducing demand growth (about 65% reduction in emissions compared to 2015 at an annual growth rate of 2% instead of 4%). When renewable resources are used as the base material, the CO_2 benefit of climate-neutral or carbon-sequestering disposal by incineration or composting (with energy or gas recovery) or landfill disposal may be offset by induced emissions as a result of land use (Chapter 2). For example, 100% bio-based plastic (from sugar cane) reduces emissions by 25% – as much as 100% recycling, albeit here combined with an increase in land-use competition and thus an exacerbation of the trilemma. Bio-based but non-biodegradable plastics have exactly the same effect as fossil-based ones when distributed in the environment (Heinrich Böll Stiftung and BUND, 2019). All four options together can reduce emissions by 93% relative to the 2050 baseline, or about 75% relative to 2015.

Evaluation and recommendations

The potential reductions in emissions from non-land-based options are significant, especially by using renewable energies and reducing demand – the potential of which is far from exhausted in view of the large share of non-returnable packaging in plastics production (Tab. 3.5-2). Although recycling potential is limited, the non-land-based options for efficiency improvements in production and CCU, especially with CO_2 from process emissions, have not yet been considered. Thus, considerable decarbonization of plastics production seems possible even without a massive input of biomass; this should be prioritized in view of the competition for land use and the other environmental benefits associated with a reduction in plastics production and waste. Bioplastics will be needed on a larger scale than today in order to fully decarbonize the plastics sector and will therefore remain important. However, this is a small lever compared to other approaches such as changing dietary habits, bioenergy policy and timber-based construction, and the required land areas can probably be made available if progress is made in those areas. The most important sustainability strategies affect conventional as well as bio-based plastics (due to their chemical similarity and the limitations of biogenic raw materials) and are not land-based: the switch to renewable energies and efficiency improvements in production should be combined with a reduction in demand and with recycling measures (Box 3.5-2).

technologies are already available, but it is essential to take into account the potentially drastic consequences for land and forest use, and thus to link this strategy with regulations on sustainable forest management if these technologies are to contribute to defusing the trilemma.

Storing carbon in products made of wood is already contributing to climate-change mitigation today as an 'artificial sink' (Section 3.1; Rockström et al., 2017). Furthermore, timber-based construction has a positive cultural connotation, while CCS is less safe and less economical (He et al., 2011). Thus, timber-based construction is an important instrument both for reducing emissions and for removing CO_2 from the atmosphere (Section 3.1.1). However, this strategy is only sustainable if the corresponding demand for wood, as part of the bioeconomy, is reconciled with adherence to planetary guard rails and food security (Section 3.5.2).

When it comes to the possible applications of timber-based construction, it is necessary to stipulate which building methods and construction elements timber is suitable for, i.e. which materials can be replaced in which applications. Biogenic materials are available for almost all structural elements: concrete can be replaced by wood in most cases, reinforced concrete as a load-bearing element by (solid or laminated) timber. Among the wood types, deciduous wood is often used in the form of laminated wood products, coniferous wood as solid timber for load-bearing elements; sawmill by-products can be glued. Local woods are the first choice due to the low transport costs and traditional construction methods practised by 1 billion people in Asia and 150 million in Africa (Churkina et al., 2020). Timber-based construction is also possible in combination with concrete and steel or other building materials, e.g. clay (Colling, 2009).

Especially in (sub-)tropical regions, bamboo can be used as an alternative to other kinds of wood and makes ecological sense (Yu et al., 2011). This also applies to papyrus in parts of Africa (Gronau et al., 2018). Bamboo can be harvested every seven years (Churkina et al., 2020) and can also be laminated (Sharma et al., 2015), so that it can be used just like ordinary laminated wood. Especially in China, the use of bamboo should be considered because of the large volume of construction (Shen et al., 2019).

In order to estimate the effect of timber-based construction on climate-change mitigation, other building materials and the buildings' life cycles from planning to demolition must also be taken into consideration. Chipboard and other glued elements are suitable for non-load-bearing parts such as interior walls (Latour and Rizzano, 2015). Natural materials that can be used for insulation include biochar (Box 3.3-9), natural fibres,

Box 3.5-5

GHG sources and ways to reduce emissions in conventional construction

At present, buildings and infrastructure are built mainly with concrete or cement and steel. Both material procurement and the buildings themselves are relevant to land use and, above all, to climate change (WBGU, 2016a). The entire life cycle of buildings – planning, construction (use of materials), use (thermal comfort) and demolition (recycling) – must be considered. The global annual figure of 7 Gt CO_2 eq of emissions from the construction industry comes from several sources (Fig. 3.5-5), but is dominated by cement and steel production. In addition, there are emissions from land-use changes of about 0.7 Gt CO_2 eq. Global demand for cement is growing strongly and is dominated by China (Armstrong, 2013; Smil, 2014: 91; WBGU, 2016a:173f.; Van Ruijven et al., 2016).

Cement production generates high energy- and process-related emissions (Farfan et al., 2019). Cement consists mainly of marl (limestone), clay and admixed sand (Locher, 2015). Grinding the base material and heating it to 1,450°C requires a lot of energy and releases CO_2 through chemical reactions (Naqi and Jang, 2019; Pade and Guimaraes, 2007). However, about 15% of the process-related emissions (Zhang et al., 2020) are reabsorbed during the use phase (depending on atmospheric pressure, temperature and humidity; Pade and Guimaraes, 2007) when the cement reacts with ambient air (Skullestad et al., 2016). To improve its material properties, cement is subsequently sometimes mixed in the cement plant with fly ash from coal-fired power stations (Jayaranjan et al., 2014), granulated slag, limestone and gypsum and is then ground again. On the construction site, concrete is made by adding stones, water and (in some cases wood-based) chemicals; reinforced concrete (Locher, 2015), which can withstand greater tensile forces, is made by adding steel. Energy-related emissions can be reduced by using renewable energies, and higher energy efficiency can save 10–20% (Neuhoff et al., 2015), e.g. by increased utilization of waste heat. Process emissions are more difficult to avoid, despite the existing approaches described below.

However, emissions savings of up to 40% can also be achieved by (non-bio-based) material substitution in cement production (Allwood et al., 2010). Cement clinker can be replaced by limestone and granulated slag, which significantly reduces GHG emissions and energy demand depending on the cement type (Neufert et al., 2016); in high-rise construction, the reduction potential is estimated at 10–20% (Gan et al., 2016). Other technical options include substituting blast-furnace slag for clinker, calcination during the transition from the wet to the dry process, and the increased use of volcanic ash, granulated slag, fly ash, limestone powder and crushed glass (Palm et al., 2016; Naqi and Jang, 2019; Allwood et al., 2010). The extent to which the use of fibres in concrete (steel, plastic, glass, textile) can make significant cement savings possible while ensuring high component stability is currently being tested in practice (Wietek, 2017).

By capturing and subsequently storing CO_2 from the exhaust gases of the production process (CCS), process-related emissions from cement production can be reduced by 73–90%, depending on the process (oxyfuel process, use of chilled ammonia, CO_2 liquefaction, calcium looping process; Voldsund et al., 2019). These processes can be retrofitted to existing plants, but they are energy-intensive and would double or treble the cost of cement clinker (UNEP, 2018).

The construction sector also consumes half of globally produced steel (Moynihan and Allwood, 2012; Cullen et al., 2012). Steel production also releases large quantities of GHGs due to the amount of energy required and the process used (Fig. 3.5-5); the process emissions come from the reduction of iron oxide (Davis et al., 2018; Yellishetty et al., 2010), which cannot be substituted in the smelting process (Scholz et al., 2004). Inputs of primary raw materials can be reduced by using melted steel scrap. Because the required amount of steel scrap is not available – due to the time gap between production and remelting or because of increased demand in the meantime (Pauliuk et al., 2013) – savings of only 30-40% are considered realistic (Graedel et al., 2011). However, this can be increased by using steel without melting it (non-destructive recycling), i.e. reusing steel girders from demolished buildings (Allwood and Cullen, 2009). The savings are up to 60–95% compared to new steel girders (van der Voet et al., 2013).

Aluminium is another GHG-intensive raw material used by the construction industry – about a quarter of global annual production, primarily in window construction, is concentrated

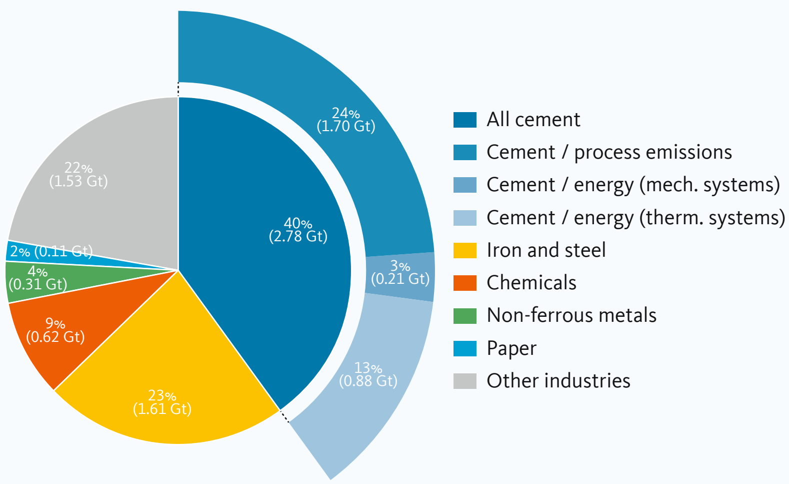


Figure 3.5-5
Breakdown of global emissions from the construction industry in 2011 by sector (total 7 Gt CO_2eq, excluding emissions from land-use changes and transport). For estimates of transport emissions, see WWF (2019); for the process-related share of steel emissions, Birat et al. (1999); for emissions from cement production, Fischedick et al. (2014); for process-related emissions, Andrew (2018).
Source: WBGU according to data from Bajželj et al., 2013: 9

in industrialized countries (including the USA and Germany in particular) and China (Churkina, 2016). Further materials used include plastics, e.g. PVC in window construction (UBA, 2017), and materials for noise and heat insulation and interior fittings.

In the long term, material substitution, CCS and the use of non-destructive steel recycling can considerably reduce GHG emissions and transform the construction industry. However, the interests of the industry stand in the way of substitution. In the case of concrete and cement, however, rising costs could also increase willingness to substitute raw materials. Moreover, a successful transformation of the construction industry will require not only changes in infrastructures cast in concrete, but also in the thinking patterns that lead to the perpetuation of these structures (Altvater, 2019).

Box 3.5-6

Problems with sand

Sand and gravel are the materials most commonly extracted from the ground worldwide (UNEP, 2014; Torres et al., 2017). They are used primarily in the construction industry, but also in the manufacture of glass and computer hardware, in cosmetics, and for land reclamation and coastal protection (UNEP, 2014). The sand used is predominantly the angular marine or river sand from CO_2-storing ecosystems, which is only available in limited quantities, as well as sand from quarries; desert sand, which is rounded by wind erosion, is less suitable for use, even though there are (energy-intensive) processes for making this sand usable (Zhang et al., 2006).

Large-scale sand mining for the construction industry and for land reclamation causes considerable problems in all areas of sustainability (Sonak et al., 2006; Kondolf, 1997). Extracting sand from rivers not only destroys ecosystems and endangers biodiversity, it also lowers the water table and alters entire landscapes (coastal erosion, changed delta structures, quarries, river pollution; UNEP, 2014). In coastal areas, sand mining reduces protection against extreme events such as floods or storms. In extreme cases, the disappearance of sand islands has even led to a shifting of national frontiers, for example in Indonesia (New York Times, 2010; Guerin, 2003). Negative economic effects of sand mining can affect tourism (Kondolf, 1997) and fisheries through the destruction of seabed fauna (Thornton et al., 2006; John, 2009; Cooper, 2013; Desprez et al., 2010). In developing countries, where fishing is the main source of income for many rural households, this deprives them of their livelihoods. Land loss due to river erosion and lowered water tables also affects agriculture (Kondolf, 1997) and destroys buildings and infrastructure near the coast and rivers (John, 2009; Franke, 2014).

Especially in parts of Asia (China, Thailand, Hong Kong and Singapore) the demand for sand for construction projects is high. In this context, sand scarcity is seen as a growing problem with significant implications for sustainability and policy (Torres et al., 2017). Although many countries have imposed an export ban on sand (Malaysia since 1997, Indonesia since 2003 for marine sand and 2007 for sand in general, Cambodia and Vietnam since 2009; Maya et al., 2012; Saviour, 2012), sand can be mined there without prior environmental impact assessments. Weak governance and corruption allow illegal mining in many areas (Saviour, 2012; Ashraf et al., 2011), which encourages mafia-style practices and makes sand trading a lucrative business. Illegal sand trading has already been observed in Malaysia, Sri Lanka, Nepal, Bangladesh, South Africa, Tanzania, Botswana and the Philippines (Gavriletea, 2017).

External costs should be internalized. The demand for sand can be reduced, for example, by optimizing processes in concrete production, by substituting concrete with recycled building materials (especially for low-quality uses), and by alternative construction methods using wood, straw or recycled materials (UNEP, 2014).

straw, wool (Asdrubali et al., 2015) and cellulose (Churkina et al., 2020). This saves CO_2 in manufacturing, sequesters it over the longer term depending on the material (Asdrubali et al., 2015), and is particularly relevant because many buildings are not adequately insulated. There is evidence to suggest that timber buildings are more energy-efficient than conventional ones (FNR, 2018; WMBW, 2019), although not everyone agrees (Kaufmann and Wolfertstetter, 2017). The minerals and fossil raw materials used in window construction can also be largely, but not yet completely, replaced by bio-based materials. Traditional building methods, especially in developing countries, largely get by without modern climate-damaging building materials anyway.

But despite the expected high levels of climate effectiveness there are limits, e.g. for plasterboard. In this case, a replacement with wood-based materials "does not offer any environmental benefit" (UBA, 2017a: 48), because other aspects apart from material production, such as raw-material extraction, become more important. Concrete foundations, too, are difficult to replace with more sustainable components (Churkina et al., 2020). In some cases, pile dwellings are used where concrete is unsuitable or uneconomical (mudflats, Venice), but they pose durability problems. Brick masonry or natural stone are also possible, but they are more expensive, and demand is limited. Difficulties arise with statics in high-rise buildings, but structural engineering with wood offers new possibilities today (Bowyer et al., 2016; Hurmekoski et al., 2015; Lazarevic et al., 2020) and has become a trend especially in Nordic countries (Hurmekoski et al., 2015;

Lazarevic et al., 2020; Toppinen et al., 2018).

Another sustainability consideration concerns the costs. As an example of modern construction systems in an industrialized country, there are detailed insights into the costs of the entire life cycle from Germany. In the planning phase, timber-based construction is much more time-consuming because conventional building materials shape the norms, i.e. building regulations are geared towards materials such as mineral wool, polystyrene and concrete (Schwenke et al., 2018) and any deviation from these norms increases the amount of planning needed. The fact that timber-based construction is hardly standardized and no standard costing values are available for timber makes a reliable cost estimate difficult (Koppelhuber, 2017). During the construction phase, on the one hand some elements, e.g. exterior walls (ARGE, 2015) or insulation material (Schwenke et al., 2018), are currently much more expensive than in conventional construction. On the other hand, the shorter construction times in timber-based construction reduce labour costs (Schwenke et al., 2018). A recent study shows that sustainable timber-based construction in Germany is only slightly more expensive overall than conventional construction (1–4% more than concrete and 4–6% more than masonry for single-family homes and apartment buildings; Walberg, 2016). Construction of high-rise buildings could be cheaper as a result of the reduced construction time (Bowyer et al., 2016). In this context, the cost of timber-based construction is highly dependent on the type of wood used (Tam et al., 2017) and on building specifics. No general statements can be made about the use phase, since a building's energy efficiency depends on its insulation. However, demolishing wooden houses is less problematic because of better recyclability. In the future, changes in standardization, innovations and economies of scale (Bowyer et al., 2016), for example in the capacity utilization of sawmills, could make timber-based construction cheaper; while a complete internalization of climate and environmental costs, e.g. via a CO_2 price, as well as stricter building regulations relating to climate-change mitigation, would greatly increase costs for conventional construction in particular. The decisive factor determining the costs and overall scope of sustainable construction at the global level will be how much timber and other bio-based building materials can be sustainably produced and how demand will develop in other sectors, where there are good alternatives in many cases (Section 3.5.2.2). Ways of reducing land-take (for buildings) per person or business unit (UBA, 2019c) and distributional effects, e.g. via house prices (especially in conurbations), should be strategically considered in good time and, if necessary, sought outside the building sector.

Sustainable forestry and wood-processing companies occupy a key position in the transformation of the construction industry (Kleinschmit et al., 2014), flanked by formative measures by the state and global governance (Chapter 4). In general, the circle of stakeholders in the (sustainable) construction industry includes actors from business, civil society and politics. Along the value chain, the picture is dominated by large corporations (especially the steel industry, but also cement, polystyrene and mineral-wool companies, large construction companies and property developers) and subordinate or executing companies (idw, 2008). Other relevant actors in timber-based construction include forest owners, carpenters and the wood-processing industry, although it is sometimes difficult to distinguish between actors in timber-based construction and the conventional construction industry, as some companies offer both (Leimböck et al., 2017; Leimböck, 2000). This heterogeneous constellation creates obstacles, but it also offers multipliers for effective impulses for change towards sustainability, for example if large property developers decide to use more wood. However, because timber-based construction involves different players than conventional construction, there are conflicts of interest because path dependencies have to be breached.

An expansion of timber-based construction increases the demand for qualified carpenters, engineers specializing in wood, and sawmill personnel. These actors should be encouraged to pass on their knowledge through training and/or to ensure their succession. In particular, the role of women should be strengthened, since they are under-represented in manual and engineering professions both in industrialized countries and in developing countries and emerging economies. Furthermore, an innovation boost can be expected, for example, from robotic timber construction (RTC; Willmann et al., 2016) or from building components and architectures inspired by folding and textile structures (Weinand, 2009). Strengthening the sector and/or R&D and innovation activities can promote employment and economic growth and help offset negative trends in the conventional construction industry. Other stakeholder-related aspects include the inclusion of indigenous population groups and other forest users, the preservation of *Eigenart*, the containment of illegal logging and slash-and-burn practices, corruption and fragile statehood, as well as the right to housing (according to a second-generation human right, people have a right to adequate housing). The City of Wood offers a positive example of the implementation of timber-based construction involving the participation of numerous stakeholders (Box 3.5-7).

In order to reveal or estimate the potential impact of timber-based construction on the climate, it is also nec-

Box 3.5-7

City of Wood in Bad Aibling

The 'City of Wood' in Bad Aibling is exemplary in innovative timber-housing construction. This urban estate has been developed on a former military site and combines living with working. One of the multi-storey houses built from prefabricated timber components (Weber-Blaschke, 2019) is an eight-storey high-rise building (Bowyer et al., 2016). Other urban-planning elements such as noise-insulating walls are built of wood, with a self-sufficient energy supply rounding off the picture of sustainability (brand eins, no date). The aim is to boost the image of sustainable building with wood and to create a lively housing estate by using an appealing architecture, branding the district as a tourist destination and promoting it in urban marketing (Bad Aibling, 2020). This urban-development project demonstrates how very different elements made of wood can be combined in a sustainable way and how the conversion of a brownfield site can contribute to the Great Transformation to Sustainability. The experience gained here should be explicitly incorporated into research and knowledge transfer, also for building refurbishments.

Figure 3.5-6
High-rise wooden building in the City of Wood.
Photograph: Thomas Wieckhorst / dach+holzbau

essary to clarify questions on the amount of timber required and sustainably available at the regional level, on the potential amount of CO_2 sequestration and savings through timber-based construction, and on the effects of timber extraction on the carbon remaining in the forest ecosystem. Because of a lack of estimates on the impact of timber-based construction on the construction industry as a whole, this section examines only urban residential and commercial construction (the figures are therefore not directly comparable with estimates of total emissions from the construction industry, as in Bajželj et al., 2013).

How much wood is needed worldwide for building construction?

Both load-bearing and non-load-bearing building components need to be considered, as well as insulation and interior fittings such as flooring, windows, stairs and doors. To calculate the requirements, the area per person is an important variable: the global average is currently 30m² of residential and commercial space per capita, with an upward trend, albeit with very large variations (Güneralp et al., 2017). The global population is expected to grow from 7.7 billion to 9.7 billion between 2019 and 2050, and to 10.9 billion by 2100 (UN DESA, 2019). As the urban population's share of the total population will rise from 55% (2018) to 68% (2050; UN DESA, 2018), additional urban housing is expected to be needed for about 2.3 billion people by 2050 (Churkina et al., 2020), supplemented by infrastructure buildings. However, some applications made of concrete such as tunnels, foundations and bridges cannot be substituted by timber-based construction. Combining wood with carbon or infra-light concrete and other concrete-saving materials (e.g. clay or plastic) reduces the amount of wood required. Assuming that 90% of additional urban buildings will be made of wood and most of them will have 4 to 12 storeys (residential with commercial units), 0.51 Gt C of wood would be required per year (Churkina et al., 2020: SI) for an additional 2.3 billion people in cities, each with an average of 30m² of living space).

How much sustainably produced, certified wood is available?

Forests do not grow in all climatic zones and their availability is limited. Only in forested regions, therefore, is wood potentially available locally for building construction (Fig. 3.5-7, although the availability of wood is presented too optimistically here; Box 3.1-1). On the other hand, not every kind of wood is suitable for every application.

Of the 4 billion ha of forest land that exists worldwide, about 31% is used primarily for the production of timber and other forest products; another 22% is subject to multiple uses, which may include wood production (FAO, 2020g). The global timber harvest is about 1.3 Gt C (FAO, 2016b cited in Churkina et al., 2020). Consistent with this, Carus et al. (2020) estimate the 2018 timber harvest (dry matter) at 2.3 Gt (Fig. 3.5-1). Many countries are harvesting less wood than is actually growing back (Churkina et al., 2020; FAO, 2015c),

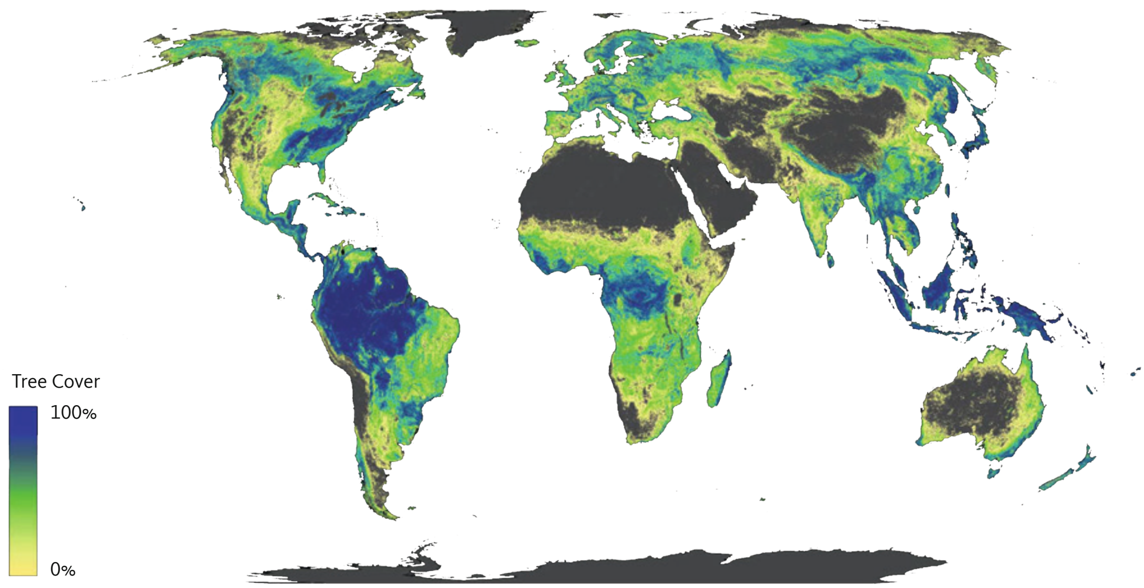


Figure 3.5-7
Potential natural forest cover. The diagram is based on grid cells. Their colour indicates the degree of tree cover. A tree cover of 100% is reached when the entire area of the grid cell is covered by trees. In the areas marked in colour, wood is potentially available; forest is the potential natural vegetation there, i.e. forest would grow there without human influence. This diagram is criticized as being too optimistic (Box 3.1-1), since e.g. grasslands were also indicated as potentially forested areas.
Source: Bastin et al., 2019

although the rate of extraction is already on the increase, at least in Europe (Ceccherini et al., 2020). The unused, and thus still usable potential worldwide is approx. 0.68 Gt C per year (Churkina et al., 2020). The amount of wood available for harvesting could increase significantly in the future (Carle and Holmgren, 2008; Yousefpour et al., 2019), although distinctions need to be made here. The amount harvested from natural forests is falling, but this is offset by planted forests (Warman, 2014). Research needs to be carried out to determine the harvest volumes that can be achieved in the long term if ecological sustainability and, in particular, biodiversity conservation are to be ensured. Should large increases no longer be possible, forestry geared to building materials could only expand by reducing or limiting the use of wood in other areas, especially for traditional and modern bioenergy (Box 3.5-3; Fig. 3.5-1).

In the longer term, reforestation can create further raw-material potential, although a high priority must be given to biodiversity conservation and natural carbon reservoirs rather than to wood use (Section 3.1.3.2). Forest plantations are significantly inferior to natural forests when it comes to carbon storage and biodiversity conservation (Lewis et al., 2019). However, extreme scenarios on CO_2 removal by forests – such as the 0.9 billion ha of additional forest area worldwide calculated by Bastin et al. (2019; Box 3.1-1) – are often conceived not as restoration but as afforestation with plantations, with corresponding losses of biodiversity and soil carbon, as well as new land-use competition. Another option is to change dietary habits towards a marked reduction in the consumption of meat and other animal products, especially in OECD countries (Section 3.4). This would also free up large areas of land, although these cannot or should not be used entirely for timber production (Drenckhahn et al., 2020; Fig. 3.5-1).

Overall, it seems realistic that the 0.51 Gt C per year of demand for timber for urban building construction estimated above could be met by a combination of sustainable forestry (including a proportion of planted forests; Churkina et al., 2020; Carle and Holmgren, 2008), a reduction in use for energy generation, an increase in the use of waste wood and bamboo (Churkina et al., 2020), plus land savings from the conversion of dietary habits.

However, by no means all forest areas are managed sustainably. Sustainably produced timber must meet the following criteria: the conservation of the forest, its health, productive capacity and biodiversity, and the preservation of its protective and socio-economic functions (Leskinen et al., 2018; PEFC, 2014; FSC, 2018). It is not possible to estimate the amount of wood that is sustainably produced but not officially certified. 12.5% of the world's forest area is certified, and 85% of this is in Europe and North America (PEFC, 2019). However,

Table 3.5-3
Comparison of CO_2 and C data of timber-based construction and conventional construction.
Source: based on Churkina et al., 2020: supplementary information

	Timber-based construction (90%)	Reinforced-concrete construction	
	Wood	**Steel**	**Concrete**
Raw-material requirement for residential buildings [kg per m^2]	194	46	252
Average emissions coefficient of the building material [t CO_2eq per t of material]	0.44	2.1	0.15
Emissions from the primary structure and interior fittings [Gt C] (assumptions: additional residential construction 2020–2050 for 2.3 billion people, 30m^2 living space per capita)	1.8 by timber-based construction 0.44 by reinforced concrete	4.4 total	
Carbon storage [Gt C] (on the same assumptions)	7.7	–	low

sustainable timber harvesting is also possible in the tropics (Sasaki et al., 2016). It is important to comply with and monitor the standards of the PEFC and the somewhat stricter FSC (SRU, 2012; Ludwig et al., 2015; Villalobos et al., 2018; Di Girolami and Arts, 2018). In 2017, 427 million m^3 of wood was harvested in FSC-certified forests and 689 million m^3 in PEFC-certified forests. However, the total is less than the sum of these two figures due to double certification (FAO, 2018i). It corresponds to 11% of the global forest area, or 29% of roundwood production (UNECE, 2016) and thus totals about 0.3 Gt C. The share of sustainably managed forest could be increased by making the certification of imported timber mandatory (Zengerling, 2020). There are also economic factors (especially marketing) in favour of the certification of wood. The expansion of sustainable forestry goes hand in hand with reforestation (Section 3.1.3.2).

Demand for certified timber is high, mainly in industrialized countries, while in developing countries it is almost exclusively wood for export that is certified. Overall, 55% of the wood harvested is consumed mainly for cooking and heating (Box 3.5-3). In Ethiopia, 97% of wood is used as fuel, in India 89% (CCC, 2018: 28). The certification of wood for the domestic market therefore does not play a role there at present. However, the use of firewood should be substituted, wherever possible, by giving the population broad access to modern forms of energy; the certification of wood should then be expanded. At the same time, local approaches to wood processing can make on-site sustainable forestry and timber management more attractive.

If a rising supply of wood leads to falling prices due to economies of scale, cheaper certified wood can also replace other materials both within and outside the construction industry. Even in the construction sector, using wood is not always the more environmentally friendly alternative, as explained earlier. It would make sense for governments to establish a framework that prevents the overexploitation of forests, for example through financial incentives, sustainability requirements and planning approaches (Section 4.2). Furthermore, the effects of climate change are damaging forests on a large scale. In Germany, the proportion of damaged trees increased specifically in the two very dry years 2018 and 2019 (BMEL, 2020b). Changes in precipitation and climate or damaging events could further increase the amount of wood produced (unsustainably) in the short term. There is currently a discussion about burning this wood instead of leaving it in the forest (Haas and Schneider, 2020) – neither strategy would have the desired result, unlike using the wood for timber-based construction.

What quantity of CO_2 emissions can be saved by substituting conventional building materials and how much carbon can be sequestered by timber-based construction?

For every kg of carbon (C) in wood products that replace conventional raw materials, emissions averaging 1.3 kg C can be saved for load-bearing elements and 1.6 kg C for non-load-bearing parts, with even higher values achievable for individual products (Leskinen et al., 2018). Globally, urban residential and commercial buildings will generate emissions of 16 Gt CO_2 (or 4.4 Gt C) by 2050 if reinforced concrete construction is maintained; this can be halved to 8.2 Gt CO_2 if 90% wood is used (1.6 Gt from the remaining 10% cement and steel, 6.6 Gt from the wood industry, Churkina et al., 2020: SI). Moreover, 90% timber-based construction can bind 0.26 Gt C per year (assuming a constant 30m^2 of living

Box 3.5-8

The EU Timber Regulation as an approach to a sustainable biomass strategy

Sustainable land-based biomass production depends critically on effective supranational regulations, but these are challenging to implement. The EU Timber Regulation (EU) 995/2010 (EU, 2010), in force since March 2013, provides an example. It lays down obligations for market participants who, as natural or legal persons, put timber and timber products onto the market for the first time, and for traders who buy or sell these products in the internal market. Correspondingly, in Germany the Timber Trade Security Act (HolzSiG) regulates the enforcement of this EU regulation. It does not include timber products made from timber that is already on the market.

The EU regulation obliges operators to prove that timber and timber products originate from legal harvesting. Due-diligence requirements must be met relating to the provision of information and submission of certificates, the use of risk-assessment procedures on illegal logging and risk-mitigation procedures. Their implementation can be supported by monitoring organizations recognized by the European Commission (in Germany, for example, DIN CERTCO Gesellschaft für Konformitätsbewertung mbH), which, among other things, check for proper application and initiate measures if there are violations. The proof to be submitted or due diligence to be performed by market participants is regularly checked by nationally designated authorities. Traders, in turn, must ensure traceability throughout the entire supply chain and therefore be able to identify both their suppliers and their buyers of wood and wood products to the competent authorities for the last five years. Overall, these requirements make every supply chain fully traceable.

Under the HolzSiG, the Federal Agency for Agriculture and Food (BLE) is responsible for enforcing the EU regulations in Germany in the case of wood and wood products that are brought to Germany from a third country or from another EU member state and are put on the market here for the first time (section 1(2) of the HolzSiG). The BLE is supported in this by the customs authorities. Otherwise, monitoring is incumbent on the authorities responsible according to federal-state law. In addition, member states, with the support of the European Commission, can provide relevant information, such as guidance on illegal logging – which makes risk assessment easier for market participants – and on how best to implement the regulation. The supervisory authorities regularly check whether market participants are meeting their obligations properly and documenting this adequately; on-site spot checks are also carried out. If the competent authority discovers deficiencies, it can order measures to be taken – such as the seizure of the wood or the imposition of a marketing ban, in order to prevent future infringements (Article 10(5) of Regulation (EU) 995/2010 in conjunction with section 2 of the HolzSiG).

However, despite EU-wide regulations and controls, there are implementation gaps. For example, an empirical study shows that of 540 German market participants surveyed, only about one third comply de facto with the due-diligence requirements (Köthke, 2020). While small companies in particular show considerable gaps in their knowledge of applicable rules and their implementation, most of the larger companies comply with the due-diligence obligations as defined in the regulation, which covers the majority of wood imports. However, there is a lack of data on the extent to which sanctions such as fines or penalties have been imposed in Germany under the HolzSiG for putting illegally harvested wood on the market.

In general, criticism of the EU Timber Regulation is on the increase. Although it is considered a conducive framework of European cooperation in the fight against the illegal timber trade (Sieveking, 2014), it lacks binding requirements (Bernhardt, 2019). Determining the legality of the wood is particularly problematic: the process is based on national legislation in the wood's country of origin and thus varies accordingly. This makes quality assurance particularly difficult in the case of wood from countries with weak or unenforced environmental legislation (e.g. Brazil). EU countries also differ in terms of both the benchmarks applied for sufficient due-diligence systems and the criteria for selecting the companies to be audited, the controls to be carried out, and possible penalties (gdholz.de/themen/eutr/; UNEP-WCMC, 2020). This leads to distortions of competition because, in practice, wood importers in different countries have to meet very different standards. Even within one and the same authority, the standards applied to due-diligence obligations may differ (Bernhardt, 2019: 188), which further increases uncertainty for companies. Although the compatibility of the EU Timber Regulation with WTO law has been controversially discussed, no action has yet been taken (Brack, 2013; Fishman and Obidzinski, 2014; Zengerling, 2020: 17). There is a lack of evidence for the enforcement of the regulation (European Commission, 2018f). As far as sanctions are concerned, NGOs describe the authorities as 'friendly advisers' to market participants, imposing small fines at most (Leipold, 2017: 46). Although the EU states should also provide technical support for the implementation of the obligations, this has so far been missing in Germany, for example in the form of a model due-diligence regulation or an online portal for exchanging data on risk criteria.

The inconsistent implementation of the EU Timber Regulation and the uncertainty of economic actors suggest there is a considerable need for reform. Standardized, practical requirements based on strict sustainability criteria should be created for all areas of application to improve legal certainty for market participants and to put a stop to unsustainable deforestation in fragile ecosystems. Import requirements should urgently be tightened and cover more than just legality, for example within the framework of an EU-wide harmonized certification mechanism (Zengerling, 2020: 17; Section 4.3). Such rules should, however, take into account the principle of equal treatment of nationals in order to be compatible with WTO law (Art. III of the GATT): wherever domestic and foreign products are covered by the same regulations, products from another WTO country may not be treated less favourably than those from domestic production. The ban on quantitative restrictions (Article XI of the GATT), which covers all measures that impede market access for foreign goods, could also be affected by certification requirements. To be compatible with WTO law, the regulation would have to be designed in such a way that it meets the requirements of Art. XX of the GATT. This includes a certain flexibility in the verification procedure (Zengerling, 2020:17ff.). Mechanisms to curb illegal logging should also be strengthened in the substantive law of EU Economic Partnership Agreements (Zengerling, 2020:54f.).

space per capita), which adds up to 7.7 Gt C over 30 years (Churkina et al., 2020: SI). Other estimates arrive at similar figures, but are difficult to retrace in terms of their assumptions (e.g. McLaren, 2012; Royal Society, 2018).

According to this model calculation, a total of 2.2 Gt C (corresponding to 8.2 Gt CO_2) in emissions could be saved from 2020 to 2050 by using wood instead of concrete and steel for urban construction; a similar amount could still be emitted and 7.7 Gt C (corresponding to 28 Gt CO_2) could be stored long-term. Thus, over a period of 30 years, a net amount of around 20 Gt of CO_2 would be removed from the atmosphere (without taking into account the extraction of raw materials, see below). No directly comparable estimates are available for special structures (such as tunnels), foundations, non-residential urban developments, roads, or residential development in rural areas. Moreover, completely timber-based construction will not be possible everywhere in the future. However, by comparing this with total current emissions by the construction sector (7 Gt CO_2 eq per year, of which 4.4 Gt comes from cement and steel; Bajželj et al., 2013; Fig. 3.5-5), it is clear that there is still a considerable need to decarbonize other building structures and activities in the construction sector, and that greater efforts are needed to achieve a negative net CO_2 balance for the construction sector, even excluding the forestry sector.

How does timber extraction affect the forest ecosystem?

As CO_2 reservoirs, forests are per se important for mitigating climate change (Leskinen et al., 2018) and, as forest areas are expanded or restored for timber-based construction, the amount of CO_2 sequestered there increases (Section 3.2). However, long-lived wood products store more CO_2 than the same wood would do in the forest (Oliver et al., 2014), as the latter undergoes decomposition processes earlier and only a small proportion of the carbon remains in the soil permanently. There are estimates (Hennenberg et al., 2019) of the amount of carbon that is stored both in the forest itself (Orb et al., 2018) and in the forest soil (Sanderman et al., 2017), as well as of global storage in the soil (Friedlingstein et al., 2019). Furthermore, climate change and the resulting damage caused by forest fires, heat waves, droughts and pests tend to reduce the forests' storage capacity (Churkina et al., 2020; Seidl et al., 2017; Ciais et al., 2005). This has already been verified for Europe (Seidl et al., 2014; Reyer et al., 2017). Timber-based construction can therefore help offset the loss of CO_2 from forests (Churkina et al., 2020). In addition, young forests, including post-harvest forests, absorb more CO_2 per year than old forests (Harmon et al., 1990). The sustainability effects of wood production and forestry must also be taken into account because, in return for carbon storage in wooden buildings, the carbon stocks in forest ecosystems are reduced (at least temporarily), and there is a (small) increase in GHG emissions from the forestry and timber industry due to increased production (UBA, 2017a: 68f.).

In summary, the following data should be compared: the demand for timber for building with wood instead of cement and steel for 2.3 billion additional people living in cities by 2050 is estimated at 0.51 Gt C per year worldwide, assuming an average residential and commercial space of 30m² per person. The current global wood harvest amounts to 1.3 Gt C per year; about 0.3 Gt C of this is harvested sustainably, the unused potential is 0.68 Gt C. In urban construction alone, up to 7.7 Gt C could be stored in wood by 2050 and 2.2 Gt C avoided by substitution (Table 3.5-3). The sink potential is reduced by the amount of carbon that would remain in the forest without timber harvesting.

In order to maximize the effect of CO_2 reduction and storage, wooden houses should have a lifespan of 80–100 years; they should be replaced by wooden houses, and after demolition the wood should be used as far as possible in cycles. Demolition and material recycling are much easier with wooden buildings, because concrete cannot be recycled to a high quality, or only serves as a filler material for new concrete (WBGU, 2016a; Skullestad et al., 2016). Wood should be used in high-value form for as long as possible via cascade use, and this should already be taken into account in the planning and construction phase (Churkina et al., 2020). Multi-stage cascade use is a realistic and quantitatively relevant option for wood. Already today, the recovery of construction timber is important in Germany, and timber is used on average 1.57 times (UBA, 2017a). This cascade factor depends on the extent to which sawmill by-products, recycled material and fresh base material are used in the construction phase. Furthermore, not treating the wood makes subsequent use easier. Direct energy recovery has a negative effect on the cascade factor, while multiple material use has a positive impact. In view of the current oversupply of waste wood in Germany, demand for subsequent material uses should be increased where this is possible in view of the declining fibre quality of waste wood (UBA, 2017a). This applies especially in the production of chipboard and in areas of the chemical industry. If material recycling is given preference over utilization for energy, low-level cascades can also be worthwhile if the substituted material (such as concrete) is particularly harmful. One example of multi-stage cascade use (Box 3.5-2) in the construction industry would be to use roundwood first for load-bearing, then for non-load-bearing structural elements, and subsequently in the form of biochar as an insulation material. At the end of the life cycle, biochar is used as a soil conditioner in agriculture, where, as a positive side effect, the stored CO_2 is sequestered in the soil long-term (Box 3.3-9).

Other factors that influence the CO_2 balance of timber-based construction have minor effects or effects that are difficult to quantify. Wood, for example, is lighter than cement (only half the transport weight; Churkina et al., 2020) and therefore requires less transport energy for the same distance; the use of local wood is particularly advantageous. However, the availability of local wood or wood products is often limited. Economies of scale in timber-based construction make production more efficient and reduce the demand for resources and energy.

Some obstacles and barriers prevent the expansion of timber-based construction. Due to its heterogeneous structure and the volume fluctuations caused by the absorption and release of water, wood is sometimes regarded as a poor building material. Furthermore, additional work is required because different types of wood require different processing methods. In timber-based construction consideration must also be given to optical aspects of the material such as knotholes and growth rings, restrictions imposed by building regulations (Purkus et al., 2020), insurance implications, fire-safety aspects and, in the case of high-rise buildings, difficulties with statics (Churkina et al., 2020), although in some cases wood even has better properties than concrete when it comes to statics and fire. Timber-based construction is also not suitable for all regions or climatic zones because, for example, too little local wood might be available. In addition to a lack of knowledge about technical possibilities, institutional path dependencies such as the existing power structures of the conventional construction sector also stand in the way of the expansion of timber-based construction.

Apart from timber-based construction, there are other options for sustainable building, but they have only a limited effect on the climate or the environment, or are restricted in their applicability. That is why timber-based construction is the recommended multiple-benefit strategy. Where it, too, reaches its limits, for example in the tropics because of humidity or termites (Findlay, 2013; Ghaly and Edwards, 2011) or due to a lack of available timber, regionally adapted, often traditional construction methods can provide solutions: clay and brick construction is one example (Volhard, 2016). Clay can be used an unlimited number of times in the same way and, in the customary combination with wood, replace concrete in many applications, although it is susceptible to humidity. Specialized bacteria can take over the hardening of bricks, making energy-intensive firing in kilns obsolete (Raut et al., 2014; for sandstone Bernardi et al., 2014; for earth blocks Irwan et al., 2016). 'Living concrete' which hardens with the help of bacteria (Mukherjee et al., 2013) is not ready for the market and cannot be used in drier climates including mid-latitudes (inter alia Germany) for the time being. However, it potentially allows GHG savings of 70–83% compared to conventional concrete (Myhr et al., 2019), so that this technique could become relevant in the future. In some regions, such as parts of the UK, stone construction still plays an important role (Hudson and Cosgrove, 2019). In the approaches mentioned, the demands of architecture, costs and material availability limit global potential, even though the use of these techniques may well be advisable on a regional basis. Another relevant aspect in the construction industry is low-impact reconstruction. It can use the same sustainable construction methods as new construction, although building-specific features must be taken into account, as in below-ground civil engineering. The same applies to special buildings and infrastructures, the global expansion of which to western levels using conventional methods would cause considerable CO_2 emissions (Müller et al., 2013).

A switch to sustainable, wood-based construction methods would also be noticed in urban architecture and thus in everyday life. Due to this visibility aspect, timber-based construction contributes to the Great Transformation towards Sustainability in socio-cultural terms, as the users of timber buildings become more familiar with its advantages. The WBGU therefore expressly welcomes the high priority given to sustainable construction and the EU's planned 'renovation wave' (European Commission, 2020g), as well as its embedding in a "new European Bauhaus" that gives "our systemic change its own distinct aesthetic – to match style with sustainability", as recently announced by the EU Commission President (von der Leyen, 2020).

3.5.3.2
Existing instruments for promoting timber-based construction

Several instruments in Germany and Europe already promote timber-based construction today, e.g. Germany's Charter for Wood 2.0 ('Charta für Holz 2.0' BMEL, 2018a; Purkus et al., 2020), which is oriented towards the UN's 2030 Agenda and the Paris climate goals. The primary aim is for sustainable forest management and timber-based construction to contribute to climate-change mitigation and achieve a high value added (in absolute terms and relative to the forest area). However, there is a lack of binding targets and regulatory requirements. There are already many certification options for sustainable construction, as described in the Guide to Sustainable Construction ('Leitfaden Nachhaltiges Bauen', BMI, 2019) and the Assessment System for Sustainable Construction for Federal Buildings ('Bewertungssystem Nachhaltiges Bauen für Bundesgebäude' BMVBS, 2010) both for the planning and construction phase and for existing buildings. In particular, the consideration of a life-cycle assessment in accordance with DIN EN ISO 14040 and the aim of minimizing land use are to be welcomed. However, the weighting of ecological, economic and social aspects should be examined on a case-by-case basis and any under-weighting of ecological quality corrected. There are also regulations at the regional level, such as the Building Code of North Rhine-Westphalia (Bauordnung NRW), which was amended in 2019 (Ministerium des Innern des Landes Nordrhein-Westfalen, 2018) and is now more focused on timber-based construction, as is the case in other German Länder (Walberg, 2016). However, norms should be further adapted to sustainable construction. Research activities are accompanying the trend, e.g. on insulation made from renewable raw materials (BMEL-funded research project; Fraunhofer WKI, 2020).

At the European level, in terms of raw-material supply, the EU Timber Regulation (EU, 2010) has prohibited the marketing of timber products from illegal sources since 2013, but inconsistent (and, from an environmental perspective, often too low) standards and insufficient enforcement remain a problem (Box 3.5-8). According to the new EU Circular Economy Action Plan (European Commission, 2020e), sustainable construction also plays a role in the European Green Deal; for example, the recyclability of buildings is to be improved. However, reductions in the total area used for buildings, which is a decisive factor in the use of land and resources – and not only for timber-based construction – are not addressed. Clear targets for reducing resource use and emissions by the circular economy and timber-based construction are lacking at the EU level, and the focus is on consumers rather than the private and public sectors (Pantzar and Suljada, 2020). With the Renovation Wave initiative (European Commission 2020g), the EU is focusing more on the ecological refurbishment of buildings.

3.5.4
Recommendations for action

In order to make the bioeconomy viable in the future and to enable sustainable land stewardship at the same time, on the one hand biogenic raw materials and new technical options should be used to replace emissions-intensive processes and fossil raw materials. On the other hand, care should be taken to ensure that the corresponding demand for biomass and land does not jeopardize biodiversity and food security, either in industrialized countries, developing countries or emerging economies. Intensifying selected applications like timber-based construction should therefore be combined with a limiting framework for the bioeconomy as a whole that ensures sustainable land stewardship.

An overall concept is required for raw materials, innovations, training, building law and regulatory law, among other things, in order to help sustainable construction achieve a breakthrough worldwide (Section 3.5.4.1); the associated research recommendations follow in Section 3.5.5.1. Overarching recommendations for action and research in the bioeconomy can be found in Sections 3.5.4.2 and 3.5.5.2. Some specific recommendations on the circular economy, bioenergy, bioplastics and sand mining (Boxes in Section 3.5) are taken up and generalized.

3.5.4.1
Recommendations for action on timber-based construction

With the following recommendations, the WBGU supports, accentuates and supplements the proposals of the Thünen Institute (Purkus et al., 2020) on overcoming path dependencies, on knowledge and knowledge transfer, and on the internalization of environmental costs as important factors in promoting timber-based construction. However, in order to achieve global climate neutrality by 2050 at the latest in accordance with the Paris climate goals and to substantially reduce local environmental damage, there should be a worldwide switch from conventional to sustainable construction, above all using wood from an overall system of sustainable land stewardship. In order to do justice to regional differences in resource availability and demographic development, as well as to global sustainability challenges, locally adapted but transnationally coordinated efforts are required. Germany and Europe should play a pioneering role in this context; this would make the timber industry and timber-based construction fit for the future and, thanks to the high visibility of timber buildings, also strengthen the shift towards a sustainable way of life, the possibilities of which are also to be explored within the framework of a 'new European Bauhaus' (von der Leyen, 2020). In the WBGU's view, the German government should therefore:

Proclaim a global 'Mission for Sustainable Construction' together with international partners

This action programme should strategically ensure the technical development and large-scale implementation of sustainable construction methods and be strictly linked to a sustainable supply of raw materials. Such a mission should involve as many partners as possible: European and other states, and in particular the forestry and construction sectors, academia and civil society (in a similar way to Germany's Charter for Wood (BMEL, 2018a), with greater inputs from environmental policy, research and NGOs). Mainly the conventional building industry and several cities are for example also organized in an initiative of the World Green Building Council (WGBC, 2019). These partners should jointly drive forward the four sets of measures described below (as well as two research priorities, Section 3.5.5.1) and also provide funding for coordinating activities (e.g. a permanent secretariat). Existing national and EU approaches to sustainable timber-based construction should be placed in a global context and extended thematically. Moreover, this can be linked to clear, binding targets for the successive replacement of conventional building materials by sustainable ones, which can initially be driven forward primarily by Germany or the EU, but then be extended internationally.

Develop global strategies on sustainable raw materials and use of building materials

Joint strategic deliberations on which technologies and raw materials from which sources can make the construction industry more sustainable worldwide should form the core of a Mission for Sustainable Construction. They should be developed iteratively by the partners involved and be based on research into feasible raw-material scenarios and new building materials and construction methods (Section 3.5.5.1). In addition to land-use and biomass requirements for food, environmental protection and climate-change mitigation, the regionally different starting points and developments should also be taken into account. These include the availability of biogenic resources, technologies and actors of the building-materials and construction industry (Deloitte, 2019), and a skilled workforce. Also relevant are regional building traditions, the building stock, demographic trends and resulting building requirements (e.g. improving the energy efficiency of buildings in Europe, urban growth in Africa). In particular, the climate-dependent variable availability of raw materials, e.g. in the case of coniferous timber (BMEL, 2020b), requires strategic coordination between the regional forestry and construction industries (e.g. so that prefabricated construction can absorb large quantities of fallen or damaged timber). The strategy could also incorporate suggestions from the World Green Building Council (WGBC, 2019).

Strengthen the supply of sustainable raw materials and the pricing of environmental costs in conventional construction in parallel

The internalization of real costs makes sustainable construction (including recycling) more attractive relative to conventional construction, but also increases the demand for biogenic materials, which should only be met from sustainable sources. Therefore, a higher effective CO_2 price for cement and steel in the EU ETS (and if appropriate a border tax as well as tougher regulation of sand) should, for example, be combined with a roadmap for the massive expansion of sustainable forestry and the global conservation of primary forests (an aim that is already being pursued: European Commission, 2019b; Council of the European Union, 2019). To this end, for example, a credible system of certification should be developed for sustainable forestry (e.g. from the FSC seal), expanded especially in tropical regions, independently monitored and made a prerequisite in public procurement. This certification should effectively exclude the use of primary forests and actively contribute to their conservation. The EU Timber Regulation should be enforced consistently across the EU (Box 3.5-8), and sustainability requirements should apply to all traded timber in the medium term (Sections 3.3.3.3, 4.2.6, 4.3.3). An important basis is provided by the strengthening of raw-materials monitoring (Section 4.2.4), for forestry for example by the new Forest Information System for Europe (FISE), which helps to monitor the condition, health and sustainability of European forests (European Commission, 2015b).

Strengthen education and further training for sustainable building

In order to establish all stages of the value chain of sustainable construction worldwide, also in rural areas, the necessary knowledge must be disseminated on (in some cases new) biogenic building materials and sustainable construction methods (Section 3.5.5.1), norms and certification approaches, as well as possibilities and preconditions for the conservation and reuse of materials. A greater number of practice-oriented, inexpensive engineering and dual-training courses, as well as advanced training in sustainable construction should be offered – not only by industry associations but also by educational institutions. Strengthening the role of women should be integrated into existing funding measures such as the directive on the promotion of grants for 'Innovative SMEs: Bioeconomy' (BMBF, 2020a).

Establish timber-based construction in industrialized countries – adapt regulations, promote a circular economy and sustainable public construction

In order to reduce discrimination against sustainable construction methods and to actively promote them, first of all, building regulations, i.e. norms and standards (e.g. on statics, wind load, fire safety and insulation), as well as regulatory law should be adapted in many countries (e.g. in Germany building regulations and laws on waste, crafts and emissions control). Timber-based construction can raise the energy efficiency of buildings and should be placed on an equal footing with conventional construction in building projects to improve energy efficiency (e.g. in the 'Renovation Wave' initiative, European Commission, 2020g). Second, the circular economy can be strengthened by eco-design regulations for buildings (modularity, re-usability, energy efficiency), the improved certification of sustainable building materials and construction methods (e.g. reusable chemically treated wood products; Section 3.5.5.1), the separation of contaminated wood during demolition, and the standardization of waste-wood products. Regulations and financial incentives should encourage reuse and cascade use (rather than use for energy generation). Third, in Germany and the EU the public sector itself should only build sustainably with wood (and in Germany follow an enhanced version of the pertinent guideline from the Federal Ministry of Transport, Building and Urban Affairs; BMVBS, 2010); public building subsidies should be subject to sustainability requirements (and in cases where housing subsidies are motivated by social reasons, it should be possible to increase the amount of the subsidy where appropriate). For this, timber should not only be sourced from already sustainable forestry, but the certification of additional sources should also be actively supported.

Sustainable construction in developing countries and emerging economies: develop regional, sustainable building-materials and construction industries

Above all, countries should be supported that require a lot of new construction or have a lot of potential for sustainable resources (taking into account ecological limits and food security) – from the production of raw materials and their processing (partly for export) to the planning, construction, maintenance and reuse of regionally adapted, sustainable buildings. In practical terms, a three-part programme should be launched by the partners of the 'Mission for Sustainable Construction' – especially actors in development, environmental, foreign and trade policy, investment banks, the construction industry and construction research. The programme links (1) the promotion of local farmers and foresters together with (preferably local) R&D institutions and enterprises to develop sustainable, regionally adapted building-material production and low-cement construction methods with (2) a local investment programme and (3) an international or bilateral trade programme (e.g. improved technology transfers).

3.5.4.2
Recommendations for action on the bioeconomy as a whole

In order to be able to strengthen sustainable construction and other meaningful application areas of the bioeconomy (in accordance with Section 3.5.2.2) without jeopardizing food security and biodiversity, sustainable land use for the bioeconomy also requires an overarching and responsibly designed limiting framework. To this end, the WBGU formulates the following recommendations for action:

Take ecosystem conservation and the finiteness of sustainable resources seriously as preconditions of the bioeconomy

The expansion of the bioeconomy (Section 3.5.1) and the increased use of bio-based resources should be explicitly linked to preconditions of ecosystem conservation, in particular responsible land stewardship and biomass use according to specific priorities and within planetary guard rails. To be more specific, Germany's Federal Government should align its sustainability and bioeconomy strategies as well as its innovation funding (Section 3.5.5.1) more closely to these conditions; up to now they have only been mentioned in 'soft' guidelines and framework conditions. In addition, the Federal Government should set quantified, binding targets for absolute reductions in the consumption of biogenic primary resources (Box 3.5-2). Currently, Germany's sustainability strategy only contains the target of raising raw-material productivity by 1.6% per year (Bundesregierung, 2018). Furthermore, it should aim for a consistent system of binding sustainability requirements, financial incentives and raw-material monitoring for all produced and traded biomass (experience with the EU's Timber Regulation could be used to enforce corresponding verification requirements, Box 3.5-8; it could also be linked to a supply-chain law; Section 3.3.2.4; Rudloff and Wieck, 2020). The resulting distribution effects (mainly via land, food and commodity prices) should be taken into account. Since the latter recommendations relate not only to the bioeconomy but also to the demand for food (Section 3.4) and directly to land stewardship (Sections 3.1–3.3), they are elaborated further as an overarching topic in Section 4.2 and specifically for the EU in Section 4.3.

Fully exploit non-bio-based climate-friendly alternative technologies and adapt current uses of biomass

Potential for cutting the use of fossil raw materials by reducing demand, improving efficiency and using non-bio-based low-emission technologies should be optimally exploited (Section 3.5.2.2), especially in land-based transport that can be easily electrified, and in power generation, where biomass use with and without CCS quickly comes up against political and sustainability limits (Heck et al., 2018; Roe et al., 2019; Box 3.5-3). Climate-policy measures such as CO_2 prices, emissions trading or subsidies should take effects on biomass use into account. Uses of traditional energy in developing countries and emerging economies, and energy generation using wood pellets or biofuels, should also be replaced by non-bio-based technologies or made more efficient, e.g. by continued development cooperation in programmes such as EnDev or GET.pro (GiZ, 2020a, b) or by means of energy policy requirements such as those of the EU (2018a). Reducing demand for biomass should primarily serve the conservation and restoration of ecosystems; however, in some cases, biomass would also be 'freed up' for applications for which there will be a shortage of other low-emission alternatives in the medium term (e.g. air transport) or where carbon will remain sequestered long-term (e.g. timber-based construction).

Give preference to the use of efficiency-enhancing innovations and encourage reuse

Bio-based innovations, efficiency-enhancing technologies and the circular economy should above all contribute to ecosystem conservation by significantly reducing demand for raw materials. This should be reflected in corresponding investment and innovation programmes (Section 3.5.5.2). Circular and cascade use (Box 3.5.2-1) can be promoted e.g. via eco-design regulation (including the reduction of chemical treatments that hinder circular use), take-back and recycling regulations and standardization, also for bio-based plastics. Existing approaches in the EU and in Germany (European Commission, 2020b; SRU, 2020) should give more attention to biogenic products and materials and become more ambitious in order to reduce the overall demand for primary raw materials, despite the increasing substitution of emissions-intensive raw materials by biomass.

Embed the transition to a sustainable bioeconomy into societal transformation

Due to the need for complete decarbonization, the bioeconomy (together with the circular economy, non-biogenic low-emission resources and renewable energies) is not a concept for a single sector but for the economy as a whole, and should therefore be embedded in a broad societal transformation (Chapter 4). But "the desired transformation and the ways to achieve it must be put up for discussion and decision-making, using appropriate procedures to enable democratic inclusion" (Albrecht et al., 2012: 36; see also WBGU, 2011:52). The first steps should be for (global) environmental protection and civil society in particular to be more strongly represented than hitherto in the new Bioökonomierat (Bioeconomy Council; BMEL, 2020). Investment should be made in education and training on the bioeconomy, which many bioeconomy strategies seek to reinforce (Chinthapalli et al., 2019; IAC, 2018; Bioökonomierat, 2013). Critical perspectives on expanding the bioeconomy (Box 3.5-1) and, for example, the issue of resource limitation should also be included. Integrated models (e.g. the 'bioprincipled city'; Bioökonomierat, no date) should be systematically included in planning approaches as guiding principles. Bioeconomy strategies should be synchronized not only with e.g. sustainability policy, but also, for example, with fundamental agricultural and economic-policy strategies (in the sense of overarching scenarios and strategies for sustainable land stewardship), as well as with the programme for the 'new European Bauhaus' (von der Leyen, 2020) that is being developed.

3.5.5 Research recommendations

3.5.5.1 Research recommendations on timber-based construction

The WBGU recommends the following as elements of the 'Mission on Sustainable Construction' to promote timber-based construction by means of a multilateral and intersectoral policy and research network (Section 3.5.4.1):

Improve the knowledge base and scenarios on sustainably available biogenic raw-material potential for the construction industry

The development of a strategy for the transformation of construction worldwide (Section 3.5.4.1, first recommendation) requires the detailed documentation and forecasting of raw-material potential (e.g. wood, bamboo, papyrus), i.e. current production and uses, substitution possibilities (e.g. in the case of traditional bioenergy; Box 3.5-3), ecological limits and future changes, including those caused by climate change. Corresponding research on sustainable construction should be embedded into assessments of potential for the bioeconomy as a whole (see recommendation below).

Further develop sustainable building materials and construction methods as well as their standardization and certification

Relevant building materials in this context are, on the one hand, biogenic materials based on coniferous wood (hitherto predominant in timber-based construction, possibly less widely available as climate change progresses) and, on the other, increasingly deciduous wood, bamboo and papyrus, other non-biogenic climate-friendly materials (e.g. clay, brick, natural stone) and low-emission cement (e.g. 'living concrete'). The further development of sustainable construction methods based on sustainable building materials should take GHG emissions into account over the entire life cycle, the durability, 'reparability' and flexible usability of buildings, as well as the re-use of entire building components or materials. To this purpose, institutes for construction (materials) research should be involved in the 'Mission for Sustainable Construction' (Section 3.5.4.1) and be more strongly networked internationally. The further development and dissemination of international norms, standards and certifications on sustainable building materials and construction methods should also be supported.

3.5.5.2
Research recommendations for the bioeconomy as a whole

The WBGU formulates the following recommendations with regard to research tasks for a sustainable bioeconomy. They tie in with the above recommendations for action and to some extent with existing approaches, e.g. those of the BMBF ('Bioeconomy as societal change' / Bioökonomie als gesellschaftlicher Wandel; BMBF, 2019), but focus on approaches to defuse the land-use trilemma:

Improve documentation and forecasting of biomass supply and demand

Monitoring biomass use for different sub-sectors of the bioeconomy (BMBF, 2019) and forecasts of supply and demand (IPCC, 2019b: Chapter 6) should be continued and methodologically refined in order to analyse, on the one hand, trade-offs between different biomass uses (Fajardy et al., 2019) and, on the other hand, areas of land that are available now or will be required in the future – and their potential for biomass production. Regional specifics, worldwide food security and the global conservation of biodiversity should be taken into account. Examples include analyses of the potential for the non-food-related bioeconomy of agricultural by-products or marginal agricultural land that is less suitable for food cultivation (Section 3.5.1). This is also important for increasing and diversifying smallholder incomes, above all in developing countries and emerging economies. Further distribution aspects and their related research are discussed in Section 4.2.5.3.

Promote applied research specifically on sustainability-oriented areas of application and technologies of the bioeconomy

Research and technology funding should focus more than hitherto (Box 3.5.1-1) on approaches that extend the 'reach' of the limited amount of available biomass. On the one hand, this refers to research and development on the possibilities of reuse and recycling, on efficiency potential and non-bio-based alternatives to energy-related 'bridge-technology' applications of biomass, e.g. for aviation, shipping, heavy-goods transport, electricity storage, industrial heat and CO_2 removal from the atmosphere (Section 3.1; Box 3.5-3). On the other hand, process technologies for biorefineries should be further developed towards the digitally optimized 'Biorefinery 4.0' in order to improve their efficiency and integration into the circular economy and cascade use. Research should also be pursued on potential biomass gains from artificial photosynthesis and the extended use of aquaculture.

3.6
Interaction and implementation of multiple-benefit strategies

After presenting exemplary multiple-benefit strategies that can be used to overcome the land-use trilemma, this section focuses on the possible interplay between multiple-benefit strategies and on ways to implement them in practice as part of an integrated landscape approach.

3.6.1
Interplay between multiple-benefit strategies: examples

Climate-change mitigation, biodiversity conservation and food security are complementary and closely interlinked goals that can to some extent be supported simultaneously by the multiple-benefit strategies described above. Three examples are presented below that illustrate additional synergies between multiple-benefit strategies:

Nexus between protected-area systems, reforestation and timber-based construction

The expansion of protected areas (where effective ecosystem and biodiversity conservation is the top priority) and their interconnection via corridors can be combined in many ways with the restoration of degraded areas and the reforestation of near-natural, biodiverse forests. This not only offers relevant potential for carbon sequestration, it also serves to restore and promote biodiversity. When planning large-scale restoration projects, existing protected-area systems should therefore always be included and corresponding synergies with biodiversity conservation actively sought. In the long term, wood from the sustainable use of restored forests can also serve as an alternative for scarce building materials or materials with high GHG-emissions.

Nexus between agriculture, agrobiodiversity and protected areas

Sustainable agriculture can make sense in protected-area systems, but only if it is necessary for, or compatible with, the purpose of conservation, which has top priority there. For example, in their graduated categories of protection and sustainable use (Box 3.2-1) many protected-area systems can be used in such a way that, in addition to conserving biodiversity, they also serve as natural carbon reservoirs and CO_2 sinks and provide the local population with a basis for food and income. There are also synergies in the conservation of old cultural landscapes, whose biodiversity, and in particular agrobiodiversity, depends on extensive sustainable use. There, traditional cultivars can be preserved in situ through cultivation and use. Conserving the genetic diversity of species that are wild relatives of our crops is another important conservation objective in some protected areas. Conversely, care should always be taken in agriculture to also preserve near-natural biotopes in the landscape bordering on production areas, as they not only form important elements in the ecosystem network, but also provide ecosystem services and resilience potential for agriculture.

Nexus between dietary habits, agriculture and the bioeconomy

Falling demand for animal products can help defuse the competition for land between food production and the bioeconomy, as it reduces the amount of land required for food security. Freed-up areas of land can be used, at least in part, to cultivate agricultural products to meet the growing demand from the bioeconomy. Diversified agriculture, including e.g. agroforestry, conservation agriculture, use of biochar and improved forest management, can also mitigate competing uses. In agroforestry systems, for example, trees can be selected in such a way that they are also a source of products for the bioeconomy, such as rubber or timber.

3.6.2 Implementation of multi-benefit strategies in the context of the integrated landscape approach

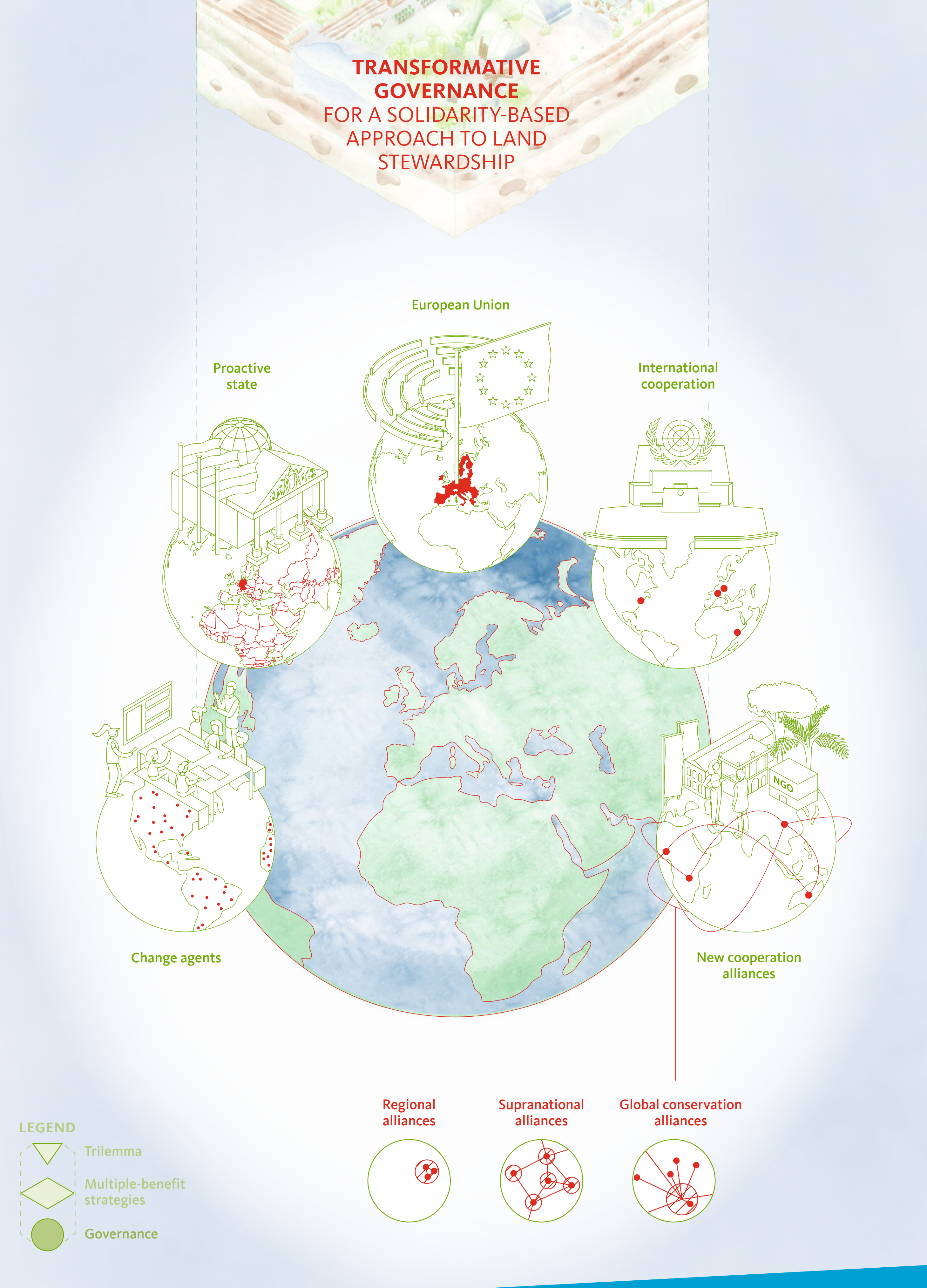
The implementation of an integrated landscape approach (Box 2.3-3) can help to leverage the synergistic potential of the multiple-benefit strategies outlined above. The integrated landscape approach aims to merge ecological, economic and socio-cultural issues and interests; it is highly participatory, inclusion-oriented and transdisciplinary; it prioritizes enabling synergies, and can thus contribute to defusing land-use competition (Box 2.3-3; IPBES, 2018a, 2019a; Sayer et al., 2013; Arts et al., 2017). Integrated landscape planning and landscape governance are of central importance for the practical implementation of the multiple-benefit strategies described.

Sustainable land use in the context of an integrated landscape approach is based on multifunctionality of and in landscapes and, compared to purely sectoral approaches (e.g. of agriculture, forestry, mining, tourism, nature conservation or climate-change mitigation), it is strongly oriented towards the participation of stakeholders and the use of synergies. This means that different uses are not in competition with one another, but can merge or follow each other – for example as agriculturally used protective areas, agroforestry areas with a CO_2-sink effect for climate-change mitigation or as restoration areas for highly diverse objectives. However, such synergies neither arise, nor are they maintained, by themselves; they must be shaped, agreed on and promoted by the stakeholders involved (e.g. farmers and foresters, landscape planners). Telecouplings and displacement effects should also be borne in mind (Sections 2.3.1, 4.2.5). Local measures should correspondingly be oriented towards compliance with the planetary guard rails (Box 2.3-1). These relate to a limit on climate change and ocean acidification by halting CO_2 emissions, a limit on biodiversity loss by halting the anthropogenic drivers of this loss, stopping land and soil degradation, limiting dangers from persistent pollutants by stopping their release, and halting the loss of phosphorus.

Instruments of landscape governance (IPBES, 2019a) – which uses flexible forms of planning, also making it possible to cross existing administrative boundaries (Section 4.2.3) – are used to implement the integrated landscape approach. Landscape governance focuses on the interplay between state institutions, the business community and civil society at the landscape level; it is oriented towards iterative, adaptive management and continuous learning over long periods of time; and it explicitly relies on the comprehensive inclusion of civil society and other stakeholder groups (i.e. doing more than just staging hearings and offering opportunities to make objections), including the use of transdisciplinary approaches (Görg, 2007; Sayer et al., 2013).

This integrated approach requires information and frameworks which provide orientation when weighing up what action to take over conflicting objectives and address the irreversibility of land use and undesirable telecouplings. There is no blueprint for this, however. The unique characteristics *(Eigenart)* of natural areas and cultural landscapes also make it necessary to be context-specific when designing framework conditions and choosing policy instruments.

Chapter 4 takes up the narrative here and discusses framework conditions for advancing a transformation of land use. In this context, it addresses the role of private actors as pioneers of a solidarity-based land-use transformation, as well as the possibilities of state and supranational governance to promote sustainable land stewardship.


TRANSFORMATIVE GOVERNANCE
FOR A SOLIDARITY-BASED APPROACH TO LAND STEWARDSHIP
European Union
Proactive state
International cooperation
NGO
Change agents
New cooperation alliances
Regional alliances
Supranational alliances
Global conservation alliances
LEGEND
Trilemma
Multiple-benefit strategies
Governance

Transformative governance for solidarity-based land stewardship 4

In order to accomplish the transformation to sustainable land stewardship, (1) innovation stimuli should be supported by change agents. (2) States should promote the landscape approach by offering financial incentives, setting ambitious sustainability standards and by means of spatial planning. With this in mind, the EU should (3) use the European Green Deal to transform its agricultural policy into an ecosystem policy. Existing international processes should (4) be more closely coordinated at a Global Land Summit, and (5) regional, supranational and global cooperation alliances should be deployed for a global land-use transformation.

The basic message of this report could be summed up in one simple sentence: our current global approach to land stewardship is an acute, systemic problem, but one that we can solve by taking smart, synergistic action and assuming solidarity-based responsibility in multi-actor partnerships. As shown by the examples of the multiple-benefit strategies (Chapter 3), sustainable land stewardship is possible in many areas. But what design conditions need to be met beforehand? The multiple-benefit strategies offer starting points for important changes, but rethinking global land-use in the Anthropocene is a transformative challenge that goes far beyond individual multiple-benefit strategies.

Solidarity-based land stewardship is dependent on committed citizens as drivers of change: in consumption and lifestyle, in agricultural and forestry practice, in nature conservation and in professional and societal engagement. And it also needs committed multipliers and supporters who make solidarity possible and help create conditions in which difficult contexts and forces of inertia can be overcome. The global land-use transformation requires that a conducive political and legal framework be established by states that are willing to take the initiative. Precisely because almost the entire 'land' of the Earth is subject to national territoriality and consequently to nation-state control, nation states and self-interest-driven economic actors often thwart the goal of a global land-use transformation. This state of tension between the national goals of individual states and global goals can only be resolved by multilateral cooperation. The WBGU is developing solutions to this need – for both existing and new forms of multilateral cooperation in broad multi-stakeholder partnerships. This chapter outlines how this 'Transformative Governance for Solidarity-Based Land Stewardship' can be shaped in order to meet the transformative challenge of a global land-use transformation. In this context, governance generally refers to the "totality of the diverse forms of control and regulation of societal issues" (Risse and Lehmkuhl, 2006). Global sustainability governance in particular encompasses the overall system of institutions, actors (both public and private), governing processes (both formal and informal), and binding and voluntary regulatory instruments for dealing with global sustainability problems (Pattberg and Widerberg, 2015). In order to take account of the transformative goal of this chapter, its structure is based on five key actors and levers of a successful transformation towards sustainability (WBGU, 2011; Box 4-1). Change agents can make an individual impact in their particular niches and develop it more widely as multipliers; they can also design and try out sustainable innovations (Section 4.1). States can accept and implement transformative change as a creative task (Section 4.2). The

Box 4-1

The land-use transformation as a key building block of the transformation towards sustainability

In 2011, the WBGU formulated the need for a Great Transformation towards Sustainability as a (global) societal project to address the pressing issues of the future (WBGU, 2011). This Box briefly recapitulates the conceptual 'ingredients' of this transformative change and relates it to the need for a global transformation of land use. The WBGU (2011) identified three key transformation fields: the energy sector (focus in WBGU, 2011), urbanization (focus in WBGU, 2016a) and land stewardship. In each of these fields, a shift is required away from the status quo and previous paths and practices towards sustainability. For such a transformative, i.e. not merely incremental change, all societal actors – the state, academia, business, civil society – are called upon to enter into a learning process. Through the interaction of these actors within the various societal subsystems, the overall societal system ultimately also changes (Geels and Schot, 2007).

It is always specific individuals and groups – in their different roles, functions and practices – who initiate concrete changes (WBGU, 2011). That is why niche activities are so relevant for transformation processes: in the protected space of the niche, new ideas and practices can be conceived and tested, giving rise to innovation. In a temporal perspective, some of these stimuli for change then persist and outgrow the niche; they gain wider societal attention, change societal, collective normality, and themselves shape or are shaped by new laws, scientific studies, market structures, social practices or technological development (so-called 'regime dimension'; e.g. Geels and Schot, 2007). In the transformation towards the solidarity-based land stewardship under consideration here, a special role is played by integrative learning and exchange processes and the multiple testing of solidarity-based lifestyles. The WBGU has already proposed a model (WBGU, 2016a, b) that focuses on responsibly acting individuals and does not artificially separate their role as private consumers from that of citizens, for example: this model is based on the concept of a solidarity-based quality of life. The WBGU advocates a differentiated view of the changeability of lifestyles which, on the one hand, are embedded in specific contexts of action (infrastructural restrictions, cultural constraints), but on the other hand also exhibit degrees of freedom and windows of opportunity for change.

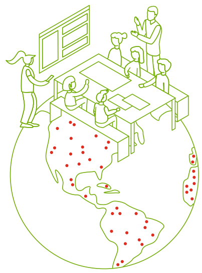
Successful mainstreaming in the sense of a broad consideration of transformative stimuli is constitutive for transformative change: transformative changes depend on strong alliances and conducive conditions on the one hand, and on inclusive implementation and strategies for overcoming manifest blockages on the other. Examples range from social movements such as Fridays For Future to scientific cognitive knowledge processes like the IPCC and IPBES to technology breakthroughs or changed market structures.

Finally, transformative change takes place in dependence on, but also interaction with, ecological, economic and legal system conditions which are relatively inert when it comes to changeability (e.g. some ecosystem contexts, economic and property regimes). A proactive state is called upon to create framework conditions that comprehensively promote social innovation for sustainable development and to demand and support the assumption of responsibility by all actors. In doing so, it should perform its function in such a way as to promote consultation, co-determination and participation opportunities for civil society. In this way, it acts in the interests of its own future viability (WBGU, 2011).

Action is needed not only by states or alliances of states such as the EU. The global land-use transformation, like the global climate, biodiversity and food crises, requires intergovernmental cooperation in the relevant forums of the UN and other international organizations. However, the need for action to address global problems should not be reduced to international, i.e. intergovernmental, policies and arenas. The WBGU therefore emphasizes the need for a polycentric responsibility architecture to solve global problems (WBGU, 2016a), i.e. the relevance of many state and non-state actors and their reciprocal action within and between the usual political levels of action from local and national to inter- and transnational (Dorsch and Flachsland, 2017). The special legitimacy of state actors and their ability to orchestrate actor action continue to play a key role.

EU is dependent on its member states' willingness to cooperate across borders, but, as a supranational community of law, it can also take action itself (Section 4.3). Finally, existing international cooperation among states can be vigorously further developed (Section 4.4), and joint action for a global land-use transformation can be given fresh motivation by setting up new types of multilateral cooperation alliances (Section 4.5).

4.1 Change agents: empower actors to take responsibility



Worldwide, the number of analyses of the threats posed by climate change is increasing, but so is people's willingness to contribute to climate-change mitigation (WBGU, 2011). Recent studies (BMU and UBA, 2018; Bouman et al., 2020; Poortinga et al., 2018) confirm this trend. With the Paris Climate Agreement and the adoption of the UN Sustainable Development Goals (SDGs) in 2015, this shift in values was prominently reflected by the international community.

Diverse actors from all sectors of society are involved in such change processes. The concept of change agents here refers to individual actors who, out of personal commitment, are willing to take responsibility for transformative change (Schneidewind, 2018; WBGU, 2011:241ff.). This does not deny the fact that companies, initiative groups or associations can also be regarded as change agents. Here, the WBGU highlights individual actors who take on responsibility for the transformation in very different roles: in their role as consumers through consciously solidarity-based consumption decisions; in their role as citizens and part of civil society by advocating and supporting corresponding transformative policies; but also by taking initiative in their role as entrepreneurs or scientists.

In this sub-chapter, change agents are described as solidarity consumers (Section 4.1.1) and as people in other roles (Section 4.1.2), people who consciously contribute to overcoming the trilemma. Based on the idea of multiple benefits, those actors and initiatives are considered that relate to several trilemma dimensions and thus contribute to sustainable land stewardship in multiple ways. In particular, the framework conditions that enable and support such pioneering activities are analysed. The study concludes with overarching recommendations for implementation (Section 4.1.3).

4.1.1 Possibilities and limits of sustainable solidarity-based consumption

The number of citizens who wish to assume responsibility for a sustainable society with their consumption choices and lifestyles is increasing on a daily basis (KPMG, 2020; e.g. for the energy sector: Poortinga et al., 2018). The WBGU has coined the term 'solidarity-based quality of life' to describe both this phenomenon and the normative claim associated with it (WBGU, 2016a). The fact that solidarity-based consumption also involves land stewardship and the use of ecosystem services is becoming clear in various areas of consumption: for example, the market share of fair-trade products has been increasing internationally for years (it amounted to approx. €9 billion in 2019). The turnover of organic food as a percentage of total food sales has also increased in Germany since 2001 and currently stands at just under 10% (UBA, 2019a). Certified wood also has a growing market (Section 3.5.3); in Germany, PEFC- and FSC-certified wood products now have a market share of over 90% in hardware stores (UBA, 2017b), and since spring 2019, German horticultural and garden-centre associations (e.g. the Verband Deutscher Garten-Center e.V. and the Zentralverband Gartenbau e.V.) have reported a marked increase in demand for bee-friendly plants (ZVG, 2019).

Which framework conditions promote the development of solidarity-based consumption?

Here the WBGU takes a systemic view of individual consumer behaviour and the changeability of lifestyles. On the one hand, it sees these lifestyles as embedded in consumer contexts: consumption patterns are shaped and influenced by supply, product prices and cultural norms. On the other hand, there are also degrees of freedom and windows of opportunity for a conscious change of everyday consumption practices and for conscious decisions (Jaeger-Erben, 2010; WBGU, 2014). Such consumption movements can be triggered by initiatives that specifically support solidarity-based consumption. Some of these initiatives have been created by individual pioneers, such as entrepreneur Claudia Langner, who founded the information platform Utopia in 2010 to provide interested consumers with knowledge about alternative products (e.g. about FSC certification); other initiatives are civil-society organizations, such as the regular information provided by the WWF about areas of consumption that have a serious impact on climate, land use and social sustainability. Such initiatives disseminate scientifically sound background information and provide knowledge for action, including concrete possibilities for action, e.g. via alternative offers.

However, studies indicate that knowing about problems and possible actions alone does not usually lead to changes in consumption behaviour (Bamberg and Möser, 2007). Factors that can influence sustainable consumption have been investigated in a number of studies of environmental psychology. Nielsen et al. (2020) provide an overview of the roles in which

Box 4.1-1

Citizen science: citizens as change agents in science and SDG monitoring

Citizen science (CS) aims to extend public inclusion in scientific practice by supporting alternative forms of collaborative knowledge production (Hecker et al., 2018). In addition to a general strengthening of research activities and the targeted promotion of inter- and transdisciplinary content, opportunities are opening up for improving the role played by citizens and their knowledge, including a new, complementary data source for SDG monitoring and reporting (Fig. 4.1-1) and greater participation. Both are important elements for the transformation of land stewardship. The former makes it possible to shape research activities more precisely by means of an improved analysis of the initial situation and of changes. The latter strengthens environmental awareness and networking between actors, as well as inclusion in the transformation process.

In line with the roadmap presented by Fritz et al. (2019), CS could be integrated into formal SDG reporting mechanisms under UN guidance, although this would also require innovation in national statistical offices and a focus by the CS community on identifying the indicators where substantive contributions are possible. This would require global support for local CS projects, each of which reflects different initial conditions. That would lay a foundation stone for the kind of social innovation that enables citizens to contribute both to improved monitoring and to the implementation of SDGs (Fritz et al., 2019: 929). Shulla et al. (2020) have also studied possible collaboration channels between CS and SDGs (Table 4.1-1). They define five spheres of influence for CS, which can interact at different levels:

1. in multi-stakeholder partnerships at the national and international level,
2. through individual contributions,
3. through integration into political processes,
4. through education, and
5. through SDG monitoring and reporting.

Compared to this largely untapped potential of CS, the vision of real-time global monitoring based on big data (Jaric et al., 2020; Box 3.2-2) seems much less feasible. Therefore, CS should be expanded to improve both the pool of research data and the monitoring of levels right up to the SDGs by means of targeted funding (Boxes 3.1-2, 3.2-2, 4.2-5). Open-source applications for CS should be (further) developed with a view to both local embedding and international scalability, and integrated into an interoperable open-data ecosystem. The integration of CS data and practices should also be increasingly promoted in the context of the European Open Science Cloud and the National Research Data Infrastructure.

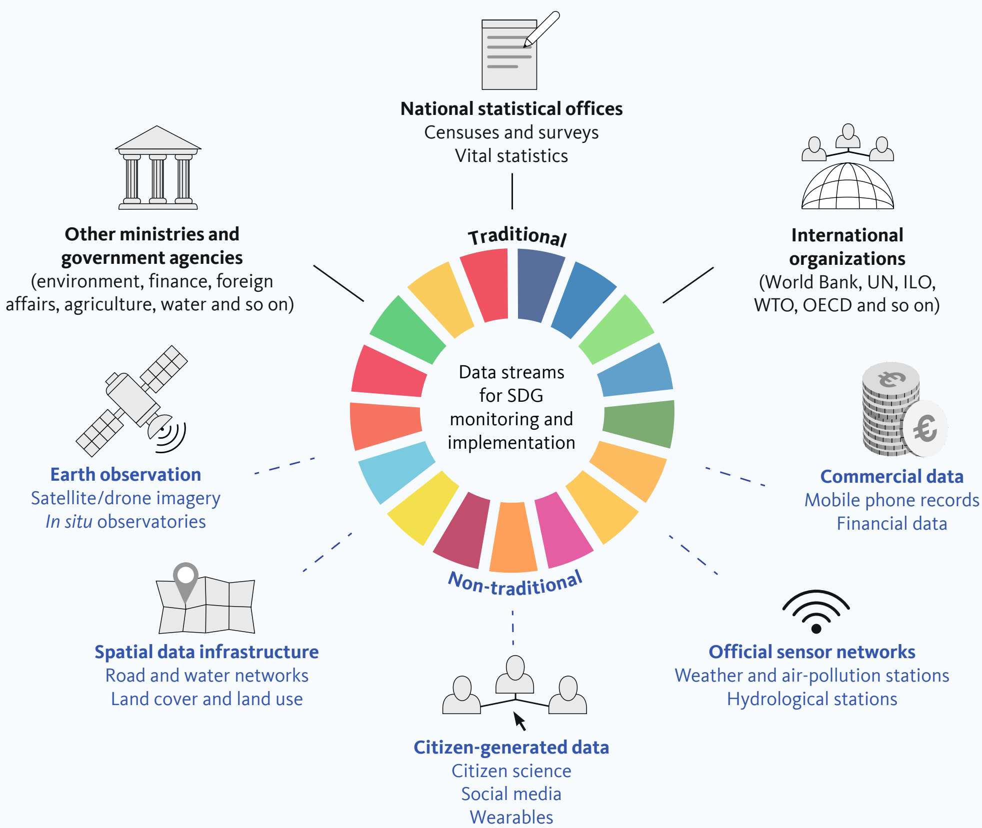


Figure 4.1-1
Citizen science as an additional data source for SDG monitoring and SDG implementation, and five dimensions of corresponding data
Source: Fritz et al., 2019:924f.

Table 4.1-1
Interaction diagram for citizen science and the 2030 Agenda.
Source: WBGU, own diagram based on Shulla et al., 2020:9

Citizen Science Bottom-up	Interaction paths	2030 Agenda top-down
internationally organized CS networks	international partnerships for SDGs (a)	international organizations
national CS networks	national partnerships for SDGs (a)	member states
CS in public policy	SDGs in national/local policies	national/local governments
CS in organizations	SDGs in strategies and actions (b) (c) (e) (d)	companies, science companies, NGOs
CS and scientists	SDGs in projects/research (b) (d) (e)	science community
individuals or groups conducting CS	SDGs in individual action (b) (e)	public sphere

individuals participate in transformation, and include references to recent studies. Consumers looking for opportunities to show solidarity in their actions usually already have a strong ecological orientation and are embedded in a social environment that expects them to act in an ecological way (Gifford and Nilsson, 2014). When it comes to actually using their new behavioural options, further conditions are important for the consumers: studies from the field of sustainable consumption reveal the relevance of self-efficacy expectations (i.e. the conviction of making a meaningful contribution through one's own actions), the importance of social norms (Schultz et al., 2018) and, in particular, the availability of individual resources (time and money). This also points to important obstacles to the realization of a solidarity-based lifestyle.

Obstacles to taking on responsibility

From the psychological point of view, changes in behaviour towards sustainable consumption follow action types that differ according to action conditions and limits to changeability (Stern, 2000; Nielsen et al., 2020). Deliberate sufficiency in consumption, i.e. economical and shared consumption (reduced use, doing without, repairing, sharing, reusing), is strongly influenced by an ecological motivation and subjective norms (the expectations of important other people) as well as self-efficacy expectations (see e.g. Klöckner and Blöbaum, 2010, on modelling individual changes in use; Steg and Nordlund, 2018). Limiting factors on change lie predominantly in the person of the consumer, for example in the extent to which behaviour has become a habit and in a partial lack of social recognition or in contradictory cultural norms (e.g. reducing consumption of meat; Rees et al., 2018; Section 3.4).

Decisions in favour of sustainable alternative products (energy-efficient appliances, ecological building materials, sustainably produced food) or services (soft tourism, 'too good to go') are also influenced by an ecological orientation (Kastner and Matthies, 2016), but to a lesser extent than sufficiency-oriented consumption. More relevant factors here, in addition to availability or the effort required for decision-making, are price and financial resources, especially in the case of larger investments (Wolske et al., 2017).

These barriers primarily affect the area of land-related consumption (food, purchase of wood products, construction, etc.). Sustainable products and services are currently only accessible to consumers to a limited extent. Although, not only health food shops but also discount grocery stores now also offer organic and fair-trade products, the range of products they offer is not comparable to that of conventionally produced products (in Europe, Denmark has the highest overall share of organic products in food sales at 11%; Foodwatch, 2020; Statista, 2020; BÖLW, 2019). Due to the lack of internalization, the higher relative price of sustainably produced products proves to be an additional obstacle to consumers' willingness to buy. Similarly, the ecological option of timber-based construction is not the norm for owner-occupier home builders. On the one hand, turnkey terraced homes in Germany, for example, are rarely offered as timber buildings – in contrast to Scandinavia – partly because timber-based construction is more expensive (Section 3.5.3). On the other hand, there is often a lack of information about new technologies, which discourages innovation. For example, there are reservations about timber-based construction (Venables et al., 2004), and sustainability certifications of timber are also controversial (Section 3.5.3).

4.1.2 Change agents in powerful roles

Change agents can initiate and try out scalable changes (Box 4-1). Such changes are manifested not only in specific initiatives and actions, but also by developing desirable visions of the future and laying the foundations for change at the political, institutional, economic and technical levels (Schneidewind, 2018). In addition to individuals who consume sustainably, i.e. on the basis of solidarity, investors, producers and participants in organizations, institutions or communities (social, cultural or religious) can also contribute as change agents to a global land-use transformation (Schneidewind, 2018:457f.).

Even if there are currently still obstacles to a transformative change in land stewardship, pioneers are showing in many ways how their own spheres of action can be expanded. Despite unfavourable incentives and obstructive structures, they seek out niches and make an impact there. In the following, examples of actors of the land-use transformation are examined in the context of the multiple-benefit strategies outlined in this report (Chapter 3). This is followed by an examination of the existing framework conditions and an identification of points where policy-makers can begin expanding the scope of action for change agents.

Furthermore, some actors overcome socio-cultural barriers and, specifically for this reason, make a key contribution to the success of the sustainable land-use transformation. Important barriers include gender-based discrimination (Box 2.3-2), racism and intergenerational injustice. For example, women* are already driving the Great Transformation as change agents (Röhr et al., 2018a; the term women*, as used here, includes any person who identifies as a woman in some way). Yet their contribution is hampered by discrimination, which is pronounced in all countries of the world (UN Women, 2019), risking the success of the sustainable land-use transformation (Shukla et al., 2019: 7; IPBES, 2018a; FAO, 2019d). Despite the increasing attention that the issues of gender equality and environmental protection have received in recent years, reform processes in this important nexus area are making only slow progress. Currently, research and practice lack the differentiated data they need to take into account barriers, constraints, opportunities for transformation and interactions between the global land-use transformation and the diverse, lived realities of all gender groups (UNEP and IUCN, 2018; Röhr et al., 2018; UNEP, 2016).

Change agents at the interface with institutions

Citizens can become change agents in institutional roles, for example within the framework of non-governmental organizations (NGOs). NGOs, e.g. environmental associations, have a considerable leverage effect, as they communicate corresponding values in addition to offering activities and support services. In the WBGU's view, they can have a particular impact in three functions:

1. across the board as 'champions' of sustainable land stewardship (e.g. IUCN, The Nature Conservancy, Commonland, Friends of the Earth),
2. in communicating scientific results to civil society, processing knowledge and providing information (e.g. WWF, BUND, 350.org, Earthwatch),
3. as activists, role models and (practical) supporters of solidarity-based lifestyles (e.g. WIR, Rainforest Alliance, NABU, 1t.org).

Furthermore, they can exercise a societal and legal control function by scrutinizing state agencies in their implementation of environmental law and, in the event of shortcomings, can also take governments to court, depending on the legal situation (see Schlacke on 'representative action', 2019: 134f.). As part of their support for sustainable-solidarity lifestyles, they can collect examples of barriers and obstacles that arise (e.g. lack of choice, information gaps, legal barriers to new practices; Section 3.4), address them and work for their removal. Science too can operate at the interface between science and civil society, for example by effectively getting citizen science involved and thus contributing to learning processes and changes in awareness (Box 4.1-1).

Examples of powerful pioneers in the land-use transformation

In addition to NGOs, there are also individual pioneers who advocate for the land-use transformation and for overcoming the trilemma. These are mainly landowners, resource owners, farmers and foresters, as well as builders and carpenters.

Landowners manage land sustainably when they use their land for diversified cultivation or make it available to others so that further sustainability interests can be pursued, such as the development of local energy-generation and energy-supply concepts (Schön et al., 2019), the private establishment of protected areas (Section 3.2), or restoration activities (Section 3.1). For example, the leasing of land can be made conditional on sustainable use. 'Passive' owners of agricultural or forest land can be motivated by other owners to convert to sustainable forms of use. In addition, Schön et al. (2019) discuss the deployment of land managers, who, like climate-change managers, are "positioned between all stools in the best sense of the term, have authority and staff, sovereign powers and proper resources to enable them to perform their tasks effectively" (Schön et al., 2019: 25). These tasks include mediating between different user interests and possibilities of use (management of cultural landscapes). In the same way, resource owners with large financial resources can donate their property to sustainable initiatives, foundations or enterprises, or use it to set up protected-area systems or diversified production companies. The Swiss association called Organization for People and Nature (Organisation für Menschen und Natur), for example, pursues the basic idea of "establishing land and nature as inalienable and generally worthy of protection [as well as] passing this land on to our fellow human beings free of charge for purely ecological and sustainable economic use" (OFMUN, 2020). Sustainable organizations such as ProVeg, Greenpeace or Oro Verde offer to organize donations via wills.

As users of land and producers of products, farmers and foresters are also driving the land-use transformation forward, for example by restructuring their own farms and diversifying production (Section 3.3) or by switching to a circular economy (Section 3.5; see the example of Hansalim: Box 4.1-2). Integrating teaching courses and values into training curricula (e.g. Center for Integrated Agricultural Systems, USA) and networking with each other also have a transformative effect, and this gives rise to sustainable alliances such as the 'Wir haben es satt!' (We've had enough!)' initiative (Section 3.4).

Builders, carpenters and other craftspeople act as change agents when they implement sustainable building concepts (Section 3.5.3; see example of Thoma: Box 4.1-2) and thus create a demand for sustainable raw materials, which is then met by farmers and foresters. Here, too, sustainability is becoming a fixed element of training curricula (ZDH, 2020). Catering is another business sector where change agents are active, with many examples of initiatives for switching to a sustainable range of dishes (Section 3.4; see example of Amass: Box 4.1-2).

Despite ubiquitous obstacles, these pioneers still manage to be innovative and transformative in the spirit of the land-use transformation. There are outstanding pioneers in the global environmental movement – like biologist, restorer and founder of the Green Belt Movement Prof. Wangari Maathai – who enjoy international recognition for their commitment (Box 3.1-5). Box 4.1-2 highlights other pioneers working in the spirit of the multiple-benefit strategies presented in this report.

The examples of change agents show that innovations for a land-use transformation can be born out of very different and sometimes very individual motives. Even if the transformative potential does not unfold until the pioneers' ideas are actually taken up and disseminated, the value of diversity and *Eigenart* can be seen in their ideas. The pioneers succeed in overcoming existing barriers to transformation (such as mistrust or a lack of availability) independently and by dint of their individual abilities. Research work has shown that barriers can be overcome in part by expertise and professional skills, and in part by organizational knowledge or relationships in one's own networks (Ahaus, 2019). As the opposite of change agents, there are also blockers of change who exacerbate the trilemma (Chapter 2, Section 3.4), such as food-industry lobbyists (Section 3.4). Heads of state, too, can act to thwart sustainability goals, as evidenced by US President Trump's decision to pull out of the Paris Climate Agreement, or Brazilian President Bolsonaro's endorsement of slash-and-burn rainforest clearance.

4.1.3 Recommendations for promoting solidarity-based consumption and niche actors in the land-use transformation

To make sure that pioneers' niche activities enter the mainstream – i.e. are imitated and can thus develop their innovative potential – the proactive state must create framework conditions that support transformative change in a variety of ways (Section 4.2). The main relevant barriers here are the lack of pricing of external effects, making non-sustainable products too cheap compared to sustainable products, and the related lack of choice of sustainable products. Effective measures should therefore start with the price (Section 4.2.1). Furthermore, however, sustainable consumption should also be promoted by supporting information services, and direct measures should be taken to promote networking between the many different initiatives and to provide information and resources. The individual assumption of responsibility by consumers motivated by solidarity can also be supported by state measures.

The state should promote trustworthy information services

Consumers need reliable information for many individual decisions (e.g. buying garden furniture made of certified wood, buying or building a wooden house). Committed consumers can be demoralized by a lack of – or by contradictory – information (von Massow, 2019). It is helpful if the state consistently advocates alternatives – e.g. nutrition guidelines (Section 3.4.3.5) or sustainable construction (Section 3.5.4) – especially to

Box 4.1-2

Outstanding examples of transformation actors

Ecosystem restoration: organize land-based CO_2 removal in a synergistic way

Sebastião Salgado – restoration through reforestation. Alongside his artistic work as a photographer (including 'Genesis' with photographs of untouched nature), Salgado is committed to the restoration of areas of land and to campaigns against deforestation. Behind this is his view that restoration is not only a matter of investing in nature, but also a way of making amends for the degradation caused over generations by livestock farming. As part of this commitment, he and a team of students planted more than two million trees on his family's Bulcão farm, which was already affected by land degradation, and restored the area; this was accompanied by a recovery of the local climate and water balance. Together with his wife Lélia Deluiz Salgado he founded the Instituto Terra. This organization is committed to nature conservation and promoting the restoration of cleared forests. Very much in the spirit of transformative research, the Instituto Terra provides knowledge and experience that can be used directly by other transformation actors.

Expand and upgrade protected-area systems

"My land is now owned by lions" – Ol Kinyei Conservancy. The Ol Kinyei Conservancy in Kenya is located in the Mara ecosystem and covers an area of over 8,000 ha, an area that was created by the municipality for wildlife in the absence of human settlements and livestock. The reserve belongs to a Maasai community, who make the land available for wildlife conservation (Fig. 4.1-2). The Conservancy was founded in 2005 as a partnership between 171 private landowners and a company called Gamewatchers Safaris & Porini Safari Camps.

The basic idea is that landowners in a nature reserve cooperate with a tourism provider, who sets up a safari camp. The funds generated by a combination of nature conservation and user fees, e.g. accommodation costs, are shared between the operators and former landowners at agreed percentage rates.

Expand restoration and protected-area systems

Associação Mico-Leão Dourado and Save the Golden Lion Tamarin – reintroduction of the golden lion tamarin in Brazil. Deforestation, expansion of agricultural systems and advancing industrial development have significantly restricted the habitat of the golden lion monkey. The Associação Mico-Leão Dourado (AMLD) was founded in 1992 to save these primates. The group began buying up land to create contiguous protected-area systems and reintroduce the golden lion monkey to

Figure 4.1-2
Tourists getting a close-up view of three giraffes in the Ol Kinyei Conservancy in Kenya's Maasai Mara.
Source: Make it Kenya (public domain 1.0), flickr.com

Figure 4.1-3
Construction of a bridge over a Brazilian highway connecting several parts of the protected-area system.
Source: Maria Magdalena Arrellaga

Figure 4.1-4
Division of labour in the Hansalim initiative.
Source: Jun Michael Park/laif

Figure 4.1-5
Matt Orlando.
Source: amassrestaurant.com

Figure 4.1-6
Example of a Thoma house in South Tyrol.
Source: ©Thoma Holz GmbH

Brazil (Fig. 4.1-3). They were not only supported by zoos; in the USA, the Save the Golden Lion Tamarin initiative was set up with the aim of ensuring basic financial security for the AMLD's further work. The population, which had dropped to 200 animals, has risen to 2,500 animals in the meantime; they live in about 2 million ha of forest (New York Times, 2020).

Diversify agricultural systems
Hansalim Nong San – mainstreaming sustainable solidarity agriculture. The Korean association Hansalim is an example of how a local idea can become a national movement. The initiative, which grew out of a single shop, is characterized by the principle that consumers guarantee the livelihood of farmers via a solidarity fund; in return, farmers contribute to consumers' health with modern, ecologically produced organic products (Fig. 4.1-4). By 2014, a system of cooperation involving distribution points, organic food stores and a delivery system enabled about 2,000 farms to supply about 1.6 million people (One World Award, 2014). The movement also works to preserve endangered seed varieties as well as animal and plant species.

Transform dietary habits
Matt Orlando – 'Amass' low-CO_2 restaurant in Copenhagen. In his restaurant, Matt Orlando uses new methods of recycling food waste, grows ingredients in his own restaurant garden, and installs water-collection stations. His philosophy is to make sure he uses all food components (peel, seeds, stems) when cooking. Waste that cannot be further recycled is composted on site and used as fertilizer for an aquaponics system in the restaurant's own greenhouse (Fig. 4.1-5). Externally, he works exclusively with companies that reuse packaging. Altogether, 90–100% of the food and drinks are organically produced, and 95% of all products sold are sourced regionally.

Design the bioeconomy responsibly and promote timber-based construction
Erwin Thoma – solid wood houses. Erwin Thoma is a forester and author whose work focuses on our relationship with wood and its natural properties as a CO_2 reservoir. Based on these values, he has given his construction company the credo of building largely energy-autonomous timber houses that heat and cool themselves and use no environmentally harmful building materials (Fig. 4.1-6). His solid timber house-construction system 'Holz100' uses only wood as a building material, including the dowels. The resulting houses offer a healthy living environment, comply with insulation and fire-safety regulations, and allow for individual diversity, since asymmetrical window shapes and wood/glass combinations are also possible in timber-based construction.

overcome old consumption practices (i.e. which are now inappropriate from the point of view of sustainability). By consistently exercising its governance functions (taxation, supply restrictions, quotas, etc.) the state also transports a general societal normative standard (and can, where necessary, reduce 'label fatigue'; Sections 3.4.3.5, 4.2.2).

Make pioneers visible and provide resources for networking

Individual actors who, in their roles as part of civil society, science or business, advocate land-use transformation by trying out new ideas, can be supported in their transformative action by making existing individual activities or initiatives visible, networking them and providing them with resources (e.g. premises, funds to professionalize an initially voluntary commitment; Hofmann et al.).

Actors are offered a chance to overcome barriers more effectively in spaces where either relevant skills or knowledge about political, societal, organizational or institutional contexts are taught. In this context, it would be advisable to make greater use of the opportunities offered by digitalization and to further strengthen networking among the sustainability and digitalization community (WBGU, 2019b). Experienced 'transformers' could design corresponding services and make their knowledge available to others. Corresponding financial support and the establishment of publicly usable spaces (such as 'open space laboratories', in which innovative concepts can be developed and discussed) would help pioneers who are already active to conduct their activities. Support in the form of network meetings or other opportunities for exchange also has a transformative effect – not only for the change agents 'among themselves', but also via the possibility of gathering actors in different roles around a table (such as members of food-sharing initiatives and representatives of the local retail trade).

Promote sustainable education in schools, training and further education

Education is a general prerequisite for inclusion in a changing society, for understanding problems and for developing personal norms of action. Education is also important as a resource for obtaining information (knowledge about alternative products) and the critical examination of information sources – or knowledge of trustworthy information sources. Beyond school education, the mainstreaming of new practices requires the adaptation of training plans (e.g. in the construction trade or catering) and the rapid availability of training opportunities.

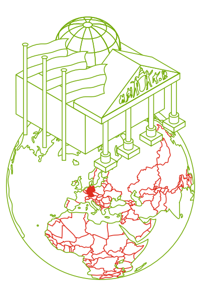
Promote gender equality as a cross-cutting issue of land-use transformation at the federal level

The political mainstreaming of gender equality should be promoted to ensure that the German Federal Government's contribution to the global transformation of land use is gender-equitable and successful; in particular, structural power differences and drivers of gender inequality in Germany and its institutions should be reduced. Economic and political inclusion are key to this. They could be promoted by gender-sensitive social policy, political and economic representation based on gender parity, and anti-discrimination training for management personnel (Röhr et al., 2018).

Promote interdisciplinary research into the nexus of gender and environmental issues and develop multilateral indicators involving monitoring

With the aim of strengthening the 2030 Agenda and the Rio Conventions by means of gender-environment indicators and corresponding monitoring, existing drafts (such as UNEP and IUCN, 2018) should be built upon, taking into account not only women* but also other discriminated gender groups. The issue of gender equity in OECD countries requires more scientific attention, not least in the context of the European Green Deal. Social-science approaches, such as feminist political ecology, can make an important contribution here (Röhr et al., 2018) and should be promoted more widely.

4.2 Proactive state: create framework conditions for solidarity-based land stewardship



The room for manoeuvre available to change agents (Section 4.1), and for land stewardship as a whole, is determined by effective state measures and decisions at various levels of governance: at the local or municipal level, at the level of the *Länder* or regions, and at the national, supranational and international level. The challenge for states and their actors is to develop a consistent system of different instruments to support a land-use transformation and to dismantle blockages.

Starting points for public frameworks (Fig. 4.2-1) that promote sustainable land stewardship are manifold and include, in particular, the creation of sufficiently strong price signals or financial incentives against degradation or destruction and for the conservation of ecosystems (Section 4.2.1), sustainability standards in the form of voluntary or obligatory certifications, up to and including statutory rules or prohibitions (Section 4.2.2), and planning approaches in spatial and landscape land-use planning (Section 4.2.3). Indicators and monitoring that document both the management of land and biogenic products and the implementation of the most important land-related strategies provide basic data and orientation for this purpose (Section 4.2.4). All these instruments are well-known in principle, and there are already a large number of partial regulations and incentives (also from non-governmental initiatives) at various levels of governance that are applied in individual countries, directed, for example, at certain sectors such as agriculture, or at individual uses of specific types of biomass.

However, at least three overarching challenges arise when designing a consistent and effective governance system (Section 4.2.5): (1) its reach across sectors and different land areas and types of use should be increased, (2) individual instruments should be coordinated with each other in the process, and (3) administrative and planning hurdles should be removed to avoid evasive reactions by actors – which can lead to counterproductive relocations of land-use effects between land areas and sectors – and to promote the use of synergies in multifunctional land use (Section 4.2.5.1). Furthermore, the existence of foreign-trade relations and cross-border ecosystems make it necessary to internationally harmonize framework conditions and goals in sustainable land stewardship (Section 4.2.5.2). Socio-economic distribution effects of changes in land-use options and overall frameworks should also be taken into account (Section 4.2.5.3) in order to reduce barriers to a transformation towards sustainable land stewardship and to stabilize this in the long term.

States exert direct influence on the use of land and ecosystems not only as designers of framework conditions, but also as owners of large areas of land and as major resource consumers (e.g. as builders). In addition to the framework conditions outlined in this section, states should act as role models for sustainable land stewardship.

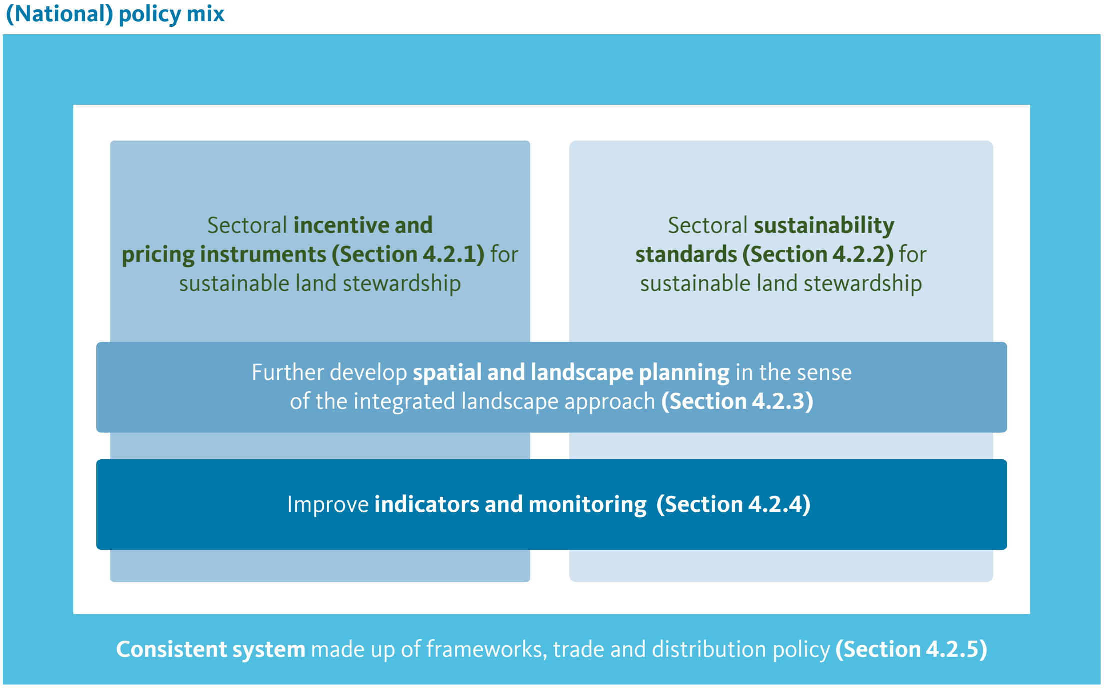


Figure 4.2-1
Classification and relation of various instruments and processes of the proactive state. The respective subchapter is indicated in brackets.
Source: WBGU

4.2.1
Reward sustainable behaviour, put a price on environmental damage: incentive and pricing instruments

Instruments of pricing, such as taxes, levies and subsidies, create targeted financial incentives, either to discourage modes of behaviour and products that cause costs for society and are not in line with sustainability goals, or to promote types of behaviour which contribute to the implementation of sustainability goals. In the context of land use, too, the basic idea is always to internalize costs and values which private-sector actors would otherwise not (or insufficiently) take into account in their (economic) decisions, because ecosystems and many ecosystem services are regarded as commons. Similarly, instruments such as trading in pollution rights (e.g. in the European Emissions Trading Scheme) or offsetting – i.e. obligations to compensate for interventions in ecosystems by taking protective measures elsewhere or making financial contributions – also create economic incentives for individual actors to take the ecological impact of their decisions into consideration (Teytelboym, 2019). More sustainable modes of behaviour and products thus become more advantageous or cheaper relative to less sustainable alternatives and thus more attractive from a private perspective.

As shown by the multiple-benefit strategies in Chapter 3, examples of pricing and incentive instruments used in the land context can already be found on various levels today, or are conceivable in the future. Elements of today's second pillar of the CAP, and especially the recommended ecological reform of the CAP, follow the guiding principle of 'public money for public goods' (Helm, 2019; Sections 3.3, 4.3). Various schemes for paying for ecosystem services already exist worldwide (Box 4.2-1). These should be further expanded in future to promote, for example, the sequestration of CO_2 through restoration measures (Section 3.1). Funds flow from industrialized to developing countries via REDD+ (Box 3.1-6) to protect and restore forest ecosystems there. Pricing-in the environmental costs of food production (Section 3.3) can make the supply of sustainable food relatively cheaper and thus contribute to a change in dietary habits (Section 3.4). CO_2 prices in other sectors indirectly influence land stewardship and the use of biomass, for example by pricing emissions from cement production to make timber-based construction more attractive (Section 3.5).

Box 4.2-1

Payments for ecosystem services

Payments for ecosystem services (PES) are intended to give a financial reward for the promotion or conservation of those services that have advantages and benefits for third parties or the general public. Their area of application is correspondingly broad and includes the protection, restoration and sustainable use of ecosystems.

There is as yet no single definition of PES. Characteristic features are (1) a reliance on the impact of financial incentives and the voluntary nature of programme participation; (2) payments are dependent on specified demands on the provision of the ecosystem service in question, so that monitoring and sanctioning measures are required (conditionality); (3) the basic idea is to financially reward those who make public assets of value available (Wunder et al., 2020). However, Salzman et al. (2018) include e.g. offsetting approaches to PES, although in many respects such compensation for the degradation of an ecosystem generated in this way does not correspond to the characteristics of the PES mentioned, for example because it is mandatory, at least in the case of regulatory approaches (Vaissière et al., 2020; Wunder et al., 2020).

A distinction is made between user-financed PES – in which the financial compensation takes place directly between the users and 'providers' of the ecosystem service (e.g.landowners) – and state-financed PES. In the case of the latter, the state or a public institution in general acts as a representative of the users and makes payments to the providers of ecosystem services (Wunder, 2015). Like ecosystem services that can have an impact at any level from the local to the global and thus have the characteristics of local up to global commons, PES can be applied at very different levels: locally between individual land owners and users, between land owners and state administrative units, between different levels of the state administration, or internationally between states or international donors and local communities or ecosystem managers.

Existing programmes at a glance

Numerous PES programmes have emerged around the world over the past two decades or so, particularly in Central and South America, the United States, and China (Salzman et al., 2018; Wunder et al., 2020). Examples in Europe include a user-funded programme by the Vittel company to protect drinking-water resources (FAO, 2013) or the METSO forest biodiversity programme in Finland (Viszlai et al., 2016). Particularly prominent are the Pagos por Servicios Ambientales programme, launched in Costa Rica as early as 1996 and managed by the national forest finance fund Fondo Nacional de Financiamiento Forestal (Fonafifo; Chapman et al., 2020), and the Pago por Servicios Ambientales Hidrologico programme in Mexico, launched in 2003 (Alix-Garcia et al., 2015, 2019). Both programmes make payments to owners or local communities for the conservation and restoration of forests, but also reward certain practices (agroforestry systems in the Costa Rican example; FONAFIFO, 2020a). They address the conservation of biological diversity in natural forests, the protection of water resources, the contribution made by forests to climate-change mitigation, but also the cultural value of intact, pristine forest ecosystems. The programmes provide for renewable five-year contracts with annual payments, and monitoring of the agreed services by government agencies, in Mexico also based on satellite data (Alix-Garcia et al., 2019). In Costa Rica, for example, financing comes from revenue from the national fuel tax, supplemented by contributions from international donors such as the GEF, the German Federal Government or KfW (FONAFIFO, 2020b). For example, the GEF also supports a PES programme in Colombia that rewards conversion from pasture-only to silvopastoral systems (Pagiola et al., 2016; Box 3.3-7). REDD+ (Box 3.1-6) not only promotes PES schemes at the regional or national level; with its outcome-based payments, it can furthermore be regarded as a PES approach between industrialized countries and developing and emerging economies (Snilsveit et al., 2019: 10).

Effectiveness of payments for ecosystem services

Costa Rica's and Mexico's programmes are among the applications that have been empirically studied most intensively. The studies have revealed (statistically) significant, albeit generally moderate protective effects, but significant changes in use practices (Alix-Garcia et al., 2019). The observed effects vary over different time windows, depending on the duration of programme participation and the degree of deforestation risk prevalent in each area; the protective effects are seen to be stronger when the risk is higher. However, recent review studies clearly show that, despite the numerous PES approaches that exist worldwide in the meantime and many case studies, there are only few empirically robust observations on their effectiveness and cost-efficiency; so there is still a considerable need for further research in this respect (Salzman et al., 2018; Snilsveit et al., 2019; Wunder et al., 2020). The need for research is similarly high in the case of other regulatory approaches such as certification initiatives or protected areas (Miteva et al., 2012; Ferraro, 2018; Börner et al., 2020). According to current knowledge, PES and protected areas have comparable protective effects (Sims and Alix-Garcia, 2017; Wunder et al., 2020); larger effects have only been recorded for the recognition of indigenous administrative rights (Börner et al., 2020). Despite the different concepts involved, PES are sometimes also used in combination with protected areas. Synergies between the two instruments, both in terms of protective effect and in terms of reconciling protection with economic interests, have only been demonstrated in (forest) areas that are adjacent to a protected area and thus have only partial protected-area status (Sims and Alix-Garcia, 2017: 22). At the political level, however, in Costa Rica, for example, the introduction of PES promoted acceptance for tighter laws on forest management and the expansion of the national protected-area system (Wunder et al., 2020).

Challenges in the design of PES

- *Accuracy:* Payments for sustainable behaviour generally entail the risk of 'free-rider' effects, i.e. that payments are received precisely by those actors for whom more sustainable behaviour incurs little or no costs. Compared to the status quo, this tends to lead to little progress in the stewardship of land or ecosystems (problem of adverse selection; Hanley et al., 2012). The usually limited financial resources should therefore be targeted as precisely as possible in order to address (1) ecologically especially valuable regions or ecosystems that (2) are simultaneously exposed to particularly high risks of destruction or degradation and (3) would not be used sustainably or more sustainably by the local actors without payments (problem of additionality). This kind of targeting is currently only practised by a small number of programmes (Wunder et al., 2018a), but it is just as relevant for the designation of protected areas, for example (Geldmann et al., 2019), where it is not the voluntary programme participation of relatively unimportant actors but political reasons that prevent particularly endangered valuable areas from being placed under protection (Sims and Alix-Garcia, 2017). The local risk of ecosystem destruction or degradation can usually only be estimated in advance via drivers such as the location's proximity to settlements or transport routes (Busch and Ferretti-Gallon, 2017). However, this information problem is context-dependent and less relevant for (re)afforestation, for example, than for the protection of a forest (Alix-Garcia and Wolff, 2014: 367).

- *Design of payments* for ecosystem services*:* In order to change behaviour, PES must at least compensate the actors for the opportunity costs of forgoing uses that are (apparently) more attractive from a purely business point of view. These 'costs of providing ecosystem services' vary between ecosystems, actors and geographic location. Unlike in the case of many current PES (Wunder et al., 2018a), effective payments should be based as far as possible on these opportunity costs; however, they are known in advance only to the individual actor. Auction procedures can alleviate this (governmental) information problem, but they make programme participation more difficult, especially in developing countries (Wunder et al., 2020). The temporal structure of costs and payments – i.e. whether they fall due at the end of (or spread over) the duration of PES contracts – also influences whether PES create effective financial incentives, especially in the case of credit-constrained actors (Jayachandran, 2013). Moreover, business disadvantages do not always arise in the long term. In Colombia, for example, time-limited PES were sufficient to permanently establish silvopastoral systems (Pagiola et al., 2016).
- *Measurable and meaningful indicators:* Even if monitoring mechanisms are provided for, many programmes have lacked sanctions up to now (Wunder et al., 2018a). In addition to effective monitoring and sanctions, ecologically effective incentives also require payments to be based on correspondingly meaningful indicators. Measurement problems in particular often lead in practice to the use of 'proxies' (e.g. forest-cover density), which only approximately ensure that changes in behaviour really improve ecosystem services (Alix-Garcia and Wolff, 2014; Wunder et al., 2020: 234) – or reward certain measures or behaviours instead of concrete changes in ecosystem conditions. This also encourages programme participation, as payments are then not dependent on uncertain natural impacts on ecosystems. However, differentiated sanction mechanisms, like those in Mexico, can achieve similar results (Alix-Garcia et al., 2015: 5).

Development-policy motives

In addition to environmental objectives, PES sometimes explicitly pursue social- or development-policy objectives, such as combatting poverty in rural areas. However, studies to date show little or no positive impact on economic prosperity at the household level (Snilsveit et al., 2019: 65f.; Alix-Garcia et al., 2019: 20). Interpreted positively, at least the changes thus achieved did not impair the households' socio-economic development. Positive social effects have been shown in relation to infrastructures and the social constitution of local communities ('social capital'; Alix-Garcia et al., 2018). In general, however, combatting poverty through PES is not always conducive to the effective implementation of environmental policy objectives, for which payments should be differentiated according to the payees' opportunity costs and independently of their economic situation, while addressing particularly vulnerable ecosystems (Alix-Garcia et al., 2015; Wunder et al., 2018a). The mixing of social and environmental motives is also seen as an explanation of why many PES programmes have to date rarely sanctioned deviations from agreed ecological targets (Wunder et al., 2018a). Lack of information about the existence and purpose of PES programmes (Snilsveit et al., 2019: 60f.), necessary upfront payments for programme participation (Jack and Jayachandran, 2019), and credit constraints (Jayachandran, 2013) can also make it difficult for poorer populations in particular to access PES programmes. Inadequately defined or verifiable ownership or control rights over land can also be a problematic factor for PES, especially in the tropics (Alix-Garcia and Wolff, 2014: 371). In comparisons between protected areas and PES in Mexico, PES tend to have more positive effects on factors of social development, while biosphere reserves tend to have more positive effects on the side of environmental protection (because, although they also aim for a balance between protection and use by the local population, they are not based on the concept of voluntary participation and therefore always place contiguous areas under protection (Sims and Alix-Garcia, 2017).

PES and intrinsic motivation

One criticism of PES is directed at the possible displacement of an intrinsic, already existing motivation for sustainable land stewardship. However, up to now this has not been observed systematically but mainly depending on the local context: such a 'crowding out' of motivation is more likely to occur in areas where high intrinsic motivation and strong social norms were already prevalent beforehand and where the local population was less familiar with market mechanisms (Wunder et al., 2020). In other contexts, however, positive effects on motivation and social factors have been demonstrated. In Mexico, PES to local communities did not reduce people's willingness to perform unpaid work in landscape maintenance or social work in the community. Rather, prolonged programme participation in particular promoted social aspects such as community infrastructures, political participation, or inclusion in the community (Alix-Garcia et al., 2018).

Advantages and disadvantages of incentive-based instruments

However, promoting sustainable land stewardship with the help of targeted financial incentives should always bear in mind the limits of the corresponding instruments. The advantages and disadvantages of these instruments have been widely discussed and are known in principle (Sterner and Robinson, 2018). In the following, the WBGU would like to highlight a number of key aspects, particularly with regard to the design of suitable framework conditions for sustainable land stewardship.

Setting financial incentives creates scope for innovative behaviour by the actors. The reason is that price and incentive instruments – unlike rigid regulations such as specific codes of conduct or bans – give actors greater freedom of choice to respond to the specified framework conditions (Miteva et al., 2012). In this way, based on their respective knowledge, the actors can develop innovative solutions adapted to local contexts for sustainable land stewardship; they can also find a balance between different claims to the use of land and its ecosystems, which are often difficult for states or central regulatory bodies to anticipate in advance or describe in detail in more stringent specifications. In addition to encouraging innovative, sustainable behaviour, this openness and opportunity to use local knowledge helps achieve sustainability goals at low cost (Hanley et al., 2012; Sterner and Robinson, 2018). By deliberately changing market calculations and the dynamics of markets, price instruments can also serve to disseminate more sustainable behaviour and more sustainable goods and services more quickly (mainstreaming). For example, in the case of dietary habits, the actors' freedom of choice can also help to raise acceptance of the regulatory framework (Section 3.4).

The impact of price and incentive instruments cannot usually be accurately estimated in advance; this is the flipside of their openness to the knowledge and decisions of individual actors. If, for example, the prices for emissions-intensive foods rise as a result of the pricing of greenhouse-gas emissions in agriculture, individual consumers are, in principle, free to continue consuming them. Price and incentive instruments, therefore, do not generally draw absolute limits on the use of ecosystems, e.g. in terms of biomass use (Section 3.5; Barbier, 2019). Exceptions in this respect are incentive-based instruments that are linked to quantitative caps, as in the case of emissions trading. However, these instruments can involve higher administrative costs and require more complex institutions (Helm and Hepburn, 2012:12f.).

Problems for the ecological effectiveness of price and incentive instruments also arise from the ex-ante open reactions of individual actors if the conservation of ecosystems or biodiversity requires the coordinated action of as many actors as possible in a spatially contiguous area. In this case, if some users of ecosystem services withdraw from participation, individual payments for behavioural changes to the others would (largely) remain ineffective (Teytelboym, 2019). Design proposals for pricing instruments in such situations (e.g. when promoting sustainable farming systems) include payments to the local community of stakeholders as a whole, whose members must then coordinate their own behaviour among themselves (Simoncini et al., 2019: 7). To reveal the special value of locally coordinated behavioural changes, local additional payments (agglomeration bonus) are also discussed in the context of payments for ecosystem services (PES) and pricing instruments for biodiversity conservation (Hanley et al., 2012; Banerjee et al., 2017; Box 4.2-1).

Individual accountability and control of emissions and ecosystem services as a challenge

Since price and incentive instruments are strongly geared to the behaviour of individual actors, their use depends to a large extent on the ability to measure emissions and ecosystem services at the level of individual actors and to attribute them to (Section 2.2.3; Table 2.2-1) those actors. This is a challenge, especially in the context of land use. For example, greenhouse-gas and CO_2 emissions at the level of individual farms cannot be comprehensively measured justiciably today, even in advanced countries such as Germany, due to diffuse emission sources (Isermeyer et al., 2019).

Problems with the allocation and measurement of actor-specific responsibility are circumvented – for example in the case of financial incentives for biodiversity conservation in the agricultural sector – by linking financial incentives not to the actual individual contributions, which are difficult to measure, but to the implementation of predefined measures or agricultural methods. However, the advantage of pricing instruments is partly lost as a result, which is that they make particularly extensive use of local or actor-specific knowledge in the implementation of ecosystem policy (Hanley et al., 2012).

Agreed changes in behaviour, for example in the context of payments for ecosystem services, are not always easily observable and thus controllable by states or donors in general. To address this information problem and the so-called principal-agent problem (Kerr, 2013), payment structures are adapted in PES approaches, for example, and outcome-based payments are envisaged (e.g. under REDD+; Box 3.1-6) which are not paid out until the agreed benefits have been verified. However, this shifts the risk of achieving the desired environmental or sustainability impact to the individual actor on site (Hanley et al., 2012:98). This can act as a barrier for risk-averse or credit-constrained actors, especially if actors have to make outcome-based payments in advance (Jayachandran, 2013).

Conclusions

In order to promote sustainable land stewardship in as focused a way as possible, incentive-based instruments should be used at different levels, depending on whether local, regional or global external effects of actors' actions are being targeted. In this context, external costs caused by ecosystem degradation should be systematically priced and the active protection of ecosystems and their services remunerated, insofar as markets or private-sector negotiation processes (largely) fail to do so (Helm, 2019). To more fully integrate the values and scarcities of natural resources and ecosystems into the motivations and decisions of private-sector actors, the substantial environmentally harmful subsidies that still exist worldwide today – conservatively estimated at US$4,000–6,000 billion globally across both terrestrial and marine ecosystems – should also be eliminated (Dasgupta, 2020: 43).

Box 4.2-1 discusses in greater detail the design challenges of pricing instruments for sustainable land stewardship and experience with their practical application using the example of payments for ecosystem services. Overarching challenges lie in coordinating instruments between different regulatory areas of environmental policy and across different (economic) sectors, land areas and biomass uses. Uncoordinated financial incentives, for example through high prices for CO_2 emissions, without correspondingly effective attempts to address the negative consequences of increased ecosystem use as a (supposedly) climate-friendly supplier of raw materials, lead to evasive reactions on the part of actors and thus to relocation effects, which in many cases run counter to more sustainable land stewardship. Section 4.2.5 considers these systemic demands on effective framework conditions and the distributional effects of changes in the price structure as an additional challenge for the application and design of price and incentive instruments.

4.2.2 Demand sustainability: voluntary and statutory standards

Compliance with sustainability criteria in land stewardship can also be achieved, as an alternative or in addition to price instruments, through voluntary certification or mandatory requirements at various overlapping levels of production and use. Approaches based on sustainability standards range from voluntary product labelling, e.g. for foodstuffs, to criteria governing offsettability against binding quotas (e.g. for 'advanced' biofuels) to bans on certain production methods. These approaches, whose specific advantages and disadvantages are outlined below, can complement each other – but their overall effect has so far been significantly weakened by their limited scope of application in each case, as well as by their differing and generally too low level of strictness and enforcement (Section 4.2.5.2).

Mandatory standards for land stewardship are imposed by states in the form of rules and prohibitions, usually within their own national territory; e.g. restrictions on use in protected areas, bans on certain forms of genetic engineering or pesticides, for example in accordance with the Stockholm Convention (UNEP, 2017), limitations on livestock concentration with a view to liquid-manure disposal or feed production (Sections 3.2, 3.3). Similarly, for some imports into the EU, importers are expected to verify compliance with the laws of the exporting countries, with human rights or other sustainability standards during production. Examples include the EU directive on illegal logging (Box 3.5-8) or supply-chain laws that already exist in individual countries and are currently being discussed for Germany and the EU (Rudloff and Wieck, 2020). Supply-chain laws can define reporting and protection obligations for companies regarding compliance with human-rights and other sustainability goals along their supply chains, especially abroad, and strengthen legal enforcement in the event of violations (BMZ, 2020b). Rules and prohibitions are indispensable when, for example, irreversible destruction must be avoided; however, they are often controversial and involve lengthy verification and decision-making processes (e.g. in the case of glyphosate). The same applies, for example, to pricing instruments (Section 4.2.1). In addition, there are challenges relating to implementation and controls, so that a combination with e.g. incentive instruments can be useful (especially if institutions are weak). For imported goods, for example, the effect depends on what is considered legal in other countries and how well this is enforced (e.g. how effectively illegal logging is tracked down and stopped; Box 3.5-8).

In addition, there are a large number of certification systems for producers or products, some of whose criteria go beyond legal requirements, but which remain voluntary (van Dam et al., 2008; Ramirez-Contreras and Faaij, 2018). They often have a limited scope of application and are awarded or supported, for example, by NGOs, growers' associations and companies, and in some cases also by government agencies (e.g. 'round tables' with the above-mentioned stakeholders on palm oil, soy or biomaterials; government organic labels; Blue Angel). These certification systems are more or less demanding and differ in orientation depending on the issuer (e.g. the more environmentally or industry-oriented FSC or PEFC certifications for wood, Section 3.5.3). In addition to ecological and animal-welfare criteria, such as forgoing certain agricultural and forestry practices and land uses (pesticides, genetic engineering, artificial fertilizers, factory farming, primary-forest clearing, etc.), social aspects such as safe working conditions and fair producer prices are also addressed in some cases (e.g. fair-trade label). Sustainability criteria

Box 4.2-2

Sustainability criteria for biomass under the EU's Renewable Energy Directive

An important example of government-defined sustainability criteria is contained in the latest revision of the Renewable Energy Directive (EU, 2009a, 2018a), which lays down regulations on the use of biomass for energy (originally only for bio-based fuels, but most recently extended to include bioenergy based on solid or gaseous energy sources). It includes differentiated targets for the use of bioenergy from different sources (above all residual and waste materials should be used; WBGU, 2009). Only fuels that cause significantly lower GHG emissions than fossil fuels count towards these targets (emissions from indirect land-use changes are not included here, however). Biomass from forest areas cleared after 2008, drained peatlands, or biomass types for which the risk of indirect land-use changes is regarded as high (e.g. palm oil for biodiesel; Valin et al., 2015) are also being gradually excluded. Since indirect land-use changes cannot be excluded even in this way (e.g. buyers in the EU could be served from previously cleared land, and freshly cleared land used for own consumption or exports to other countries), the Regulation also contains country-specific criteria (Article 29.2/6/7), but only on soil management and forest biomass for sustainable harvesting and non-positive LULUCF emissions (part of the NDCs to the Paris Agreement), with the option of area-based verification. Although all these criteria are not obligatory, they are a precondition for offsetting against binding renewable energy targets and subsidies by the member states.

It should be noted that not only the conservation of primary forests and sustainable reforestation contribute to meeting the LULUCF stipulation, but also forestry plantations, especially if the carbon stored in the soil is not or not fully captured (Section 3.1). Nor has any reference been made to date to the EU's Common Agricultural Policy; social criteria, e.g. on land rights, are also lacking.

relevant to land stewardship are being further developed internationally and across stakeholders, e.g. within the framework of the ISO standard 13065 on sustainability criteria for bioenergy and the Global Bionergy Partnership. One of the benefits of certification is that it can increase transparency and accountability for sustainability (including local concerns) along supply chains and for end consumers. Companies can use it for product differentiation, marketing and image enhancement (van Dam et al., 2008), often in response to civil-society pressure, e.g. from NGOs, and sometimes to pre-empt or influence mandatory regulations at an early stage. Higher prices for sustainable products can provide incentives for sustainable agriculture – if they are passed on to the farmers. On the other hand, one of the disadvantages is that end consumers are often overwhelmed by the variety of labels (Box 3.3-5; Section 3.4.3.5; Gwozdz et al., 2020), whose criteria and credibility they can hardly assess and weigh up against each other. Further specific problems are (1) the high information requirements and corresponding costs, (2) non-transparent certification by private testing companies, (3) 'greenwashing' and an unsustainable increase in demand if biomass flows are not (or cannot be) tracked and, above all, (4) environmental-protection standards that are too low or diluted over time. For example, elaborate multi-stakeholder processes such as the 'round tables' are often criticized for being dominated by companies that have the corresponding resources, while the local population is sometimes unable to assess the consequences, and 'rights holders' are degraded to 'stakeholders' (denkhausbremen, 2019; founding member Greenpeace has since withdrawn in the case of the FSC seal; Greenpeace, 2018). Certifications using government-mandated criteria can therefore be advantageous if they are appropriately transparent, inclusive and ambitious, also because they enjoy a relatively high degree of credibility – at least in Germany.

Finally, states can make the offsettability of certain land or biomass uses against binding target quotas, access to subsidies or public contracts dependent on compliance with sustainability criteria that go beyond mandatory requirements. In cases where financial incentives are not the main focus or only have an indirect effect, this represents a mix together with the instruments described in Section 4.2.1. Examples include CAP greening payments (Section 3.3), procurement guidelines (BMU, 2020c), and the revised sustainability criteria of the Renewable Energy Directive (EU, 2018a), which are intended to promote biomass use for climate-change mitigation but to prevent its side effects (Box 4.2-2; Section 4.3). Where biomass uses are primarily made economically attractive by public subsidies (e.g. biofuels in the EU), requirements that are actually optional but linked to the subsidy have a strong effect. However, sustainability standards should become mandatory (a prerequisite for putting products on the market) when land-use pressure increases, e.g. as a result of further regulation of fossil energies or higher CO_2 prices, and in areas where bio-based products are already economically viable or have no alternative.

In view of the existing legal and voluntary standards for sustainable land stewardship, the overarching goal should be to raise these standards step by step but rapidly. In principle, voluntary certification approaches and the criteria catalogues designed for them should also be further developed. They can also serve as a basis for legal requirements if this becomes necessary. Sector-specific regulatory approaches are well suited for some sustainability aspects, e.g. social standards in production, a diversified seed supply or ensuring fair competition. The latter relates, for example, to the coupling of seeds with pesticides and market concentrations in both segments (Deconinck, 2020), where cartel law can also influence ecological sustainability.

As with the financial incentive instruments (Section 4.2.1), however, partial sustainability standards have the weakness that they can, to some extent, be undermined by displacement effects. Requirements and certifications with limited scope (individual producers, product classes or uses, consumer information) can in particular lead to indirect land-use effects, e.g. to shifting production to other land areas, switching to other biomass types, or selling the non-sustainable part of production to other buyers. This can only be documented and avoided by means of comprehensive sustainability requirements at the level of entire biomass classes or countries or all uses, as shown comprehensively for the instruments in Section 4.2.5.

4.2.3 Develop spatial and landscape planning further in line with the integrated landscape approach

States can use spatial and landscape planning (e.g. the designation of protected areas) to exert a targeted influence on whether an area of land is to be used for one or for several purposes and how different uses are distributed over the available space.

Spatial planning varies greatly from country to country around the world. The WBGU uses the German legal situation as an example to highlight the need for change in national provisions (Box 4.2-3).

Up to now, an integrated landscape approach has not been explicitly incorporated into German spatial planning, which is already somewhat over-complex. The integrated landscape approach as used by the WBGU (Box 2.3-3) is oriented towards landscapes and not towards legally defined spaces which are dependent on (in some cases legally binding) plans that prescribe the uses of the land and its protection. This integrated landscape approach is made up of the following elements: identification of a common interest or target system, participation, development of a common monitoring and assessment framework, adaptive management (Box 2.3-3). To some extent these elements can be realized with the instrument of spatial planning. Although the reference point is not the landscape but the space, both terms can be used almost as synonyms. Spatial planning can coordinate and open up multifunctionality in the landscape or in space, and provide spaces for synergistic and long-term-sustainable multiple-benefit strategies. Spatial planning provides for the participation of all stakeholders and the public in the area concerned and ensures adaptive management by permanently adjusting plans to new realities.

In order for the integrated landscape approach (Box 2.3-3; Section 3.6) to be implemented, decisions on landscape conservation and land use must not be made (only) as a top-down process by states or government agencies. Such a top-down approach would not take sufficient account of specific local characteristics (*Eigenarten*), nor would it secure acceptance among those affected; it would therefore have little prospect of effective implementation. Rather, it is necessary to establish a legal framework that allows local and regional conflicts over the protection and use of specific areas to be coordinated and resolved in the spirit of the land-use transformation outlined here and, if possible, to generate additional land-related multiple benefits. To this end, the various local interests and local knowledge should be actively incorporated and brought to a balance, while also taking telecouplings into consideration. In Germany, the counterflow principle provides a suitable point of departure for this: it states that the development, organization and safeguarding of sub-areas should fit into the conditions and requirements of the overall area, and that the development, organization and safeguarding of the overall area should take account of the conditions and requirements of its sub-areas (Box 4.2-3).

Moreover, substantive goals – like overcoming the trilemma – have so far not been given any prominent weight in spatial planning. For example, the task of determining the goals has been left to the stakeholders and cannot be derived from the overarching legal framework. Spatial planning also takes into account, but does not prioritize, biodiversity conservation, climate impacts and other ecosystem functions, material flows (and the circular economy) and temporary uses such as mobile livestock. Spatial planning has hitherto not given special priority to telecouplings – such as indirect effects on land use, cross-border issues (e.g. in the management of water catchment areas), multifunctional land uses or an orientation towards structural and functional spatial units (which may cross administrative boundaries), or the active involvement of all stakeholders affected in multi-stakeholder procedures that are kept as open as possible.

In this respect, economic interests in the use of space or the landscape often prevail. Furthermore, spatial planning is primarily based on a coexistence of land uses and not on the integration of several uses (or forms

Box 4.2-3

Spatial and landscape planning in Germany

According to the Spatial Planning Act (Raumordnungsgesetz, ROG, 2008), the purpose of overall, supra-local and (unlike sectoral landscape planning) interdisciplinary spatial planning in Germany is to develop, organize and safeguard Germany's overall territory and sub-regions by means of spatial structure plans, spatial-planning cooperation and coordination of spatially significant planning and measures (section 1 I 1 of the ROG). Spatial planning requires the coordination of different demands on space and the settling of conflicts that arise at the respective planning level, as well as precautionary regulations for individual uses for and functions of space (section 1 I 2 of the ROG). In Germany, spatial planning's task is not only to define and secure certain demands on space, but also to coordinate conflicting demands for the use of space and to maintain the necessary functionality of the spaces within its scope. The guiding concept in carrying out this task is a form of "sustainable spatial development which reconciles the social and economic demands on the space with its ecological functions and leads to a durable, large-scale balanced order with equivalent living conditions in the sub-regions" (section 1 II of the ROG). The obligation to achieve "sustainable spatial development" is an essential principle of spatial planning (section 1 II of the ROG). Decisions on spatial-planning objectives and principles are taken by the democratically legitimized planning authorities (state government, districts and municipalities). The public participates regularly in the preparation and amendment of spatial structure plans, in which everyone has a right to be heard but not a right of co-decision. The 'counterflow principle' is intended to guarantee coordination between the different planning levels by ensuring that the development, organization and safeguarding of the sub-regions fit in with the conditions and requirements of the overall area and – *vice versa* – that the development, organization and safeguarding of the overall area take account of the conditions and requirements of its sub-regions (Section 1 III of the ROG). The counterflow principle is organized on a technical-spatial basis between different government agencies; this does not amount to a multi-stakeholder approach.

Land use at the local level is determined by area-use plans for the entire municipal area and by parcel-specific development plans (land-use planning) by the municipalities themselves. Local land-use plans are characterized by the fact that they lay down a binding framework for land use which allows certain uses, but prohibits others and also, by the designation of open, green and wooded areas, provides space for agriculture and forestry, as well as for nature conservation and environmental protection. Land is usually earmarked for a certain use, e.g. as agricultural land. The purpose of supra-local spatial planning is, among other things, to reserve areas for certain uses – such as agriculture, renewable energies (especially wind energy), settlements, nature conservation, industry or commerce – or to prioritize areas for specific sectoral planning, such as air-traffic facilities (airfields), in order to enable the economic and sustainable development of the area.

Multi-level overall spatial plans are interlinked by development and consultation requirements; for example, objectives of supra-local spatial planning – e.g. the reduction of land use for public planning – are binding for the subsequent levels and cannot be 'weighed away' (cf. section 4 (1) of the ROG). Project-related sectoral planning such as infrastructure planning for roads, railways and waterways or energy lines has a higher priority and is thus enforceable vis-à-vis local land-use planning (cf. sections 37, 38 of the BauGB).

The ecological contribution to spatial planning in Germany is provided by landscape planning (sections 8–12 of the BNatSchG) – procedurally secured by the participation of nature-conservation authorities in the above-mentioned planning procedures (cf. section 3(5) of the BNatSchG in conjunction with section 9(1), (5) of sentence 1 of the BNatSchG). It is the specialized planning of nature conservation which, as an ecologically oriented spatial use concept, takes account of the precautionary principle. Landscape planning is thus conceived as a sectoral planning concept of nature conservation. Although it focuses on protecting biodiversity, safeguarding and developing a functioning natural balance and protecting the soil, and aims to preserve and develop the landscape as an adventure and recreation area (section 9 (1) of the BNatSchG; Schlacke, 2019: section 10 Rn. 24f.), it lacks legally binding effect for spatial and project-related sectoral planning. Landscape planning does not prevail over either supra-local or local spatial planning, or over necessary infrastructure planning. Landscape planning is integrated into, or used as an information basis for spatial planning.

of protection) on one site. While it is true that spatial planning is intended to harmonize ('coordinate') different interests on a superordinate and systemic level and also to develop binding force in some cases, the conservation interests of landscape planning in particular are neither binding nor do they have priority in the context of spatial planning. An integrative design of spatial planning in the sense of the integrated landscape approach would require placing greater weight on aspects such as biodiversity conservation, climate effects and other ecosystem functions in the overall deliberation process ('weighing-up directives'). An integrative approach would also benefit if the effects of land-use designations (e.g. for global climate-change mitigation and biodiversity conservation) had to be given mandatory consideration. Similarly, up to now there has been no provision in law for the integration of climate-change mitigation in such a way that spatial planning is tied to the climate goals.

4.2.4
Measure progress, identify blockages: improve indicators and monitoring

A solid data basis is required for the precise identification of sustainability problems, the selection, design and coordination of suitable instruments, the monitoring of implementation, and the regular evaluation of ecological and social impacts. Only in this way can the chosen approaches be continuously adapted and improved. The basis for this is provided by suitable, measurable indicators and success criteria for sustainable land stewardship and progress with the most important strategies in this regard, e.g. within an integrated indicator system based on the existing sustainability goals and indicators. Improved indicators can form the basis for the introduction of incentive-based instruments and certification procedures; they can also be used as an information tool for political processes and for the public, e.g. to inform consumers as comprehensively and correctly as possible about the consequences of their consumption decisions (in the sense of an ecological footprint; Section 4.1.1).

The internationally agreed UN Sustainable Development Goals (SDGs) and their implementation at different levels of governance (e.g. sustainability strategies in Germany and the EU) already contain some country-specific sub-goals and indicators (Chapter 2). Key additions to existing physical indicators for documenting the sustainable use of land and biomass include:

- indicators on biodiversity conservation and the effectiveness of conservation measures, e.g. protected-area systems (Section 3.2; Box 4.4-3);
- indicators on the 'ecological rucksack' of nutrition at home and abroad (Section 3.4);
- indicators on biomass consumption and sustainable biomass potential (also to assess the reduction targets for the consumption of biogenic resources recommended in Sections 3.5 and 4.3).

Monetary indicators from economic valuation approaches help illustrate not only the economic value of ecosystems and their services, but also further-reaching benefits to humans. In this way, they can help ensure that the value of ecosystems and their services to humans are noticed more systematically and consciously taken into account in decision-making. However, it should always be borne in mind that their informative value for the sustainable use of land and ecosystems is limited – not only in the case of indicators such as the turnover of bio-based sectors or the productivity of land and resources (Box 4.2-4). This is particularly true when action-guiding societal goals are derived for the use of land and ecosystems. Economic valuation approaches can support these societal and political decisions, but should definitely be complemented by physical indicators (e.g. on biodiversity or the quality of protected-area systems).

More emphasis should be placed on improving the data basis for all indicators. For example, data on what proportion of land is degraded, a key indicator relating to SDG 15, Target 3 (Land Degradation Neutrality, LDN), is only available for two-thirds of all countries (UNSTATS, 2020). Monitoring land and biomass use in as much detail as possible (within the limits of data protection) should ensure that unsustainable practices can be exposed in a timely manner, the effectiveness of instruments can be verified, and any circumvention or violation of requirements can be consistently sanctioned.

Digital technologies open up many new opportunities for improving and strengthening monitoring (Boxes 4.1-1, 4.2-5). These include the development of open-source applications and the global establishment or expansion of an interoperable open-data ecosystem (as, for example, in the context of the European Open Science Cloud and the National Research Data Infrastructure), as well as easier data collection in the context of citizen science (Box 4.1-1). Citizen science should be increasingly promoted, since it not only opens up complementary data sources for research and SDG monitoring, but is also an instrument for raising sustainability awareness and strengthening the participation of civil society. It should furthermore be supported by a basic digital infrastructure oriented towards the common good, in the sense of a European platform ecosystem that serves science, business, politics and civil society in equal measure (WBGU, 2019a). However, the extent to which this – and global, digitally supported monitoring – will become a reality is not a purely technical question but primarily a political one.

4.2.5
From the individual parts to the system: consequences for a policy mix

Sustainable land stewardship cannot be achieved with a single instrument or even with one regulatory approach. It requires behavioural changes in too many areas and among too many heterogeneous actors. In order to effectively address global as well as specifically local problems, proactive states need to correspondingly combine instruments and steering approaches at different governance levels and to appropriately integrate local knowledge as well as different stakeholders.

Which instrument or combination of instruments is chosen depends on several criteria. In addition to the question of the achievability of ecological goals, important roles are played by how much administrative work is involved, by scalability, cost-efficiency (i.e. achieving ecological goals at the lowest possible private and administrative cost), effects on behaviour and technology development, and social (distribution) effects (Sterner and Robinson, 2018). Likewise, the choice of instruments should take into account whether a robust

Box 4.2-4

Appreciation and valuation of ecosystems and services for their conservation

Many actors have little understanding or awareness of the value of biodiversity or of ecosystem services for humans, e.g. their existence value, option value (WBGU, 2001:293) and intrinsic value, as emphasized in the preamble of the CBD (1992) and in the Federal Nature Conservation Act, for example. In contrast to goods and services traded on markets, many ecosystem services are seemingly available free of charge and do not thus form part of (private-sector) economic considerations. Even if the value of their conservation is understood in principle, it is often underestimated, not least because the costs of destruction arise much later than the costs of protection. The resulting lack of appreciation is one of the main causes of the current biodiversity crisis (Section 2.2.3) and an obstacle in combatting it (Leopoldina, 2020).

Benefit categories of economic valuation approaches

Economic valuations attempt to systematically define and assess the value of nature and ecosystem services to humans. They always take humans as their starting point and evaluate nature and ecosystems in terms of their benefits to humans and their contributions to human well-being. This anthropocentric view of nature and ecosystems is closely related to the concept of ecosystem services (Chapter 2; Fig. 2.1-1; TEEB, 2010; Hansjürgens, 2015). However, it is controversial, as nature and ecosystems are only ascribed values in terms of their relationship to humans and not independently as part of creation (TEEB, 2010; Deutscher Bundestag, 2015:113ff.). The WBGU has previously argued in favour of a pragmatic stance on valuation approaches and a moderate form of anthropocentrism, and takes up the same position in this report (WBGU, 1999:20).

The economic, anthropocentric valuation approach, i.e. the 'total economic value of nature', considers more than goods traded on markets and thus extends much further than might initially be assumed (WBGU, 1999:36ff.; Naturkapital Deutschland, 2012:54ff.). On the one hand, it includes various forms of use-dependent values: (1) drawn from the direct benefits that human beings derive from the consumption of natural products and services in the bioeconomy or as food, but also from the aesthetics of natural areas and landscapes and nature as a place of recreation; (2) from indirect benefits that ecosystems provide, e.g. in the form of the pollination services of insects, or regulatory services such as their contributions to protection against flooding, drought or soil erosion, and (3) with regard to future uses (option value), for example in that the diversity of species serves as a 'gene pool' for future medical research. On the other hand, the total economic value also includes use-independent values in the form of (4) existence value, where the mere knowledge of the existence of these species or ecosystems contributes to human well-being, (5) bequest value based on the motive of leaving nature in its present form to future generations, and (6) in the form of an individual appreciation of ecosystems based on altruistic motives.

Methodological approach

To give an overview, three approaches to economic valuation are distinguished (TEEB, 2010:16ff.; Barbier, 2011; Helm and Hepburn, 2012; Hanley and Herrings, 2019): (1) market-based methods, (2) expressed preference methods, and (3) revealed preference methods. Market-based methods use information available on markets for valuation purposes. On the one hand, they use market prices for ecosystem services themselves, where available, or the prices of goods and services where ecosystems verifiably contribute to their provision and which thus allow conclusions to be drawn on the ecosystems' value (production-function approach). Cost-based approaches, on the other hand, use information, e.g. on the costs of maintaining, restoring or even replacing an ecosystem (if the latter is realistically possible at all), to approximate its value. Methods of expressed or revealed preferences, however, start with individual preferences and individual appreciation of nature and ecosystems. In methods of expressed preferences, such as contingent valuation or experiments, individuals are asked directly about their preferences and their willingness to make contributions to ecosystem conservation or to accept financial compensation for impairments to nature and ecosystems. Indirect methods of revealed preferences use actors' behaviour to infer their appreciation of nature and ecosystems, e.g. how much they are willing to spend on travel to experience certain ecosystems or landscapes.

Costanza et al. (2014) summarize different global case studies with different valuation approaches and estimate that the value of global ecosystem services across both marine and terrestrial ecosystems fell by US$20,000 billion (2007) between 1997 and 2011 due to land-use changes and ecosystem degradation, and totalled US$125,000 billion (2007) in 2011. By comparison, global GDP rose over the same period from about US$46,300 billion (2007) to US$73,000 billion (2007), and was still below the value of aggregate ecosystem services in 2011. With updated data, a recent study (NABU and BCG, 2020) arrives at a value of global ecosystem services of US$170,000–190,000 billion per year. Various studies also show that the value of biodiversity and ecosystem services as a whole exceeds the costs of their protection many times over (Section 3.2.3.7; also: Naturkapital Deutschland – TEEB DE, 2018:68f.).

Challenges and limitations of economic valuation approaches

However, the limitations of economic valuation approaches should always be borne in mind when interpreting such results. Up to now, economic valuation approaches have only ever portrayed extracts of the value of ecosystems (Helm and Hepburn, 2012; Hansjürgens, 2015). Furthermore, each of the different evaluation methods faces specific methodological problems and challenges. Ecosystem interrelationships and interactions are often more complex and ramified than can be covered in evaluation studies.

The informative value of market-based methods can, for example, be impaired by influences that distort price formation in markets, e.g. as a result of market power or existing subsidy systems. Furthermore, market prices, like the costs of replacement measures, also do not necessarily fully reflect the human appreciation of ecosystems (Deutscher Bundestag, 2015:97f.). The informative value of surveys and experiments designed to directly estimate individual appreciation can be compromised by information deficits or individual sympathies for particular species (Hanley and Perrings, 2019). There is also a risk of systematically underestimating the option value of intact ecosystems, as future uses and the attitudes and values of future generations are unknown, and the services provided by intact ecosystems, as well as the human perspective of them, may change over time (Mayer, 2019).

In principle, economic valuation approaches and cost-benefit calculations are based, at least implicitly, on a comparison of relatively small-scale and reversible changes in benefits and costs and assume the unlimited substitutability of ecosystems and their services by technology, other economic goods and services (WBGU, 1999:43ff.; Naturkapital Deutschland – TEEB DE, 2018:16; Deutscher Bundestag, 2015:118). However, many ecosystems and their services create elementary basic prerequisites for human existence which cannot be replaced (using technology). At the same time, degradation up to the point of the destruction of ecosystems – and thus any catastrophic effects on humans that may be discovered later – is often irreversible. In many cases, human influence does not change the state of ecosystems linearly or gradually; rather, ecosystems can change to other states when they reach tipping points or, in extreme cases, collapse suddenly – these tipping points are usually not precisely known (Barbier, 2019; Dasgupta, 2020: 37). All these aspects and the complexity of ecosystems and their services can only be covered to a limited extent in economic valuation approaches and cost-benefit calculations, making it difficult to compare their value with (and weigh up their value against) the value of other economic goods or technical systems (Deutscher Bundestag, 2015:117ff.).

Conclusions

Economic valuation approaches and the monetarization of ecosystems and their services primarily serve to improve the visibility of different goods and services in terms of their value to humans, e.g. by documenting ecosystem services (for example in the pollination of crops) in addition to the economic benefits of arable land. In this way, they can create an awareness and appreciation, especially among actors who are familiar with economic assessments and decisions, of the value of nature and ecosystem services for humans, which is also considerable in economic terms. The exact level of the value – which is usually incomplete and can only be determined with uncertainty – is less relevant for this demonstration function (WBGU, 1999). This is not about a far-reaching integration of nature and ecosystems into markets or their purely economic exploitation. Rather, the contributions of ecosystems, which are otherwise often not taken into account, are systematically revealed, especially in economic assessments (WBGU, 1999:37ff.; Helm and Hepburn, 2012:7), although these decisions contribute significantly to the utilization and destruction of ecosystems. The character of nature and ecosystems as public goods is elucidated in this way (Hansjürgens, 2015:291) and this can be transparently taken into account when weighing up between protection and use (i.e. in the unavoidable allocation of scarce land to different uses). This also reveals damage and those adversely affected by the destruction of ecosystems, so that distributional implications become apparent.

However, particularly with a view to characterizing an 'optimal' approach to ecosystems that is sustainable in a holistic sense, it is important to bear in mind the limits and uncertainties of the evaluation approaches. The (inevitable) incompleteness of the determined values of ecosystems is not problematic in this context when even the services and values of an ecosystem determined with evidently incomplete valuation approaches exceed the potential gains from its destruction (Helm and Hepburn, 2012). Monetary estimates alone then directly justify the rejection of degradation and destruction. However, if the costs of conservation exceed the calculated value, the decision on how to deal with nature and ecosystems should not be made solely on the basis of monetary estimates, but should also include non-quantifiable, scientific and ethical aspects and findings. The way in which land, ecosystems and biodiversity are treated in view of impending tipping points, whether action is necessary or 'only' desirable, and what risks can be accepted in the process, are societal and political decisions that can be supported but not replaced by economic valuation approaches. In climate-change mitigation, such a process has led to the political goal in the Paris Agreement of limiting the rise in the average global temperature to well below 2°C. It is true that, due to its greater complexity, there is no global, aggregated 'apex' target for ecosystem and biodiversity conservation (Box 4.4-3) that would provide an easily communicable focus comparable to the temperature target in climate-change mitigation. However, even a target system such as the 20 Aichi Targets (Section 3.2.2; CBD, 2010a) or its further development in the CBD's post-2020 framework is framed politically and with an awareness of the scientific uncertainties and the risks involved in a sharp decline in biodiversity.

The inclusion of economic valuation approaches does not determine how societal goals for the management of land and ecosystems should be implemented at the governance level (Hansjürgens, 2015). The choice between regulatory control approaches, standards and incentive- or market-based instruments should be made according to the criteria mentioned in Section 4.2.5. Conversely, market- or incentive-based instruments can be designed and used even in the absence of precise overall monetary values of ecosystems and certain ecosystem services, as the opportunity costs of the actors affected are the most relevant factor for the effectiveness of these instruments (Section 4.2.1; Box 4.2-1).

long-term regulatory impact can be achieved in an uncertain and changing environment (Capano and Woo, 2018; Howlett et al., 2018). Instruments also make different demands on government institutions, jurisdictions, and rights of ownership and use, which not all countries satisfy in the same way (Blackman et al., 2018).

The decisive factor is a suitable combination and the consistent coordination of the instruments used. For example, it may be a good idea to supplement price instruments, at least temporarily, with other measures if e.g. information deficits, technological, infrastructural or culturally determined path dependencies stand in the way of their effectiveness, as is the case, for instance, with the greening of industrialized agricultural systems (Section 3.3). In parallel, it might also be necessary to adapt existing regulatory frameworks and guidelines, e.g. to reorientate food guidelines (Section 3.4), revise regulatory requirements in the construction industry (Section 3.5) or adapt land-area categories in

Box 4.2-5

Conclusion on digitalization: strengthen orientation towards the common good and use better monitoring to accelerate a global land-use transformation

As made clear by the previous boxes on digitalization (Boxes 3.1-2, 3.2-2, 3.3-15, 3.3-16, 3.4-12, 3.5-1, 4.1-1), it offers a wide range of support potential for sustainable land stewardship, particularly for monitoring but also in general, but it does not offer quick or general solutions to complex problems. Generally, and also specifically in relation to land use, these problems often lie in fields other than digitalization. In the case of the SDG indicator system, for example, they lie in the overlap between policy and official statistics. The European SDG indicator system is currently criticized for insufficient data and indicators, among other things. Their selection is always a political question. In addition, real developments and their time horizon are often not adequately reflected in terms of the threat to the goals of the 2030 Agenda, which can lead to a positively distorted picture (SDG Watch Europe, 2020). Digitalization is not the cause of this problem, but it could certainly contribute to a solution.

Even if digitalization can help find new solutions for a global land-use transformation, it is necessary to first decide on a paradigm shift in the management of land and its ecosystems. Only with clearly defined goals can context-appropriate digital tools be developed or implemented. In many cases, however, it is not possible to fall back on 'ready-made solutions', but more research and development are necessary. Furthermore, in all applications, digitalization must be prevented from becoming an 'accelerator' of unsustainable production and consumption patterns and from contributing to externalizing ecological and social costs (WBGU, 2019b).

Despite ground-breaking progress in monitoring in recent years using remote sensing, and despite its increasing use e.g. in the context of REDD+ (Box 3.1-6), material infrastructure apart from satellites is also needed on Earth to store and process the incoming data. This should not only be sustainable in terms of energy and resource consumption, it should also be designed with the common good in mind (WBGU, 2019a, b). This includes the question of open data for transparent, reliable, generally accessible and sustainable national forest monitoring systems in the context of REDD+. More public funding (and better organization regulated by public law) for the large-scale collection, storage and sharing of data can not only bolster information-based public trust in political measures, but also spur private investment (Fox, 2018). An important lever for the cross-sectoral use of open data in science, business, politics and civil society can be the broad implementation of the FAIR principles (Findability, Accessibility, Interoperability, and Reusability; Wilkinson et al., 2016; WBGU, 2019b:385), which, among others, are currently an integral element of the European Open Science Cloud. Comprehensive, international monitoring of ecosystems and land-use dynamics is now within reach, and this is just as relevant for improved SDG indicators as it is for sustainable land stewardship. However, as the research projects cited in connection with Copernicus and REDD+ show, implementation is not a purely technical matter.

This also applies to the use of digitalization for monitoring biodiversity and ecosystems (Box 3.2-2). On the one hand, observations must ensure that no risks arise with regard to the privacy of the people living in the regions under observation. On the other hand, citizen science offers many opportunities for more involvement of citizens and their knowledge as change agents, even as a new, complementary source of data for science and SDG monitoring and reporting (Box 4.1-1). In this respect, sustainable digitalization oriented towards the common good should exploit opportunities, but always minimize potential risks. Furthermore, the application of big data in precision agriculture as a basis for the continuous use of AI and robotics raises the question of who benefits from the agricultural data generated and processed (Box 3.3-16). There is a risk – not only internationally – of further exacerbating asymmetrical power relations between producers and citizens on the one hand and the agriculture industry on the other. The key issue, therefore, is who controls the technology, its design, and access to information. In this context, the design and governance of a European agricultural platform as part of a larger ecosystem ('GAIA-X' or 'Agri-Gaia'; BMWi, 2020b) currently represents both an opportunity to break down old path dependencies and a risk of exacerbating them or even creating new ones. However, unless sustainability becomes an integral part of the objective, the latter is to be expected. This illustrates once again that conflicting societal goals must be resolved before technical 'solutions' are developed. Even if digital 'solutions' are desired, previous pilot projects on blockchain and smart contracts in the agricultural sector show that political and legal prerequisites as well as societal debates and decisions are necessary for their use. A fundamental path decision on the future of digitally supported agriculture, for example, is whether precision agriculture uses the existing large-scale system of industrial agriculture as its frame of reference, or pursues innovative approaches to small-scale digitalized agriculture (Box 3.3-15).

In the field of sustainable nutrition (Box 3.4-12), it is also evident that apps can provide individual support in promoting sustainable consumption and dietary habits. However, they cannot replace reliable and universal certification and better supply-chain transparency. Only when these conditions have been created can a digital solution be imagined that brings all the information together. However, this would not necessarily require an app, as the Nutri-Score example shows. The VZBV (2020) is currently campaigning for its nationwide use instead of voluntary use, as well as for its mandatory introduction throughout Europe, accompanied by an information campaign. Furthermore, the complete digitalization of this important information would be an exclusionary system for people who lack terminal devices or digital skills.

In the case of the bioeconomy (Box 3.5-1), moreover, not only is the picture of the potential and risks of new technologies often distorted by 'hype', but it is also clear that conflicting sustainability goals always stem from ethical, political and legal issues. These cannot be calculated, as shown by a project on the application of blockchain in stakeholder processes (Box 3.5-1), but must be decided by society. This requires not only an open debate involving citizens, but also the means to reduce imbalances between different stakeholder groups. For all the digital solutions examined in this report, there is a need to address value and goal conflicts in a timely and democratic manner in order to make sustainable technology design possible. In this context, it might also become clear, as the example of blockchain illustrates, that some technical solutions are not (yet) adequate or even necessary.

However, digitalization can contribute to reflective decision-making if a basic infrastructure oriented towards the common good (WBGU, 2019a, b) is created to make better and broader information exchange and participation possible in the future. Shaping European technological sovereignty in the Digital Age "is not about isolating oneself, but about creating suitable framework conditions to enable citizens to make self-determined decisions" (March and Schieferdecker, 2020). On the technical side, this would require not only a cloud infrastructure like GAIA-X (BMWi, 2020b), but also a digital "ecosystem that already follows European values such as transparency, openness and privacy protection in its technical design" in order to "create a public digital space that offers fair conditions of access and use, strengthens public discourse, and ensures Europe's identity-forming plurality" (Kagermann and Wilhelm, 2020: 5). Digitalization could be used within the framework of a 'European public sphere' for an ambitious pan-European development project with broad stakeholder participation, which in turn would make broad stakeholder participation possible for future fields of innovation. Should this vision, which has been increasingly articulated recently (EPOS, 2018; Hillje, 2019; WBGU, 2019a, b; Messerschmidt and Ulrich, 2020), be launched in the context of the trio presidency of Germany, Portugal and Slovenia in the EU Council, a new digital public space could be constituted which could also be used to implement polycentric governance in new ways – for the transformation towards sustainability in general and sustainable land stewardship in particular.

spatial planning for multifunctional land use, e.g. using agrophotovoltaic systems. Spatial-planning solutions are useful for balancing different basic uses in a limited space at the local and regional level. How individual farmers manage agricultural land, for example, should be steered less by public planning than by financial incentives or conditions, in order to maintain economic incentives for farmers and to be able to integrate stakeholder-specific knowledge more directly.

Challenges for designing a policy mix arise from both an ecological and a social perspective. With regard to achieving ecological objectives, the evaluation must not be limited to measuring direct effects, but must also include potential evasive reactions where activities are relocated. Relocations can occur between biomass uses, land areas or sectors (Section 4.2.5.1), but can also include geographical relocations abroad (Section 4.2.5.2). From a social perspective, distributional effects in particular should be addressed at an early stage (Section 4.2.5.3).

4.2.5.1
Avoid relocations: coordinate instruments and close gaps

Most existing policy approaches promote only individual aspects of sustainable land management, affect only certain sectors, areas or countries, and are often poorly coordinated with other instruments. They run the risk of becoming ineffective by unsustainable land use being relocated to other areas of land, products or sectors. Here are some examples:

- The permanent financial incentives for farmers through the CAP are not matched by a comparable system for foresters, so that, e.g., there are potential incentives to convert forest land into arable land.
- The exclusion of certain biomass types from bioenergy promotion in the EU (e.g. palm oil, which is associated with large-scale primary forest destruction; Box 4.2-2) cannot prevent other energy crops or less regulated crops (e.g. food and feed) from being grown for the EU on the same cleared area. Cleared areas that are excluded by the sustainability criteria of EU bioenergy promotion can be used for cultivation for other customers, and cultivation for the EU can be relocated to other areas.
- Conversion of land to nature-conservation areas can lead to relocation and more intensive land use in other regions (Pfaff and Robalino, 2017).

The current 'patchwork' of incentives and regulations is also not designed to adequately address repercussions for land use from the regulation of non-land-based activities and sectors. Climate policy, for example, is already increasing demand for biomass and with it the land-use pressure on terrestrial ecosystems (Section 3.5.2). Similar risks exist if there is an increase in the promotion of CO_2 removal from the atmosphere (Section 3.1).

The WBGU therefore recommends developing the existing patchwork into a system of coordinated instruments that is as comprehensive as possible in terms of land areas, sectors (including sectors that use biomass such as energy, construction and the chemical industry) and actors. For example, financial incentives for ecosystem conservation should be provided not only in agriculture and should be supplemented by binding, universal sustainability standards for production and trade, especially where strict limits on the use of ecosystems have to be observed (Section 4.2.6). Cooperation between different administrative levels and sectors is conducive to designing and implementing such a mix of consistent, harmonized instruments. In this context, not only administrative responsibilities should be made more flexible but also categories and allocations, e.g. at the level of regional-planning procedures and spatial planning (Section 4.2.3).

The harmonization of frameworks creates a level playing field and opens up spaces for actors from different fields and (economic) sectors to engage in negotiations and trade-offs between their interests and demands on limited areas of land. Such processes make it possible to better identify and exploit synergies between different uses and demands on areas of land and ecosystems on the basis of individual and local knowledge.

The need for a system of incentives, sustainability standards and planning requirements that is as complete as possible, harmonized and sufficiently ambitious also extends to the international level, as the next section shows.

4.2.5.2 Embedding sustainable action in global contexts: a question of cooperation and leeway under trade law

In a globalized world with close foreign-trade relations, actors' behaviour in their own country as regards production and demand does not only affect the way land is used there. The behaviour of domestic actors and their reactions to a nationally determined mix of instruments on land stewardship also has cross-border effects, i.e. influences and relocations of claims to land and ecosystems from within the country to sectors and ecosystems or areas of land abroad. There is therefore a great need for the widest possible international harmonization of land-use-policy objectives and framework conditions. Where states are willing to cooperate, such harmonization can be agreed, for example, when (free-) trade agreements are concluded. If there is no such willingness to cooperate, individual states can also take unilateral steps to enforce domestic framework conditions and standards through import regulations in their foreign-trade relations. Such measures are already being implemented in the EU (e.g. under the Renewable Energies Directive II, Box 4.2-2, and the Timber Trading Regulation, Box 3.5-8), and border-adjustment taxes or tariffs are being discussed for emissions-intensive goods.

A fundamental challenge lies in the fact that a comprehensive international harmonization of trade-policy rules that promote the sustainable stewardship of a large proportion of land-based ecosystems, while desirable, is not very realistic, at least in the short term. As in the case of a unilateral approach, there is a risk that, while stricter framework conditions for sustainable land stewardship are observed in economic exchange with a trading partner, this does not necessarily cover production and consumption in the trading partner's country and its other trade relations. Efforts to use land more sustainably can thus be undermined by relocation effects in the country of the trading partner, for example leading to the consumption of non-sustainably produced biomass only in the domestic market.

Leeway under trade law

The scope for action by individual states is determined not only by the willingness of other states to cooperate but also by international trade law. In order to enshrine more sustainable land stewardship in their economic relations, states can conclude regional free-trade agreements or agreements to reduce environmentally harmful subsidies and tariff and non-tariff barriers to trade in sustainably produced 'environmental goods'. A current example of this is the ACCTS (Agreement on Climate Change, Trade and Sustainability), which is currently being negotiated between New Zealand, Fiji, Costa Rica, Norway and Iceland (Zengerling, 2020: 15; Section 3.3.2.4).

Unilateral efforts to enforce framework conditions and standards through import regulations must be carefully examined for compatibility with WTO law. For example, bans on quantitative restrictions and discrimination between similar products are only permitted under certain conditions. In any case, the framework conditions must serve a protective purpose or protected good covered by the exception provisions under WTO law, must not unjustifiably and arbitrarily discriminate between countries, and must be based on a 'genuine link' between the protective purpose or protected good and the regulating state(s), since they aim at effects outside the territories of that/those state(s) (Zengerling, 2020: 17ff.).

A further development of WTO law in the direction of stronger sustainability considerations would be conceivable, but politically very challenging (for an overview of possible measures, see Zengerling, 2020: 58ff). Examples include the continuation of negotiations under the Environmental Goods Agreement on the dismantling of tariff and non-tariff barriers to trade in environmental goods and services, and a peace clause that exempts environmental-policy frameworks on sustainable land stewardship from WTO regulations and trade disputes, or explicitly expands the exceptions under WTO law to include climate-change mitigation and biodiversity conservation (or correspondingly more precisely specified objectives in the future; Zengerling, 2020: 12, 16, 58). It would also be conceivable to explicitly lay down climate-change mitigation or biodiversity conservation (or correspondingly more precisely specified objectives in the future) as exceptions under WTO law. However, such a further development is dependent on the agreement of WTO members (in some cases requiring a unanimous, in others a two-thirds majority) and thus in turn on their willingness to cooperate (Zengerling, 2020:11, 16)

Administrative feasibility and the effectiveness of measures vis-à-vis third countries

In the absence of a cooperative approach, individual states (or communities of states) face not only trade-law challenges but also administrative challenges and questions of effectiveness when attempting to contribute to more sustainable land stewardship abroad (i.e. in third countries).

On the one hand, the opportunities for monitoring and evaluating actual land stewardship and land-based ecosystems abroad are limited. This problem arises at the country's own external borders in the case of measures aiming to apply domestic sustainability instruments and standards to imported goods and services wherever possible. For example, determining the CO_2 content of imported goods is considered a problem in the debate on the border adjustment tax on CO_2 in the EU (Cosbey et al., 2019). However, problems of measurement and monitoring also arise in attempts to financially promote more sustainable land stewardship in third countries, as envisaged in REDD+ for developing countries or as proposed in the context of the conservation alliances in Section 4.5.3 (Box 4.5-4).

On the other hand, the effectiveness of such compensatory measures at external borders, e.g. on indirect land-use changes in the exporting state, can be undermined by relocation effects (Section 4.2.5.1), especially if the goods concerned account for only a small part of the exporting state's production. It therefore makes sense to include land-use changes at the national level in the sustainability evaluation of imports. The revised sustainability criteria for biomass used for energy in the EU Renewable Energy Directive are an important first step in this direction (Box 4.2-2). They refer not only to specific biomass types and the land and methods used for their cultivation, but also to efforts made by the countries of origin as a whole with regard to land use, land-use changes and forestry under the Paris Climate Agreement. Land-use changes are comparatively easy to document and could also serve as a starting point for trade-policy measures to establish generally more sustainable land stewardship on the part of trading partners (which can be differentiated according to the situation of the respective country).

4.2.5.3
Consider distributional effects: cushion changed producer and food prices, tax land rents

The goal of more sustainable land stewardship and the instruments needed to achieve it can entail massive redistributions of income and wealth: such instruments influence which land can be used for what purpose, which methods can be used, which subsidies can be expected, and what revenues can be generated from the sale of additional biomass. The value of areas of land, the incomes of land owners and users, and the prices of food and biogenic products for end-consumers change accordingly. Most studies conducted up to now have examined possible changes in food prices as a result of biodiversity-conservation strategies (Leclère et al., 2020), land-based climate-change mitigation such as reforestation and bioenergy or BECCS (Popp et al., 2014; Fujimori et al., 2018; Hasegawa et al., 2018), and meeting the SDGs (Obersteiner et al., 2016) at the level of global food markets or world regions.

How changes in revenues and costs are distributed among different actors in different countries depends not least on the market structures in the agricultural and food sectors (e.g. seed and agrochemical companies, food companies). These effects, or the expectations that consumers, landowners and businesses form about these effects, are a crucial factor for the political feasibility and practical implementation of a sustainable land-use transformation. There are very few detailed estimates of the economic impact of certain land-related instruments on individual actor and income groups. With regard to the forthcoming reform of EU agricultural subsidies, it can be said, for example, that a small number of farms and landowners have benefited more than most from the payments, which up to now have been primarily area-related and actually intended to support farmers' incomes. Much of the land is farmed by a small number of large farms (e.g. more than half of the land is farmed by only 3% of the farms), so that 20% of the farms receive 80% of the direct payments (Heinrich Böll Foundation, 2019a). Moreover, about half of the agricultural land is only leased by farmers (Heinrich Böll Foundation, 2019a), and a substantial proportion of the direct payments is siphoned off through agricultural leases (Klaiber et al., 2017).

Apart from political resistance, however, the ability to respond adequately to price signals, regulations and information can also depend directly on the existing distribution of income and wealth. The land-use transformation can fail, for example, if affected companies and individuals do not have the necessary resources to invest in sustainable technologies or to bridge transition phases. Distribution-policy instruments and the financing they require should therefore be understood from the outset as part of the instrument mix. Examples would be, on the consumer side, support for healthy, bio-based menus in public institutions (such as kindergartens, schools, canteens and cafeterias; Section 3.4) and for recipients of state income support; and, on the land-use side, governments imposing taxes on rising land rents (Schwerhoff et al., 2020; Stiglitz, 2015).

These funds can be used to compensate other landowners or users who would be subject to new restrictions, or to purchase land for nature conservation. Bans on certain uses, restrictions on land ownership or even expropriation for the purpose of nature and landscape conservation are possible in Germany, for example (section 68 I of the BNatSchG, section 76 of the LNatSchG NRW), but losses must be made up with other land or by financial compensation. The acquisition of property for purposes of nature conservation is made possible by German nature conservation law at the regional (Länder) level through the Land's right of first refusal over land located in nature conservation areas, FFH areas or national parks (e.g. section 74 I of the LNatSchG NRW). In this way, areas can be secured for the long-term benefit of nature and landscape conservation.

4.2.6
Recommendations for action

Further develop indicators for and the monitoring of sustainable land stewardship and biomass use

The goals and strategies derived at various levels of governance on the sustainable use of land and biomass should be backed up by suitable indicators, integrated into existing systems of sustainability goals and indicators, and followed up by a corresponding monitoring system. There are important additions to the indicators which aim to make the necessary limitation targets measurable (Sections 3.5.4, 4.3); these relate, for example, to ecosystem services, protected-area systems, biodiversity and its conservation (Section 3.2), indicators on the ecological impact of dietary habits at home and abroad (Section 3.4), and on biomass consumption. Taking into account several important strategies for land stewardship within a system of indicators that spans governance levels (where appropriate, even at the international level) increases consistency between the strategies and transparency, makes responsibility at all transformation levels possible, facilitates international coordination and reduces complexity. The data basis should be improved by a shared open-data ecosystem that, for example, integrates citizen science along with satellite data for monitoring sustainability indicators at home and abroad (Boxes 4.1-1, 4.2-5), as well as state-funded monitoring institutions with improved technology and more personnel.

Improve selected partial management approaches

Some existing instruments for sustainable land stewardship or biomass use should first be consistently enforced, or else improved and expanded. Important examples of financial incentives are the forthcoming reform of the EU's Common Agricultural Policy (Section 3.3; Box 3.3-1), incentives for restoration (Section 3.1), and pricing the externalities of conventional construction. Restrictions need to be adapted, e.g. in the case of building regulations (Section 3.5). Voluntary certification approaches can be promoted and harmonized with the proviso that their criteria must not be weakened – or else must be improved and strictly applied. Examples include private CO_2 markets where CO_2 removal from the atmosphere is treated separately (Section 3.1), consumer labels and protected labels of origin (Sections 3.3, 3.4.4.4; Box 3.3-5), and stakeholder platforms on the production side (Section 4.2.2). Experience with such voluntary approaches and, for example, with sustainability requirements for biomass used for energy purposes as a precondition for funding (in the EU within the Renewable Energies Directive, Box 4.2-2; Section 4.3) could be used to develop mandatory approaches in the feed and food sector too, especially in international trade. The public sector should take the lead in implementing sustainability requirements, e.g. in the stewardship of publicly owned land (e.g. agricultural land, forests, protected areas), menus in publicly operated or supported catering facilities, and sustainable construction with (additionally) certified wood in public building projects.

Develop a consistent system from partial, sectoral management approaches

Based on research on the effectiveness and improvement needs of the various partial regulatory and incentive instruments, the latter should be ambitiously consolidated, supplemented and, in the medium term, harmonized and expanded across sectors to such an extent that a comprehensive, consistent system results. This system should include elements of financial incentives to protect ecosystem services as well as mandatory sustainability standards where incentives are insufficient or where the pressure for new uses of land or biomass is increasing sharply, for example as a result of higher CO_2 prices for fossil fuels and the dismantling of relief on prices for CO_2 and energy in the case of cement and steel (Section 3.5). One example of this is the transformation of the EU's CAP into a Common Ecosystem Policy (CEP; Section 4.3), flanked by mandatory minimum sustainability standards for all land-use sectors and for the trade in biomass. Similarly, input-subsidy programmes (Section 3.3) in developing countries could be integrated into an expanded system which, for example, combines sustainability requirements with payments for nature-conservation measures.

Apply integrated landscape approaches in planning and land-use allocation

The integrated landscape approach and, in particular, the possibility of planning and designating multifunctional land uses, should be integrated as a model and guiding concept into national planning law and planning activities. For Germany, spatial planning law is particularly relevant. In particular, greater importance should be ascribed to landscape planning's interests in protection in the context of spatial planning. To make spatial planning more integrative in the spirit of the integrated landscape approach, greater weight must be attached to biodiversity conservation, climate effects and other ecosystem functions in the overall assessment (consideration directives). The effects of land-use designations on global climate-change mitigation, for example, should be taken into account and regional planning tied to climate-change-mitigation targets. This approach could conceivably be designed to have binding effects on the planning authorities. The multifunctionality of land itself could be integrated into the designation of commercial and industrial areas by coupling the concept to the provision of compensation areas, whose use or protection counteracts the land-use trilemma. In addition, landscape planning should also have a stronger binding effect for supra-disciplinary, non-sectoral spatial planning (e.g. at the local-authority level) and not only serve as an information basis. Similar to the way it is obligatory for regions to submit a regional structural and development plan, e.g. in the case of state funding (with EU co-financing), regional consortia of actors should be required to draw up and submit the regionally adapted concept of an integrated landscape approach themselves for certain funding programmes. This approach can then be used as a framework and guideline for development measures.

Review trade-policy decisions more intensively with regard to their implications for land and ecosystems

Trade-policy decisions, and in particular the conclusion of regional free-trade agreements, should be carefully assessed in advance with regard to their sustainability impact (sustainability impact assessment; Revell et al., 2014; Kehoe et al., 2019). In order to be able to take the results of the *ex-ante* evaluations into account in the negotiation process and to develop directly corresponding, effective regulations and control mechanisms, they should be prepared and made publicly available as early as possible during the negotiation process. Local economic and environmental administrations, as well as private-sector and civil-society actors in the participating countries, should be involved in this process (Zengerling, 2020: 35f.).

Back-up frameworks for sustainable land stewardship within the existing possibilities of trade law

Domestic frameworks for sustainable land stewardship should also be applied to imports. When economically stronger countries or groups of countries follow this path, their demand also promotes more sustainable suppliers and standards abroad. Primarily, cooperative approaches should be pursued to level the playing field at home and abroad, for example with free-trade agreements or through the targeted dismantling of trade barriers for sustainably produced goods and services. The countries' different starting points and development needs should be taken into account here to ensure fair burden sharing in the provision of global common goods. In particular, however, groups of states linked by (free-trade) agreements should also explore and seize the opportunities offered by trade law with regard to border-adjustment measures vis-à-vis third countries (Section 4.2.5.2). The extent to which such measures could usefully be linked to land-use changes in the exporting country should be examined here (by analogy with and extension of the sustainability requirements under the EU's Renewable Energies Directive; Box 4.2-2).

Promote sustainable land stewardship through trade-law reforms

States should work at the international level to strengthen environmental and climate-change mitigation within the WTO, in regional free-trade agreements, other partnership agreements such as the EPAs and investment-protection agreements (Das et al., 2018, 2019; Dröge et al., 2020; Zengerling, 2020: 58f.). On the one hand, the scope for action by individual states should be extended, e.g. by including the measures for sustainable land stewardship or global commons in general as exceptions in WTO law, or by agreeing peace clauses through which a state's purely environmentally motivated frameworks cannot be challenged under trade law (Zengerling, 2020: 15f.). On the other hand, important levers at the international level exist in agreements under the WTO to reduce harmful subsidies and barriers to trade in verifiably sustainable goods and services (including products of organic agriculture or technologies for renewable energies, recycling or energy efficiency): for example by resuming the negotiations on an Environmental Goods Agreement under the WTO, which have been interrupted since 2016, on the basis of an appropriately broad understanding of the concept of environmental goods that includes land-related goods in particular, or by supporting the ACCTS negotiations. Further initiatives should aim to ensure that, for example, certifications and (environmental) requirements can no longer be classified as barriers under trade law (reform of the Agreement on Technical Barriers to Trade) and that the effects of national trade policies on the use of land or terrestrial ecosystems are included in the WTO's Trade Policy Review Mechanism (Zengerling, 2020: 11ff., 58f.).

Anticipate and address distributional effects: reform subsidies, tax land rents

Comprehensive regulatory frameworks for sustainable land stewardship lead to distributional effects as a result of existing ownership structures, land scarcity and the character of many land-based products as basic services. These effects should be evaluated at an early stage and cushioned by accompanying instruments. Land rents, or at least increases in them, e.g. due to climate- or environmental-policy measures, should therefore be taxed at a higher rate. The revenues generated in this way can be used for compensatory measures for certain actors or, for example, for expanding nature conservation areas. Land-rent taxation is a particularly attractive source of financing for public budgets because (1) its distortion effect is relatively small (provided that the supply of usable land is limited either physically or by sustainability constraints), (2) public investment in particular is 'capitalized' in land (e.g. rising land values due to adjacent recreational areas or infrastructure), and (3) it has a progressive effect in many cases (richer population groups who own more land are taxed more heavily). The motivation for such a tax would correspondingly be primarily fiscal or distributional.

4.2.7
Research recommendations

Empirical research on the impact, gaps and success factors of instruments for sustainable land stewardship

Existing approaches such as certifications, financial incentives and requirements in different sectors should be subject to systematic research to determine their respective impact (including regulatory gaps, national and international leakage effects, instruments relating to supply chains and trade), best practices and opportunities for improvement. Causal effects in particular should be identified in a statistically robust manner. The central guiding principle should be instruments which, in the sense of the multifunctionality of land, allow ecosystem-conservation requirements to be combined with local development interests and which are targeted as precisely as possible at particularly endangered ecosystems and at areas and actors that are valuable for ecosystem-conservation purposes. The evaluation of the instruments should be regularly pooled by an international panel of experts and recommendations for action deduced (possibly linked to the more general survey of the scientific state of the art in land stewardship, Section 4.4.2).

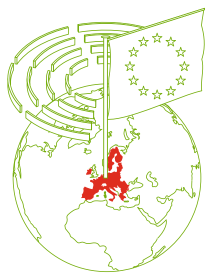
Explore the potential and compatibility of multiple-benefit strategies

To date, there is no consistent system of realistic regional, national and global scenarios for the coordinated application of multiple-benefit strategies (Chapter 3). Recent global analyses (Obersteiner et al., 2016; Roe et al., 2019; Leclère et al., 2020) provide a basis for this and should be supplemented by the (partly still missing) trilemma dimensions and by further analyses, especially at the regional and national level, to create additional multiple-benefit strategies and more concrete policy instruments. The development of such scenarios and analyses based on them can make it easier to understand the potential and interaction of different multiple-benefit strategies more precisely, and to identify coordination needs and the necessary frameworks for their application. In this way, they also provide insights into the realistic potential of individual and combined multiple-benefit strategies for defusing the land-use trilemma, and serve to shape regulatory frameworks that address at an early stage possible sustainability risks from the overly extensive application of individual strategies (e.g. in the field of the bioeconomy).

Assess the distribution effects of political frameworks on sustainable land stewardship

Considerable research is needed on the effects, broken down by actor group, that a further development of existing instruments and their expansion into coordinated, more comprehensive frameworks has on land ownership and land prices, as well as on the prices and availability of food and bio-based resources. Here, too, realistic scenarios at different spatial levels can provide valuable insights. To this end, however, data pools, which are still limited today, should be significantly improved, for example on land ownership or land values. The aim should be to identify and assess more precisely the manifold distributional effects associated with a land-use transformation, in order to be able to develop and implement compensatory distribution-policy measures on this basis at an early stage.

4.3
A transformation of land use as part of the European Green Deal



The EU is a supranational community to which – unlike other multilateral alliances and collaborations – its member states have transferred sovereign powers allowing it to control the implementation and enforcement of Union law in the member states. This globally unique community of shared laws and values is largely in a position to set the legal framework for transformation instruments and processes as defined in Section 4.2. In the WBGU's understanding of transformation, the EU can to some extent be seen as a hybrid between the 'proactive state' and 'global cooperation'. The EU can strengthen sustainable land stewardship in particular with its legislative competences for agricultural, environmental, climate and energy policy (Articles 43(2), 192 and 194 of the TFEU) and for setting up a common internal market and the convergence of laws between the member states (Article 114 of the TFEU). This applies both to land located within the EU and to the environmental, social and economic telecouplings emanating from the demand and production structures of the EU as a significant global economic area.

The European Commission's European Green Deal (European Commission, 2019c) has generated political momentum to set a new course towards an EU-wide and global land-use transformation. Section 4.3 deals with basic demands on the implementation of the European Green Deal for more sustainable land stewardship. Measures for implementation should be designed in the spirit of a global land transformation and possible multiple benefits between different environmental and socio-political challenges (Section 4.3.1). In particular, changes to the CAP will be needed to implement the multiple-benefit strategies proposed by the WBGU. In the medium term, its narrow focus on area-based direct payments and income orientation should be abandoned. The CAP should be developed coherently with other measures of the European Green Deal to become an effective lever of sustainable land stewardship and, to this end, transformed into an overarching regulatory system for the sustainable use, restoration and conservation of ecosystems and ecosystem services in the EU (Section 4.3.2).

4.3.1
Gear the European Green Deal towards multiple benefits

The European Commission defines the European Green Deal as "a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. It also aims to protect, preserve and enhance the EU's natural capital [...]" (European Commission, 2019c:2). Not so much a growth strategy but rather the European Commission's political flagship initiative for a Great Transformation, the European Green Deal also has the potential to trigger a turnaround in land stewardship. The success of the ambitious goal of greenhouse-gas neutrality by 2050 will depend, among other things, on whether the EU deals responsibly with its own and its global impact on land resources. To this end, follow-up strategies and packages of measures must be ambitiously designed and implemented by the EU and, in particular, by the member states. The EU and the member states should not be guided by an overarching goal of climate neutrality, but should always treat CO_2-emissions avoidance and CO_2 removal from the atmosphere separately in their planning and measures, and take account of the different climate-policy functions performed by the two approaches (Section 3.1).

Protection of ‚natural capital' as a key objective in the European Green Deal

The protection, preservation and enhancement of 'natural capital' within the EU is explicitly included in the definition of the European Green Deal. In particular, the starting point is to tackle the climate crisis and to achieve climate neutrality in the EU by 2050 (von der Leyen, 2019). The draft regulation of the European Climate Change Act brings the binding nature of this target closer (European Commission, 2020i). Climate-change mitigation and climate adaptation are key fields in which there is a great need for action, and climate-change mitigation is a central dimension of the trilemma in the sense of this report. In particular, the topic of CO_2 removal from the atmosphere by ecosystem-based approaches should play an increasing role in the future (Section 3.1). At the same time, the EU needs to be brought onto a sustainable path not only in terms of climate policy. Given their multifunctionality for climate-change mitigation, biodiversity conservation and food security, land resources inside and outside the EU must also be conserved in the long term and their condition improved. The European Green Deal should therefore be used to exploit the multiple bene-

Box 4.3-1

EU-Mercosur agreement

The new EU-Mercosur agreement was concluded by the EU and the four Mercosur countries Argentina, Brazil, Paraguay and Uruguay at the end of June 2019, although it has not yet been ratified. In addition to making significant tariff cuts, it sets standards for environmental protection and food safety, as well as trade quotas as ‘safeguards’.

The intention is for the EU to liberalize just over two-thirds of imports of agricultural products from Mercosur; import quotas are to be granted to the EU for individual products such as beef, ethanol and honey (Nolte, 2019). In return, Mercosur will open its markets to pork, wine, sparkling wine, spirits, olive oil, fresh fruit, chocolate and soft drinks from the EU, products that were previously subject to high tariffs. The two sides have agreed on quotas for dairy products and on the protection of geographical indications. Imports from Mercosur must still meet EU standards on food safety and animal and plant health. In addition, the two parties commit to pursuing sustainable development, for example by implementing the Paris Climate Agreement (chapter on trade and sustainable development; Nolte, 2019). Criticism against the EU-Mercosur agreement is being voiced, especially among some agricultural interest groups and various environmentalists, who point to links between Brazilian beef and soybean production and the destruction of Amazon forests (Nolte, 2019).

Impact assessments of the agreement expect generally positive economic impacts of the proposed EU-Mercosur Free Trade Area both in Mercosur and in the EU. The interregional redistribution of production could marginally reduce aggregate net emissions by the EU and Mercosur (Kirkpatrick and George, 2009; Revell et al., 2014). However, this is offset by a greater increase in emissions due to the growth in international transport (Kirkpatrick and George, 2009). Furthermore, increased environmental pressure is expected, particularly from a potentially significant loss of global biodiversity, unless suitable mitigation measures are taken. Within the EU, there could be serious negative effects on the conservation and cultivation of agricultural land in the most disadvantaged and economically poor areas. However, the main driver of environmental pressure is the growth of agriculture in Mercosur. Here, the expansion of agricultural production in all the countries could significantly exacerbate deforestation and contribute to the reduction of biodiversity, especially in the Amazon and Cerrado regions. In addition to the potential worsening of water- and soil-resource stocks, there is also the issue of the spread of plant diseases and threats to animal welfare (Kirkpatrick and George, 2009; Revell et al., 2014). These results do not take into account the influence of the other trading nations or the environmental impacts associated with their production systems.

Conclusions

These findings from the impact assessments should be taken seriously and incorporated into the opinion-forming process during the ratification procedure of the EU’s free-trade agreements with Mercosur (Zengerling, 2020:32f.,35f.). Only if corresponding safeguards have the desired effect with regard to the conservation of forests and other sensitive ecosystems, e.g. in the Amazon and Cerrado regions, can such a regional agreement generate positive overall effects. By contrast, failure to take this into account would exacerbate existing sustainability problems.

fits of measures for various objectives and to ward off the threat of conflicts over the use of land, particularly as a result of a too one-sided focus on climate policy. The testing of solutions in accordance with the integrated landscape approach should be made possible, ecologically harmful subsidy structures should be ended, and the regional, supraregional and international environmental impacts of consumption and production patterns shaped by Europe should be comprehensively internalized, thus laying the foundation for the assumption of responsibility by different groups of actors.

The roadmap for the European Green Deal presents a list of planned directives, regulations and strategies which, when reviewed, can be further developed in the spirit of a global land-use transformation. For example, the already published European Biodiversity Strategy (European Commission, 2020c) and the Farm to Fork Strategy (European Commission, 2020d) are important first steps towards responsible management of European land resources, as is the new Action Plan for the Circular Economy (European Commission, 2020e). The revision of the EU Regulation on the inclusion of emissions and the removal of greenhouse gases from land use, land-use change and forestry in the 2030 climate and energy policy framework (LULUCF Regulation; EU, 2018b), which is due in 2021, sets the course for the role of land-based CO_2 removal from the atmosphere. Within its remit, the EU as a legislative body can take its orientation from the requirements set out by the WBGU in Chapter 3 and Section 4.2.

The EU’s global responsibility

The European Green Deal is predominantly focused on the ″preservation and restoration of natural capital″ within the EU itself, but the EU also recognizes the conservation of global land-based ecosystems as part of its global responsibility. The framework for assuming this responsibility is to be laid down by a ‘diplomacy’ of the European Green Deal, which has not yet been spelled out in detail. The EU can play a particularly important role here in closing financing gaps for ecosystem protection (Section 3.2) and in promoting the enforcement of sustainable product standards worldwide. The European Commission has shown its willingness to take on such responsibility, for example, in the communication

'Stepping up EU Action to Protect and Restore the World's Forests' (European Commission, 2019b). The EU should also make the alliances and instruments proposed in Section 4.5 core elements of the European Green Deal diplomacy. If no Europe-wide consensus can be established to initiate such new cooperation alliances, the EU should encourage and support member states to become initiators or part of such supranational alliances themselves.

As one of the economically strongest regions in the world, the EU also has political (trade-policy) sway with which to promote sustainable land stewardship abroad. In the sense of Section 4.2.5.2, there are (at least) three points of departure for this. First, in negotiating processes on new or future reforms of existing (free-) trade agreements, the EU can focus on the sustainable management of land and global commons and only conclude such agreements if sustainability impacts have been comprehensively evaluated and addressed accordingly (for more details see Zengerling, 2020; Box 4.3-1). Second, the EU can use its foreign- and trade-policy clout to take unilateral action. To back up domestic frameworks for sustainable land stewardship with trade policy, pricing instruments can be enacted, for example by taxing unsustainably produced imports of goods and biomass, or conditions can be imposed in the form of mandatory certifications for imports or with import bans. Such measures are already being implemented by the EU (e.g. via the Renewable Energies Directive II and the Timber Trade Regulation), and border tax adjustments or tariffs for climate-intensive goods are being discussed. In addition to foreign-policy risks, however, WTO law in particular could place possible obstacles in the way of such measures; but could be further developed as a third, more long-term trade- and/or foreign-trade-related starting point for the EU (Zengerling, 2020:13ff.; Section 4.2.5.2).

4.3.2
Embed the CAP into a Common Ecosystem Policy in the medium term

The Common Agricultural Policy (CAP) is the EU's land-use policy. The Commission drafts for the 'new CAP' currently being negotiated (European Commission, 2018c, d, e) will apply from 2021 at the earliest – more likely from 2022. The Commission regards them as compatible with the European Green Deal (European Commission, 2020a). In the WBGU's view, however, the CAP should not only be compatible with the European Green Deal, but also be consciously used as a transformation instrument for achieving its goals. The WBGU has already made recommendations on important short-term reform steps for the CAP post-2020 in the light of the multiple-benefit strategy of greening industrial agriculture in the EU (Sections 3.3.2.2, 3.3.3.1). Although a CAP reformed according to the current drafts would have transformative potential, this potential runs the risk of not being exploited (Section 3.3). According to the current proposals (European Commission, 2018c, d, e), the CAP after 2020 can be shaped by the member states in the strategy plans in such a way that they can partially implement or at least support a land-use transformation as described by the WBGU. At the same time, however, this room for manoeuvre in implementation also entails the risk for the member states that the CAP will continue to be organized primarily as a form of income support rather than as a steering instrument (Box 3.3-1). The European Commission's ambitious proposals for regulations must therefore be followed up by assertive measures in the member states' strategy plans. A rethink is needed by all actors involved in agriculture (among others: farmers, ministries of agriculture, agricultural interest groups and agribusinesses) to ensure that environmental policy is seen as an integral part of agricultural policy. Up to now – and this can be explained by the historical development of the CAP (Box 3.3-1) – environmental protection and climate-change mitigation have not been among the primary objectives of the CAP agreed in the European treaties (Article 39 of the TFEU), but has only been included in agricultural policy as a cross-cutting objective of the EU in accordance with Article 11 of the TFEU.

In addition to the short-term corrections to the CAP called for in Section 3.3.3.1 with regard to the agricultural sector, the WBGU sees a need to fundamentally question the CAP's exclusive focus on agriculture and to make it the central transformation instrument for a land-use transformation. Within the EU, funds are needed not only for the greening of agriculture but also for sustainable forestry, for the establishment and expansion of protected-area systems, for restoration and the development of land-based approaches to CO_2 removal from the atmosphere, as well as for other objectives, all of which have an impact on the quality, protection and use of land and terrestrial ecosystems. The WBGU considers it expedient to bring these different requirements together in a European Common Ecosystem Policy (CEP), into which the CAP should be integrated. The aim of this policy should be to conserve and enhance European ecosystems. It should follow a systemic approach that supports multiple benefits and the multifunctionality of land and involves various actors in rural development. This would be an expression of a fundamental paradigm shift: the budget for the CAP, which accounts for over a third of the EU's budget, should be understood as an integral part of European sustainability policy. Agricultural production would continue to be actively promoted but very much as a building block of the sustainability transformation.

The transformation of the CAP into a broader Common Ecosystem Policy proposed here requires further specification and elaboration. Since such an extension can probably no longer be implemented solely on the basis of Articles 39–42 of the TFEU, at least the environmental-policy competences would have to be included or even the competence of the EU extended.

However, there is no problem in using additional funds from the LIFE programme to support such a transformation of the CAP. The necessary structural change for farmers towards agriculture that uses ecosystems sustainably (Section 3.3) should be taken into account in the sense of a just transition by taking corresponding accompanying measures and pledging corresponding financial resources. The 'Just Transition Fund' currently under preparation focuses on "regions and sectors that are most affected by the transition due to their dependence on fossil fuels, including coal, peat and oil shale, and on greenhouse-gas-intensive industrial processes" (European Commission, 2020h:1). Such Just Transition Funds are also needed in the land sector to make rural structural change towards multifunctional cultivation systems possible – with the active participation of the farmers themselves as transformation actors. The WBGU has already presented proposals for corresponding accompanying measures for coal fields that are to be phased out (WBGU, 2018).

A strong role and involvement of the farming community is essential for the successful application of the integrated landscape approach and the implementation of many multiple-benefit strategies. Today, farmers provide key services to society as a whole, for which they deserve recognition and, of course, appropriate remuneration: a reliable and high-quality food supply, the professional and sustainable use and care of soils and landscapes, active concern for biodiversity and cultural diversity. They are important transformation actors in the necessary transformation towards a sustainable stewardship of land and its functions as a valuable resource. On principle, framework conditions must be laid down in such a way that farmers are able and willing to play this role. The shared goal of national and supranational environmental and agricultural policies should therefore be to make the agricultural sector in all its diversity a proactive driving force in this readjustment. Systemic drivers of non-sustainable food production – such as western dietary habits that do not meet scientifically well-founded standards of sustainable and healthy nutrition (e.g. based on the Planetary Health Diet) – and their feedback interactions with agricultural production must not be ignored in this context (Section 3.4).

4.3.3 Recommendations for action

The general recommendations made in Section 4.2.6 for government frameworks for sustainable land stewardship are also particularly relevant for the European level. In principle, the German Federal Government can and should therefore work with its European partner states to advocate the implementation of these recommendations in the EU. The European Commission's work plan includes a large number of legislative acts, programmes and strategies to be worked through in the coming years under the umbrella of the European Green Deal. They include European climate legislation, the conservation of biodiversity through the Biodiversity Strategy and subsequent legislative acts, the transformation of industry towards a circular economy, and the revision of the CAP (European Commission, 2019a). The WBGU recommends pursuing the following fundamental policies in particular:

Transform the CAP into a Common Ecosystem Policy in the medium term

In the medium term, the EU's CAP should be integrated into a Common Ecosystem Policy (CEP), laying down a comprehensive, coherent support system for sustainable land stewardship. In all areas relating to land stewardship – from agriculture and forestry to settlement construction – activities that help avoid adverse land-use changes or conserve ecosystem services and greater sustainability should be rewarded in a coherent system. Ineffective (i.e. not promoting public goods) and above all land-area-based direct payments should be abolished as early as possible in favour of a fixed link to ecosystem services.

Strengthen sustainability standards for products that have an impact on land stewardship outside the EU

The Renewable Energy Directive II (RED II; EU, 2018a) currently imposes sustainability requirements on biomass used for energy; the EU Timber Trade Regulation includes a requirement to prove that wood placed on the market comes from legal sources (Box 3.5-8). Harmonized and evenly enforced EU-wide sustainability criteria in these regulations are important first steps towards promoting sustainable land use outside the EU. In the medium term, however, the sustainability criteria of RED II should be supplemented by further or more specific social and ecological criteria (e.g. relating to water and soil balance, biodiversity conservation). Other groups of goods that impact on land use should also be regulated in a similar way, e.g. biogenic building materials not already covered by the Timber Trade Regulation, which should be supplemented accordingly, or food and feed from within the EU and abroad. Furthermore, requirements that have so far only been a prerequisite for offsetting against binding minimum quotas and state subsidies (as in the EU RED II) should become binding – at the latest when more ambitious climate policies in the energy and transport sector make biomass use interesting even without subsidies. The successful implementation and enforcement of the guidelines remains key. Biomass flows should be documented by better (self-) monitoring (Boxes 4.1-1, 4.2-5). In the context of the ongoing review, the EU Timber Trade Regulation should, if possible, be strengthened and tightened, especially with regard to substantive certification requirements (Box 3.5-8). A European supply-chain law put on the agenda for 2021 can also be used, where appropriate, to promote sustainable land stewardship outside the EU.

Develop a quantified target for resource consumption in the EU

The European Commission's European Green Deal aims to increase resource efficiency. The new action plan on the circular economy is intended, among other things, to "reduce [the EU's] consumption footprint and double its circular material use rate" by 2030 (European Commission, 2020e). These targets are too vague and too unambitious. Concrete targets for the reduction of absolute resource consumption with a sub-target for biomass could help initiate societal and economic processes for a timely transformation. There is a lack of quantified overall targets for total resource consumption analogous to the European goal of climate neutrality by 2050, from which quantified targets on emissions can be derived. In particular, when it comes to reining in biomass use to bring it back within planetary guard rails, securing the food supply and biodiversity, and meeting social concerns in agriculture and forestry, the EU has a special responsibility as a developed economy whose per-capita biomass consumption is 70% higher than the global average (Kastner et al., 2015). A reduction in biomass consumption, for example to the global per-capita average (in each case in a base year whose production or consumption can still be considered scientifically 'sustainable') would therefore be a first quantification proposal.

Gear an EU strategy for CO_2 removal towards ecosystem restoration and diversified farming systems

In addition to the revision of the LULUCF Regulation planned for 2021 as part of implementing the European Green Deal (EU, 2018b), the EU should develop a way to strategically plan its contributions to possible future targets for the removal of CO_2 from the atmosphere as part of a European long-term strategy on the Paris Agreement in accordance with Article 4 (19) of the PA. The time horizon should extend at least until the year 2050, preferably longer. Such strategic planning should include the evaluation of possible potential that could be realized in view of sustainability risks, especially in the form of repercussions for the land-use trilemma. It should be coordinated with the EU's further future claims on land and land-based ecosystems, for example via biomass demand from the European bioeconomy. It should be clearly separated from the EU's efforts and strategies on CO_2 avoidance, in order not to weaken avoidance targets or delay, let alone replace, corresponding efforts. With regard to sustainability risks, particular emphasis should be placed on approaches that promise multiple benefits in the sense of synergies between climate-change mitigation, biodiversity conservation and food security. Examples include the restoration of forests or peatlands (Section 3.1) and the enrichment of carbon in the soil as part of diversified agricultural systems (Section 3.3). Given differences in natural (and economic) conditions, the strategy can include national projects as well as European cooperation projects. The latter would have the advantage that costs and burdens could be shared, and the most favourable location from an environmental, social and economic point of view could be determined independently of internal borders.

Use EU foreign-trade policy as an instrument for taking responsibility for global land-use transformation

For a comprehensive analysis including detailed recommendations for action to strengthen climate-change mitigation and development in trade relations and international trade law, the WBGU has commissioned an external legal expertise (Zengerling, 2020), on which the following recommendations are based. In the short to medium term, the EU should make the sustainable management of land and land-based ecosystems a central issue in negotiations on new or revised free-trade agreements. Key ecosystems within the sphere of influence of the parties should be identified and the effects of trade-policy decisions should be evaluated in depth and at an early stage – and, where appropriate, addressed through joint frameworks. Alongside explicit commitments by the parties to international environmental agreements and goals, such as the precautionary principle, the agreements should specifically promote trade in sustainably produced goods and services and provide for more effective control and dispute-settlement mechanisms. In principle, the WBGU also supports the EU in considering, where necessary, unilaterally introducing border-adjustment measures or expanding certification requirements to back up climate- and environmental-policy frameworks under the European Green Deal. In the longer term, the EU should also work for reforms of WTO law, so that measures to protect global commons do not become the subject of trade disputes (Zengerling, 2020). Possible approaches in this field include corresponding peace clauses or waivers that are clearly limited in time and subject matter, for example exception clauses for national measures to protect specified commons, e.g. climate-change mitigation (Bacchus, 2017) or certain particularly important ecosystems such as the Congo Basin. At the WTO level, the EU could also launch a new initiative to negotiate an agreement on sustainably produced environmental goods and services, which would reduce or abolish tariff and non-tariff barriers to trade in this field. As an intermediate step towards this, the EU should also support the ACCTS negotiations and agreement (Section 4.2.5.2).

4.3.4 Research recommendations

'Farm to Fork' – the importance of the Planetary Health Diet for European agriculture

A change in agriculture is systemically linked to a change in dietary habits (Section 3.4). How national and global nutrition guidelines relate to societal goals such as healthy eating options, climate-change mitigation or biodiversity conservation is an important subject of research (Box 3.4-8). With regard to the further development of European framework policy on agriculture (Section 4.3.2), the question also arises as to how changes in the average diet, e.g. towards dietary habits involving fewer animal products, would affect agricultural production. The distributional effects of the conversion of the CAP to a Common Ecosystem Policy are a possible accompanying research topic.

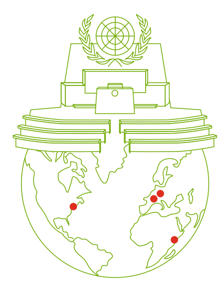
Reduction of resource consumption as a political objective

An absolute target for reducing resource consumption at the EU level should be made measurable and verifiable as a political objective with indicators and monitoring procedures as described in Section 4.2.4. How such a goal can be meaningfully formulated and made measurable should be the subject of further research. A particular challenge lies in determining a sustainable level of consumption.

A European roadmap for CO_2 removal from the atmosphere

To prepare and accompany its strategic planning on the future removal of CO_2 from the atmosphere, the EU should explore the various approaches for CO_2 removal both individually and in interaction in long-term research projects. In addition to further technical development and the question of sustainably realizable potential, particular consideration should also be given to possible repercussions that may result from climatic changes over time, for example, in the case of ecosystem-based approaches such as (re)afforestation. In parallel, effective governance and financing mechanisms should also be developed and scientifically evaluated that take appropriate account of the recommended separation of CO_2-emissions avoidance and CO_2 removal from the atmosphere, the specific sustainability risks of individual approaches to CO_2 removal, and the different (natural and financial) capabilities of the member states; such mechanisms could thus prepare the ground for business models in the field of CO_2 removal from the atmosphere that are viable in the longer term (Section 3.1).

4.4 Strengthen existing international cooperation and coordination of land stewardship



The protection and use of land, including land-use change and land degradation, are not primarily negotiated internationally in a single intergovernmental forum in the way, for example, that climate change and its consequences are dealt with under the Framework Convention on Climate Change and the Paris Agreement. Rather, land use, land-use change and land degradation are subjects covered by many different international institutions, organizations and forums. World summits on the environment and development like the Rio conferences have been important forums in the past. For example, the goal of Land Degradation Neutrality (LDN, Section 2.1.3) gained international consensus in Rio in 2012 (Rio+20). The UN Food Systems Summit scheduled for 2021 is also particularly relevant for multiple-benefit strategies in the agriculture and food sector. Important actors in multilateral cooperation are institutions such as UNEP, the FAO and the Global Soil Partnership. The three 'Rio Conventions', i.e. the Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (UNCCD), also touch on and regulate land-based ecosystems in particular. But other agreements also influence the way we treat land, such as the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Ramsar Convention on Wetlands, the Stockholm Convention on Persistent Organic Pollutants (POPs Convention), and the Convention on the Conservation of Migratory Species of Wild Animals (CMS), which is particularly committed to trans-border protected-area systems.

The global UN Sustainable Development Goals (SDGs, UNGA, 2015; Chapter 2) are particularly relevant politically as a common objective of international cooperation and for national policy strategies. Particularly worthy of note in relation to terrestrial ecosystems and land management are SDG 2 (Zero Hunger), which focuses on food security, improved nutrition and more sustainable agriculture, and SDG 15 (Life on Land), which aims to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (UNGA, 2015: 24) Furthermore, land tenure and access to land are important parameters for several SDGs, such as poverty reduction and gender equity (e.g. SDG 1.4, 5.a). However, the pursuit of all SDGs directed at human economic activities also has a significant impact on our use of resources and thus on our land stewardship. There are no binding instruments under international law for dealing with overlaps or contradictions between the various areas of international law, some of which have arisen independently of each other (e.g. on human rights, world trade or environmental protection). In this respect, the SDGs have a political "umbrella and integration function" (Zengerling, 2020:8). It should be noted, however, that the SDGs have a much shorter time horizon than many of the other agreements.

The WBGU cannot analyse the entire institutional structure on the subject of land in this report; but in the following it further develops individual examples of existing elements that can facilitate better global cooperation in land stewardship. Yet without stronger commitments and, in particular, decisive implementation and enforcement by states and the respective actors involved, as outlined in Sections 4.1 and 4.2, even better coordination of international activities will have only limited success. However, it is important to use the resources of all actors involved in international cooperation in a more targeted way and to make the best possible use of potential synergies, which can also facilitate implementation on the ground.

This concerns *first* the Rio Conventions (Section 4.4.1). They are examined below as they attract a particularly high level of international interest, partly because almost the entire community of states are signatories. They have developed a kind of reference value for international land stewardship. *Second*, global reports by scientific advisory services for policy-makers have become increasingly important for governance; in these reports internationally renowned scientists in consensus compile the current status of research on topics such as climate change (IPCC) or biodiversity (IPBES) either on their own initiative, or on behalf of non-governmental initiatives or the international community itself. Section 4.4.2 looks at whether and how the latest scientific knowledge can be better pooled and evaluated in the context of land stewardship. *Third,* local initiatives, distribution conflicts and ownership structures, as well as local and landscape-related *Eigenart* play a decisive role in sustainable land stewardship. They are key to successful transformations in the landscape context. Section 4.4.3 discusses ways of making local perspectives more visible and integrating them in global forums.

4.4.1 Challenge for the Rio Conventions: the cross-cutting topic of land

The WBGU is not the only body to have stressed in previous reports the need for greater cooperation on issues relating to global land stewardship in the areas of overlap between the three Rio Conventions (WBGU, 2011:237; Akhtar-Schuster et al., 2017). All the Conventions are already doing valuable work, providing negotiating spaces and implementation resources that should be built on. Although the UNFCCC, CBD and UNCCD each sets its priorities based on the different objectives (Table 4.4-1), land stewardship is a central part of all three Conventions. The main objectives of the UNCCD are land-degradation prevention and land-degradation neutrality; the CBD also aims to conserve and sustainably use terrestrial ecosystems and their biodiversity; and the UNFCCC also addresses emission sources and sinks from land areas, as well as the impacts of the climate on terrestrial ecosystems, including agriculture (Box 4.4-1). There is considerable synergy potential between the Conventions through overarching, systemic approaches to land stewardship (Fig. 4.4-1). With regard to the use of land and con-

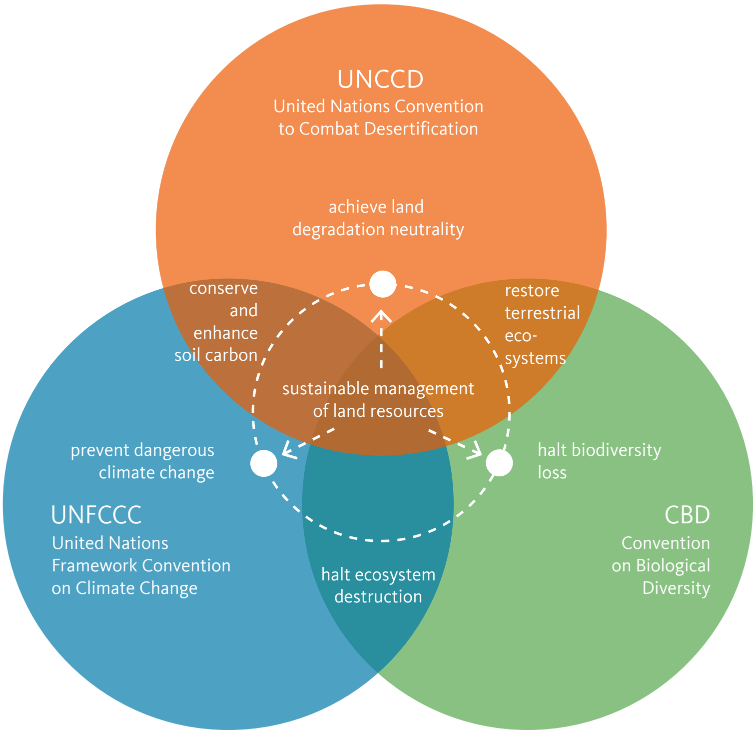


Figure 4.4-1
Sustainable management of terrestrial resources as a central task of the Rio Conventions. Sustainable stewardship of land resources not only contributes individually to the overarching goals of the Rio Conventions (preventing dangerous climate change, preventing land degradation and achieving land-degradation neutrality, as well as halting biodiversity loss, using biodiversity sustainably and ensuring equitable access to genetic resources). Various land-based measures can act synergistically to achieve the goals of the Rio Conventions. The measures mentioned in the figure in the sectional areas are examples. A global land-use transformation is thus an important prerequisite for the success of the Rio Conventions.
Source: modified from UNCCD, 2017b:15

sumption of land resources, all three Rio Conventions contain only limited binding requirements; in particular, there are no effective enforcement mechanisms for protection and use obligations.

However, more effective implementation of the three Conventions and mutual mainstreaming of their concerns across sectors could lead to more responsible management of terrestrial ecosystems as a whole. But this will only be the case if the Parties take a systemic view of land resources, if the Conventions exploit potential synergies and multiple benefits through better cooperation, and if they pursue overlapping goals in a spirit of solidarity.

4.4.1.1
Synergies and coordination of the Rio Conventions in relation to the land-use trilemma

All three Rio Conventions address the land-use trilemma in different ways and with their own focus. Each contains references to the work of the other two Conventions and information on institutional cooperation. The text of the UNCCD (Article 8) explicitly encourages Parties to coordinate their activities under the UNCCD with their activities under other agreements, in particular the UNFCCC and CBD. The 'theory of change' of the Zero Draft of the CBD's post-2020 strategic framework emphasizes the CBD's complementarity with and support for the 2030 Agenda with the SDGs and its consideration of other multilateral conventions, such as the other two Rio Conventions (CBD, 2020).

There are already activities to improve institutional cooperation and coordination of the Conventions. In particular, a Joint Liaison Group (JLG) between the secretariats of the UNFCCC, CBD and UNCCD was established as early as 2001; it also focuses on cooperation on land-related issues (Box 4.4-2). Institutional cooperation with the other Rio Conventions respectively and with further institutions is regularly on the agenda of the Conferences of the Parties (e.g. CBD in 2018, UNCCD in 2019). However, using shared working resources and better coordination could improve the working basis, especially for the Conventions' secretariats (Sands et al., 2018:97). Potential synergies in procedures, data pools, and monitoring and reporting requirements between Conventions are on the agenda of the JLG (2016). However, they are not getting enough of a chance, probably due to weak support for the JLG's findings by the Parties, which should enable their implementation at the respective COPs (Elsässer, 2017).

In terms of content, the Rio Conventions address interactions between the three dimensions of the land-use trilemma (Section 2.2) in several places. Important land-related areas of overlap between the Conventions include, for example, climate adaptation and forests, for which the non-binding Forest Principles were adopted in Rio de Janeiro in 1992 after a legally binding forest convention had failed to find a consensus (Hönerbach, 1996). The UNFCCC addresses forest protection and afforestation under Article 5, while the CBD includes in the negotiations the forest as an ecosystem and a haven for biological diversity. The work of the CBD is characterized by complex discussions on demarcation, e.g. from the UNFCCC and the UN Forum on Forests, a follow-up process to the Forest Principles. The UNCCD addresses the fight against land degradation. The Parties to the UNCCD submit National Action Programmes (NAPs) on this topic for the implementation of the Convention's goals and report regularly on their progress. Furthermore, the UNCCD supports projects such as the African Union's 'Great Green Wall' initiative, which aims to establish a green belt in North Africa (Section 3.3). In addition, further UN activities are underway in the UN Forum on Forests and in the context of the Bonn Challenge (Section 3.1.3). The UNCCD's work on land degradation neutrality takes a fairly broad approach to land stewardship. Land degradation causes both biodiversity loss and soil-carbon loss. Achieving land degradation neutrality (or even reversing the trend in terms of building up fertile land) is seen as a concept with the potential to contribute multiple benefits for the environment and development, especially also to the success of the UNFCCC and the CBD (Akhtar-Schuster et al., 2017:4). In addition to ecosystems' natural ability to adapt to climate change, safeguarding food production is also named as a goal of climate protection in Article 2 of the UNFCCC and as a goal of climate adaptation in Article 2.1 letter b of the PA. In the case of land-related measures within the meaning of Articles 4 and 5 of the PA, non-carbon benefits are to be included and encouraged, i.e. for example the conservation of biodiversity. Conversely, according to the draft of the CBD's future post-2020 strategic framework, nature-based solutions should contribute to climate-change mitigation and adaptation, while maintaining biodiversity and food security (CBD, 2020:5).

Although systemic interaction between the Rio Conventions on land in the sense of Chapter 2 is highly desirable, it is currently not taking place to anything like a sufficient degree. There has been progress towards better cooperation, but this is more project-related than programmatic and can clearly be expanded.

4.4.1.2
Starting points for better land governance through the Rio Conventions

As a Party to all three Rio Conventions (UNFCCC, CBD, UNCCD) and within the framework of the EU, Germany's Federal Government should advocate better cooperation and coordination of activities under the Rio Conventions and support them with financial and logistical capacity. In the following, the WBGU discusses various governance options for more sustainable land stewardship in the Rio Conventions' area of responsibility. A particular focus will be on setting the course for the CBD's new post-2020 framework, which will largely determine its work over the next decade.

A joint Conference of the Parties to the three Rio Conventions: the Global Land Summit

In order to achieve better cooperation and coordination of activities, it is necessary to upgrade the institutional interfaces between the Conventions that are relevant to land and between the respectively responsible bodies of the Conventions. The aim should be to further increase interaction and the joint development of standards. This is not limited to the continued need for cooperation between the Convention secretariats in the Joint Liaison Group (JLG, Box 4.4-2). Sustainable land stewardship would require a strong push for better coordination between the Conventions and their member states at all levels. In particular, it is crucial that Parties to the Conventions take responsibility for coherent policies towards other conventions to which they are bound, which is often hampered by 'silo thinking' due to different responsibilities within national governments. These aims can be achieved, for example, by holding simultaneous Conferences of the Parties to all three Rio Conventions, a 'Joint COP'. Joint COPs are technically separate Conferences of the Parties to different conventions, but which are held at the same time and place. Decisions with identical wording can be adopted in this way. Up to now, the Joint COP model has tended to be used by smaller conventions. For example, there are joint meetings of the COPs of the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (PIC Convention), the Stockholm Convention on Persistent Organic Pollutants (POPs Convention) and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Sands et al., 2018:937). This model would have the advantage of generating unprecedented attention and resources in order to manoeuvre the Conventions towards a common path.

Such a joint Conference of the Parties to the Rio Conventions should be an additional COP specifically

Box 4.4-1

Land as a subject of the Rio Conventions

The three Rio Conventions, i.e. the UNFCCC, CBD and UNCCD, were adopted in 1992 at the UN Conference on Environment and Development in Rio de Janeiro. They each pursue different objectives (Tab. 4.4-1) and relate to land stewardship differently in pursuit of their goals.

UN Framework Convention on Climate Change with the Paris Agreement

The international agreements on climate protection, the UNFCCC of 1992 and the Paris Agreement (PA) – which has been in force since 2016 and has been ratified by 186 countries (excluding the USA, which withdrew in November 2020) – only take a rudimentary systemic view of land use. While they recognize the importance of land use for climate-change mitigation and adaptation, the corresponding instruments are soft and non-binding. Land areas and soils are addressed and protected insofar as they serve to stabilize greenhouse-gas concentrations in the atmosphere (Article 2 of the UNFCCC and Article 2 (1) letter a of the PA) or climate adaptation (Article 2 (1) letter b of the PA) or are affected by it. The UNFCCC and the PA include not only CO_2 emissions, but also other greenhouse-gas emissions, such as methane and nitrous oxide, which are mainly produced in agriculture (Bodansky et al., 2017:120f.). Article 4 (1) letters c and e of the UNFCCC and Article 5 (1, 2) of the PA call upon the Parties to the Agreement to take measures to conserve and build up carbon reservoirs and sinks, in particular for forest protection. The forest-focused REDD+ programme (Box 3.1-6) is also prominently integrated here. However, these specific rules are not legally binding obligations. In addition to the obligation under Article 2 of the PA to limit climate change to well below 2°C and, if possible, to 1.5°C, Article 4 of the PA merely stipulates that binding, nationally determined contributions (NDCs) must be submitted to the UNFCCC Secretariat in order to create transparency on global progress in climate protection. However, there is no direct obligation to take Article 5 activities into account in the NDCs or other PA implementation mechanisms (Fee, 2019:261). One area that the Parties acknowledge for the first time under international law in the PA is the topic of damage and loss caused by climate change (Article 8 of the PA). These are closely related to land degradation and require effective mechanisms to enable existing funding gaps to be filled to compensate for damage and loss (WBGU, 2018:18).

Convention on Biological Diversity

The CBD has 195 states plus the EU as members. The USA signed the Convention but has never ratified it. Land and soils, as part of ecosystems, are directly covered by the scope of the Convention and should be seen above all in the context of the first two Convention goals in the CBD's Article 1 (conservation of biological diversity and sustainable use of its components). The objectives of Article 1 of the CBD cover in particular soils as components of terrestrial ecosystems in their function as a life-support system and habitat for animals, plants and soil organisms, as a component of the natural balance (including water and nutrient cycles) and with its ecosystem services (Fig. 2.1-1), e.g. for the production of food or biomass (wood, cotton, etc.), the carbon storage function, as well as decomposition, balancing and build-up processes for material influences (Ginzky, 2015:204). Compared to the UNFCCC, including the PA, the level of commitment for activities under the CBD is lower, partly because the obligations are usually limited by the phrase "as far as possible and as appropriate". Obligations exist, for example, with regard to the development of strategies, plans and programmes for the conservation and sustainable use of biodiversity and corresponding reports (Article 6 of the CBD), an inventory and the monitoring of important components of a country's own biological diversity (Article 7 CBD), the designation of protected areas and the sustainable use of components of the biosphere. Further obligations relate to the conservation and sustainable use of components of biological diversity (Articles 8–11 of the CBD). The more binding protocols to the CBD, the Cartagena and Nagoya Protocols, do not specifically address terrestrial ecosystems.

UN Convention to Combat Desertification

Negotiations on the UNCCD began in 1992 and the Convention was opened for signature in 1994. It came into force after ratification by the 50th state in 1996 and today has 197 Parties. With the 2018–2030 Strategic Framework (UNCCD, 2017a), the Parties incorporated the implementation of SDG 15.3 (Land Degradation Neutrality, LDN) into the UNCCD's work. LDN is defined as the state in which the quantity and quality of land resources needed to support ecosystem services and improve food security remain stable or increase within specific temporal and spatial units and ecosystems (UNCCD, 2015:9; Wunder et al., 2018b:28; Section 2.1.3). The UNCCD Secretariat takes on responsibility for the related indicator 15.3.1 (proportion of land that is degraded over the total land area) in the Interagency and Expert Group on SDG Indicators (UNCCD, 2019:3f.). The UNCCD is thus a key convention under international law on sustainable land stewardship. In fact, it has evolved beyond drylands by adopting five regional annexes with specific regulations for a wide range of world regions, also addressing, for example, land degradation in the tropics. Originally, it only contained binding requirements for states directly affected by desertification, i.e. the preparation of action programmes as outlined in the UNCCD's Articles 9–15. The new Strategic Framework allows states that have hitherto not been bound by the UNCCD and its annexes to use the UNCCD's forums in a legally non-binding manner to internationally coordinate their policies on land degradation and the impacts of drought, and to lay down and review voluntary targets in development towards land degradation neutrality (UNCCD, 2017a). The UNCCD's approach is that its goals should be implemented at national and local level. Therefore, no top-down mechanisms are provided for. Measures focus on the obligation to draw up action plans and strategies, the exchange of information on these, as well as cooperation and capacity building for the implementation of the UNCCD's goals by the Parties.

Table 4.4-1
Objectives of the Rio Conventions (verbatim quotes).
Source: WBGU

Objectives of the Convention	
UN Framework Convention on Climate Change (UNFCCC) The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow **ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.**	Article 2 of the Framework Convention on Climate Change (UNFCCC, 1992)
Parise Agreement 1. This Agreement, in enhancing the implementation of the Convention, including its objective, **aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:** › Holding the increase in the global average temperature to **well below 2°C above pre-industrial levels** and pursuing **efforts to limit the temperature increase to 1.5°C above pre-industrial levels,** recognizing that this would significantly reduce the risks and impacts of climate change; › Increasing the ability to **adapt to the adverse impacts of climate change** and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and › Making **finance flows consistent** with a pathway towards low greenhouse gas emissions and climate-resilient development. 2. This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.	Article 2 of the Paris Agreement (UNFCCC, 2015)
Convention on Biological Diversity (CBD) The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the **conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources,** including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding	Article 1 of the Convention on Biological Diversity (CBD, 1992)
United Nations Convention to Combat Desertification (UNCCD) The objective of this Convention is to **combat desertification and mitigate the effects of drought** in countries experiencing serious drought and/or desertification, particularly in Africa, through effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach which is consistent with Agenda 21, with a view to contributing to the **achievement of sustainable development in affected areas.** Achieving this objective will involve long-term integrated strategies that focus simultaneously, in affected areas, on improved productivity of land, and the rehabilitation, conservation and sustainable management of land and water resources, leading to improved living conditions, in particular at the community level.	Article 2 of the UNCCD (UNCCD, 1994)

on the topic of land – a Global Land Summit – and not a merger of the regular conferences, as Turney et al. (2020) propose. The systemic view of how to deal with land in view of the challenges of the transformation towards sustainability would be the main focus. It should be possible for other conventions to join, e.g. the Ramsar Convention or CITES. At such a Global Land Summit, all issues relating to potential synergies could be negotiated jointly and then adopted by consensus for the respective conventions. In this way, the systemic, synergetic and solidarity-based potential of the three Conventions can be highlighted in order to bring them out of their silos. If this conference is successful, then a corresponding Global Summit on the topic of the oceans could be considered at a later date.

The preparation of such a Global Land Summit could be decided by the UN General Assembly, perhaps at the suggestion of the G7/G20. The COPs of the participating conventions would also have to come out in favour. Subsequently, preparation must be ensured by joint meetings of the three COP bureaus responsible for organizing Conferences of the Parties and by continu-

Box 4.4-2
The Joint Liaison Group

The Joint Liaison Group (JLG) between the secretariats of the three Rio Conventions has existed since 2001, with the mandate, newly formulated in 2013, to strengthen coordination between the UNCCD, CBD and UNFCCC, in particular through the exchange of important information. Furthermore, the possibility of a joint work programme and further opportunities for cooperation were also to be discussed. The focus of the JLG is to provide effective support to the Parties in coordination at the national level (JLG, 2013). Topics include joint publications (e.g. a trio of publications on the occasion of the Rio+20 Conference in 2012 on adaptation, forests and gender), as well as the development of common indicators and improved compatibility of datasets and reports to avoid the Parties duplicating work. The focus of work in recent years has been on the joint development of indicators, especially on SDG sub-targets 6.6 and 15.2, as well as on indicator 15.3.1 for the land degradation neutrality target (CBD, 2018c:9, margin number 41). In addition to technical issues, land-related topics are already regularly on the JLG's agenda. As future goals of cooperation, the CBD Secretariat in particular emphasizes that the convergence of goals and sub-targets can enable the development of common indicators for planning and reporting processes (CBD, 2018c:10, margin number 50). It also stresses the need for better cooperation on synergies in national reporting and common reporting frameworks, as well as better interoperability of reporting tools.

ous coordination of the secretariats in the JLG. The outcome of the Global Land Summit can be much more in terms of content and impact than simply an identical decision by all three COPs about land, if common goals (with SMART indicators) are laid down there and joint commitments agreed.

In the context of the Global Land Summit, or independently of it, the work of the JLG can be upgraded with more personnel and funding, so that permanent thematic working groups can be established. The results of this cooperation can be actively incorporated into the work of the COP bureaus and COPs. Going further, the three Rio Conventions could organize cooperation and coordination in a trilateral memorandum of understanding in a more binding manner than has been the case to date (Ginzky, 2020; Section 4.4.1.1). Cooperation not only between the secretariats but also between the other bodies could be regulated in such a way that the Parties would have to deal practically with cooperation and the search for synergies. Legally, a mandate from the COPs to negotiate and a decision on the content would be necessary. The reports on cooperation with other institutions at the respective Conferences of the Parties reveal a broad practice of cooperation. There is low-threshold potential for further development here (Beyerlin and Marauhn, 2011:445). The content for such a memorandum of understanding would be common objectives and procedures for better exploiting potential synergies between the work of the Conventions. To this end, for example, meetings of the three COP bureaus of the Rio Conventions could be envisaged which could work towards raising the profile of cooperation and coordination in the interim negotiations and in drawing up agendas.

Mainstreaming and common standards for projects and programmes

Potential synergies of integrated target tracking, common indicators, compatible targets for data, strategies and reporting are well known, as the work of the Rio Conventions' JLG shows (Box 4.4-2). Closer cooperation and coordination of international conventions and other organizations should not dilute the respective mandates of the institutions, but promote integration and common standards for the various concerns, thus making synergies for implementation possible 'on the ground', i.e. at the national level (Carazo and Klein, 2017:411). In particular, comparable indicators should be used for this purpose (Section 4.2.4). Starting points could be common standards for safeguards, as well as environmental impact assessments based on them in the context of programmes and projects. These could be jointly defined at a Global Land Summit by means of identical declarations.

- *UN safeguards for local action and sustainable land use as common standards for the implementation of projects and programmes:* All projects and programmes carried out under the Rio Conventions should, as far as possible, support the objectives of other conventions or at least not run counter to them, especially in view of possible competition for land. Safeguards, i.e. sustainability requirements, are already being established for various projects and programmes within the Rio Conventions in order to optimally incorporate social (e.g. respect for the rights of local populations), economic (e.g. avoiding displacement effects) and ecological side-effects (e.g. on local biodiversity). Such safeguards exist, for example, in REDD+ (UNFCCC, 2010) and are being discussed for ecosystem approaches with climate impacts and for climate adaptation under the CBD (CBD, 2018a). A harmonization of these sustainability standards is a meaningful subject for cooperation between the Rio Conventions.

- *Environmental impact assessments as a tool for the precautionary mainstreaming of sustainable land use:* Impact assessments, particularly environmental impact assessments (EIAs) and strategic environmental assessments (SEAs), are a common tool used in the national legislations of almost all countries in the world, as well as in international law; they aim to strengthen the integration of environmental considerations into procedures relating to legislation, programme development and project design (UNEP, 2018; Craik, 2018). EIAs and SEAs are legally constituted, multi-phase procedures for the early identification, description and assessment of all direct and indirect impacts of a project, plan or programme on the environment, including ecological interactions, with the involvement of affected stakeholders (Schlacke, 2019:101). Under international law, these instruments are enshrined, for example, in Article 14 of the CBD for projects, programmes and policies that are likely to have significant adverse impacts on biodiversity, and in the Espoo Convention (UNECE, 2017) with its Protocol on Strategic Environmental Assessments for projects, plans and programmes with cross-border impacts. The UNFCCC and the UNCCD do not have binding requirements for project-based EIAs and plan-based SEAs. However, requirements for such impact assessments are the subject of technical cooperation and capacity-building measures under various Rio Conventions, e.g. the CBD's Voluntary Guidelines on Biodiversity-Inclusive Impact Assessments (CBD, 2006). By laying down coherent requirements for EIAs and SEAs – e.g. based on the UN Safeguards mentioned above for local action and sustainable land use under all conventions – a preventive system could be introduced to control direct and indirect land-use change in the design and implementation of projects, plans and programmes, which also examines interactions with the objectives of other conventions. In particular, the landscape perspective (Box 2.3-3; Sections 3.6, 4.2.3) should be included in this procedure in order to incorporate the specific character (*Eigenart*) of regional landscapes. With this in mind, it is crucial that the EIAs should be developed in such a way that they are responsive to the specific conditions of the respective landscape(s) and at the same time make their integration into global material flows and contexts transparent. To this end, for example, an EIA should take into account not only the emissions of an installation but also the long-distance effects (telecouplings) of the resources required for its operation. In the case of a biogas plant, for example, land-use changes are determined not only by the area occupied during operations but also by the farmland required for operations. Although the measurability of such indirect land-use changes is challenging, a further development of EIAs and SEAs in this sense is needed. The availability of high-quality information is a challenge for EIAs and SEAs (UNEP, 2018:5f.). Therefore, working towards a better data pool is a prerequisite for successful EIAs and SEAs.

Post-2020 framework and further development of the CBD

The CBD is currently facing an important strategic moment: the Post-2020 Global Biodiversity Framework will set the course for the CBD's work for the next decade. In the CBD's present strategic framework, the implementation of the 20 Aichi Biodiversity Targets in the signatory countries up to and including 2020 aimed to combat the causes of biodiversity loss by means of mainstreaming in politics and society, reduce direct pressure on biodiversity and promote sustainable use, improve the status of biodiversity by means of conservation, and increase the benefits of biodiversity and ecosystem services for all human beings (CBD, 2010a). The task of achieving the targets should be supported by participatory planning, knowledge management and capacity building. However, it is widely recognized that the Aichi biodiversity targets are being missed (Section 3.2.2; SCBD, 2020; Diaz et al., 2019; IPBES, 2019a; Tittensor et al., 2014). The negotiations on the new CBD framework programme have been delayed by the Covid-19 pandemic (Corlett et al., 2020). However, the adoption of new, ambitious biodiversity targets is immensely important for overcoming the biodiversity crisis (Section 2.2.3). The following statements therefore focus on recommendations relating to the CBD. Fundamental decisions in the CBD's new strategic framework should also be used to consider multiple benefits between different conventions (CBD, 2020). With the introduction of the Nagoya Protocol in the last decade, the CBD reached a milestone towards spelling out one of its key objectives. Further milestones should be placed on the agenda for the next strategic framework.

- *Further development of compliance:* There are discussions on how compliance under the CBD can be improved. Reference has been made, for example, to possible analogies with the design of the Paris Agreement with its pledge-and-review process (Voigt, 2019). However, climate change and the biodiversity crisis are not directly comparable. For example, there is no quantitative overarching goal in the CBD like that of limiting climate change to well below 2°C as stated in Article 2 of the PA. Setting

Box 4.4-3

An overall apex target for the CBD?

A question that is the subject of controversial scientific and political discussions is whether the CBD needs an 'apex target' as part of its post-2020 framework, i.e. an overarching target comparable to the 2°C (or 1.5°C) guard rail in climate policy that would do justice to the CBD's three objectives for the "conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources" (CBD Article 1). The complexity of biodiversity as a particular challenge for an apex target has already been mentioned in the current process to further develop the Zero Draft (CBD, 2020). Such an apex target could contribute to a goal-oriented implementation and, in particular, to a media-effective communication of the post-2020 framework, as well as to the communicability of the biodiversity crisis in general (Section 2.2.3). Opinions on this question vary widely. Targets to curb the extinction rate of species (Rounsevell et al., 2020) – according to IPBES, 1 million species are threatened with extinction in the next few years (IPBES, 2019b:12) – or the politically consensual goal of placing 30% of the world's surface under protection (CBD, 2020) would be both obvious and methodologically feasible and would move the CBD forward. However, both proposed targets would only cover the first of the CBD's three target dimensions: the conservation of biological diversity. The equally indispensable dimension of sustainable use, as well as the complex area of access and benefit-sharing in relation to genetic resources, would not be reflected. Accordingly, there would need to be at least three apex targets – one for each of the CBD's three target dimensions mentioned above. Moreover, the complexity of the ecological interrelationships surrounding biodiversity is already considerably greater in the first target dimension of biodiversity protection than the complexity of the physical interrelationships between CO_2 emissions, CO_2 concentrations, radiative equilibrium and corresponding temperature increases in climate-change mitigation. In order to be able to specify just the conservation of biodiversity effectively, a sub-target would be needed for the diversity of genes, species and ecosystems, i.e. for each of the three dimensions of biodiversity. An overarching target reduced to ecosystem conservation – using protected-area systems as a percentage of the total area as an indicator – is a desirable element of the post-2020 framework, but as a stand-alone apex target it could not reflect this complexity, particularly in its interaction with human beings (Purvis, 2020). However, the communication function of an apex target must be taken into account: it might be useful to name a target proactively, because in the public debate one or a few targets will be used for simplification anyway. If there is no official apex target, the Parties will be giving up control of its determination.

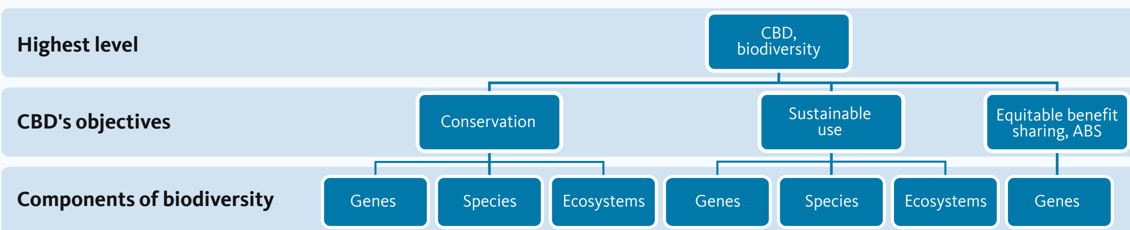


Figure 4.4-2
Target dimensions of the CBD. The CBD has three main objectives: (1) the conservation of biological diversity, (2) the sustainable use of its components, and (3) regulating access to and equitable sharing of benefits arising out of the utilization of genetic resources (Access and Benefit Sharing, ABS). While all three components of biodiversity, i.e. genes, species and ecosystems, are to be taken into account under the first two goals, ABS as the third goal refers only to genes. This multi-dimensional nature of the CBD's targets and components of biodiversity illustrates how complex the discussion of a possible apex target for the CBD is.
Source: WBGU

such an 'apex target' for the CBD is an issue for academic and policy debate, but it is challenging (Box 4.4-3). The procedure of nationally determined contributions that are regularly aggregated into a global inventory and a progressive rise in ambition under the Paris Agreement could potentially be transferred in an adapted form to improve transparency and encourage public debate on progress under the CBD (CBD, 2020). The contributions should not be measured on the basis of overly simplistic indicators, so as not to create false incentives. Here, in particular, simplification and abstraction threaten to obscure complexity and local contexts (Purvis, 2020; Barnes et al., 2018).

- *The CBD's contribution to climate-change mitigation and adaptation:* The idea of linking nature conservation and climate-change mitigation is moving higher up the CBD agenda; initially for adaptation and disaster preparedness (CBD, 2018a). The Zero Draft for the post-2020 framework also discusses contributions on climate-change mitigation and adaptation by means of nature-based solutions and ecosystem-based approaches (CBD, 2020). As explained in Chapter 2 and Section 3.1, possible contributions of terrestrial ecosystems to climate-change mitigation and adaptation must be formulated realistically and methodically in order not to put terrestrial ecosystems under excessive strain. Systemic consideration must be given to how the CBD's relationship to climate-change mitigation and adaptation affects the protection and use of land and soils, and what sustainable contribution the CBD can make to climate-change mitigation. A wide variety of measures are under discussion, ranging from emissions reduction to the creation of carbon sinks. Land-based climate measures that do not belong together methodologically must not be mixed up. The conservation of carbon reservoirs by ecosystem conservation, the reduction of land-based greenhouse gases by reducing levels of tree loss, sustainable land cultivation practices and the creation of carbon sinks, e.g. through restoration, should be looked at separately, as they have different properties in terms of climate-change mitigation (Sections 3.1-3.3, 3.6). CO_2 and other greenhouse gases differ considerably in their climate impact and long-term effects (Box 2.2-1). Terrestrial ecosystems cannot be equated with conventional climate-change mitigation measures such as the reduction of CO_2 emissions from the use of fossil fuels, because a frequent problem with land-based contributions is that they either have little long-term effect on climate-change mitigation or the effect is risky; land-based contributions are susceptible to external influences from humans, extreme events such as fires and, among other things, future climatic changes. As such, they cannot be categorized together with permanent decarbonization strategies such as the switch to renewable energies. Good ecosystem-protection strategies combine the protection of natural carbon reservoirs and restoration with the provision of new carbon sinks. Well connected protected-area systems strengthen the ecological infrastructure and the resilience of landscapes to climate change; they also have positive climate-change mitigation effects (Section 3.2).

- *Agree complementary CBD protocols on the conservation and sustainable use of biodiversity:* The CBD already has two valuable protocols, the Cartagena Protocol on Biosafety, which was planned as early as 1992, and the Nagoya Protocol on Access and Benefit Sharing (ABS) concerning genetic resources, the CBD's third objective (Table 4.4-1). However, there are as yet no correspondingly ambitious regulations on the first two goals of the CBD, the conservation of biodiversity and the sustainable use of its components. It is true that intensive work has also been carried out on these issues in the CBD; there are work programmes and a number of COP decisions on the basis of which numerous guidelines and principles have been agreed. However, these have lacked attention and clout so far. Therefore, the period up to 2030 should be used to undertake robust institutional developments and to give the CBD fresh, transformative impetus. The idea is to negotiate 'twin protocols' on the first two goals of the CBD, which would establish closely interlinked agreements on the conservation and sustainable use of biodiversity in the interests of synergistic multiple benefits. First, against the background of an integrated landscape approach, these protocols should lead to a bundling and consolidation of the diverse decisions on these issues; second, they should contribute to institutional further development in view of the overarching SDGs; and third, they should secure a higher degree of commitment. This recommendation is highly ambitious in view of the foreseeably long duration of the negotiations and the substantive challenges.
- *Protocol for biodiversity conservation:* The aim would be to bring together the multiple decisions and activities of the CBD on ecosystem conservation, including the desirable 30% target on protected-area systems as well as the integrated landscape approach in the post-2020 framework. This could generate a higher level of attention, intensify commitment to national and transborder activities, and achieve better funding to boost GEF projects as well as the long-standing work of IUCN and the many NGOs. In terms of content, the targets could build on the Programme of Work on Protected Areas (since the COP 7 in Kuala Lumpur) and on the Aichi targets and criteria (Section 3.2). These activities should reflect the state of negotiations on other CBD topics (e.g. IPLCs, Article 8j), be adapted to the current state of knowledge under the IPBES, and include options for further substantive development.
- *Protocol on the sustainable use of biodiversity:* This protocol should establish common standards for sustainable land use along the lines of existing non-binding agreements (e.g. Addis Ababa Principles and Guidelines, Forest Principles of the UNCED Conference). Sectoral provisions should improve the mainstreaming of CBD issues in agriculture, forestry and fisheries, and also include mining, infrastructure development and urbanization. Local negotiation processes in the spirit of the integrated landscape approach should be encouraged, and the training and further education of local actors addressed. A key challenge will be to agree arrangements for the internalization of ecosystem services and financial compensation mechanisms.

4.4.2
Survey of the scientific status quo on integrated land stewardship

The WBGU reiterates its fundamental recommendation that the latest status of scientific knowledge on global land stewardship should be continuously determined by globally pooling expertise (WBGU, 2011:299f.). As in the fields of climate-change mitigation and biodiversity with the IPCC and IPBES, land stewardship should be managed on the basis of the best available scientific knowledge worldwide. Over the last almost ten years, an extensive network of bodies and reports has been set up to review, communicate and intensify the status of scientific knowledge on the topic of land. With the IPCC's Special Report on Climate Change and Land (2019a), the IPBES's Land Degradation and Restoration Assessment (2018a), and the UNCCD's Global Land Outlook (2017b), up-to-date, often consensual and high-quality scientific evidence is available on global land degradation, terrestrial ecosystem restoration and sustainable land management. The UNCCD's Science Policy Interface (SPI) has been processing scientific evidence on desertification, land degradation and drought impacts for policy-making since 2013. The experts of the Intergovernmental Technical Panel on Soils (ITPS) have also been advising the FAO Global Soil Partnership on soil management in the context of food security, ecosystem services and climate change since 2013. Furthermore, since 2012, the Global Land Indicators Initiative (GLII), part of the Global Land Tool Network (GLTN) supported by UN-Habitat, has been advocating for global indicator-based monitoring through data collection on key land-governance issues such as land and usage rights. Other topics on land stewardship still seem to be far from reaching a comparable science-oriented consensus. For example, the 'World Agricultural Report' (International Assessment of Agricultural Knowledge, Science and Technology for Development, IAASTD, 2009) was an important step and source of impetus, but in view of the extremely divergent interests involved it was unable to establish a broadly supported consensus or to inspire a significant follow-up process. The EAT-Lancet Commission report became available in 2019. This report is a globally relevant scientific contribution to healthy diets in the context of sustainable food systems and addresses an important driver of land-use change (Willett et al., 2019). Even if there is no direct link to an international organization or political decision-making forum here, the recommendations on a Planetary Health Diet (Section 3.4) should inspire and guide decision-making both nationally and internationally (e.g. FAO, WHO). Last but not least, in 2019, the Food and Land Use Coalition's 'Growing Better' report provided valuable input on the need for a global transformation of the food and land-use system (FOLU, 2019).

Further development of scientific assessments

Overall, there is already a diverse network of scientific expertise, directly and indirectly linked in the environment of global debates and international institutions. Even so, the WBGU sees three ways in which the network should be further developed in a meaningful way.

1. *Global assessment on sustainable land stewardship:* An ideal development would be an assessment of the scientific status quo on 'land stewardship' that is integrated across the individual sectors and perspectives. It should have a thematically comprehensive, systemic approach, like the basis of this report with its interlinked references to climate change, biodiversity and nutrition. Only a systemic-integrative perspective can properly grasp the transformative challenges, make sustainable solutions accessible and the need for political action sufficiently transparent. An advisable first step would be intensive cooperation and a mutual analysis of the needs of the existing institutions and reporting formats (in particular the IPBES, the IPCC, the SPI of the UNCCD, the GLO, EAT-Lancet and, in the longer term, also a successor to the IAASTD). The preparation of a Global Land Summit (Section 4.4.1.2), i.e. a joint COP of the Rio Conventions, could provide an opportunity for such a joint report on land stewardship. In addition, it might be a good idea for the mandate for organizing this process to be shared between the UNCCD and the FAO, assisted by a corresponding increase in resources, since both have a network of thematically relevant actors, and closer cooperation here promises multiple benefits. The establishment of an independent new intergovernmental body could grow out of such a cooperative undertaking at a later date – but would still have to solve the problem of adequate linkage to a correspondingly powerful forum of political decision-making. In doing so, the practical experience of the IPCC and the IPBES, as well as innovative ideas for the integrative further development of global environmental assessments, should be critically incorporated (e.g. Kowarsch et al., 2016).
2. *Sustainable landscapes assessment:* Another acute need is to augment the current approach of the often thematically focused and globally aggregated assessments. Decisive added value compared to previous approaches arises from systematically compiling decentrally produced knowledge on the conditions for the successful design of sustainable and integrative landscapes, and from scientifically pro-

cessing it in such a way that local solutions are widely disseminated. Action competence can be supported from the resulting reservoir of innovative, local solutions wherever sustainable change in land stewardship still needs to be initiated and implemented. While there can be no blueprints for sustainable landscape development, an inclusive, networked, scientific assessment process on the challenges, success factors, and productive participation processes specifically for the landscape level can provide valuable knowledge for action and policy recommendations for this transformative change. For this reason, too, conducive global, national and local framework conditions for change in the diverse landscapes should definitely be the subject of this assessment process. This bridging of local practice and global scientific analysis can be particularly valuable in the field of diversified farming systems (Section 3.3.4.2). Such a process could also be institutionally linked to the existing network of established institutions such as the UNCCD and FAO. A link to organizations that already focus explicitly on the landscape perspective would offer particular multiple benefits here, so that an institutionally upgraded Global Landscapes Forum (Section 4.4.3) could also support and help shape such an assessment process.

3. *(Agro-ecological) research networks for the co-creative implementation of the land-use transformation:* The valuable approach of regional research and competence centres (e.g. BMBF, 2018) should be expanded and further developed in order to research and, in a realistic way, test local and regional methods and practices for a sustainable form of land stewardship as decidedly transformative challenges. One important goal is the broad creation of multifunctional, resilient landscapes. In order to implement an inclusive, co-creative approach from science and practice, local scientists and practitioners should work with international partners from science, civil society and business in an implementation-oriented way and promote transnational exchange, which also works towards a global assumption of responsibility for land as commons. In the networks thus created, valuable practical knowledge on integrated co-management in the landscape (e.g. on ecological intensification, agroecology, permaculture or agroforestry) can be systematically collected, analysed and further developed. The centres create a global public knowledge commons, actively work on the worldwide transfer of knowledge and, in the process, accelerate the land-use transformation in certain regions. Following the globally integrated structure of the CGIAR Agricultural Research Centres, the WBGU recommends setting up a series of international landscape-related research centres, through which land-related and landscape-related empirical knowledge can be incorporated with scientific findings, jointly further developed and ultimately transferred on a broad scale.

4.4.3 Strengthening 'glocal' cooperation: local and landscape participation in international forums

Many issues of global environmental change, and in particular many challenges of sustainable land stewardship, require multiple local efforts and changed practices to address the problems discussed in global policy forums and to implement adopted targets. Experience to date from international environmental and climate policy indicates both this requirement and initial lessons regarding the inclusion and participation of local and indigenous interests. For example, in response to critical debates about the lack of consideration of indigenous and local knowledge in the context of the IPCC, the (more recent) IPBES explicitly includes such knowledge in its reporting process (McElwee et al., 2020). Under the REDD+ programme, new attempts at participation were made and overarching safeguards introduced to reduce conflicts in the implementation of future REDD projects after a number of conflicts with indigenous and local residents in the designated programme zones (Dawson et al., 2018). In the context of international climate negotiations under the umbrella of the UNFCCC, a renewed attempt has recently been made via the Talanoa Dialogue to allow the voices of non-party stakeholders (i.e. a wide range of non-state actors) to be heard through orderly procedures (Presidencies of COP22 and COP23, 2017). Moreover, many cities are now networked worldwide to engage jointly in climate-change mitigation in alliances such as C40 or ICLEI (WBGU, 2016a). They have attracted sustained global attention, also in the context of international negotiations (van der Heijden, 2018).

The Global Landscapes Forum (GLF), founded in 2013, is attempting to develop a similar impact to that of urban initiatives. The GLF is essentially a multi-actor knowledge platform that promotes the integrated landscape approach as a valuable concept for the cooperative management of social and environmental problems on the ground using conferences, meetings and projects worldwide. Germany's Federal Government already supports the Forum both financially and in non-material ways, which is why its headquarters are in Bonn. In the course of this development, the WBGU recommends strengthening and better integrating local, rural and indigenous positions in the various relevant international forums. Interaction between different actors and positions on global needs, national interests, and local concerns and implementation require permanent forums to be productive for a global land-use transformation. Sustainable land stewardship worldwide requires the empowerment of an independent implementation perspective within the landscape, including improved inclusion and representation in international negotiations.

Combine architecture responsibility ‚glocally'

The WBGU therefore proposes institutionally improving the mutual exchange of perspectives between local actors in close connection with international forums and making this exchange more permanent. Globally sustainable land stewardship in particular must take place in the light of the many local forms of usage, interests, specific challenges and types of potential. Making the practical potential of an adaptive and integrated landscape approach visible, as already promoted in the Global Landscapes Forum (GLF, 2020), should be strengthened and linked more closely to decision-making forums. An organization and emancipation of landscape perspectives and interests should be made possible that is similar to the WBGU's recommendation (2016a:412) to grant cities and city networks a say and participation rights in national politics, international UN bodies and global forums as part of the polycentric responsibility architecture. The question of sustainable land stewardship is a burning glass for the acute need to communicate international agreements like the Rio Conventions with their global guidelines on the one hand and local implementation efforts with their site-specific negotiation processes on the other by means of strengthened existing as well as new forms of 'glocal' cooperation.

Such a cooperation linking the two should take place by:

- *Creating an independent 'L40' network initiative – Rural Areas for Sustainable Landscapes*: A major innovation in the field of transnational climate and sustainability policy over the last one to two decades has been the rise of cities, municipalities and city networks such as C40, ICLEI or the Global Covenant of Mayors as vocal and effective pioneers with their self-confident actions also on the international stage. Their motivation is born out of the concrete municipal challenges and opportunities of transformative change in the urban context, as well as the potential that global networking and advocacy bring. Elsewhere, the WBGU (2018) has already called for similar networks to be established for regions undergoing structural change, in order to bring about a 'just and in-time' transformation with political will, local initiative, scientific support and the mutual transfer of knowledge and competence, especially in these particularly affected regions. This approach must now also be developed for successful transformative change towards a new, sustainable coexistence in the landscape. As 'Landscapes 40', rural areas and eco-social landscapes could launch a joint network organization which, as a bottom-up initiative, is simultaneously a representation of interests, an exchange platform and an innovation hub for its members.
- *Further developing the Global Landscapes Forum:* Especially at the beginning of the UN Decade for Ecosystem Restoration, a visible upgrading of the Global Landscapes Forum (GLF) would be an important political signal and a relevant lever for generating attention for the importance of the landscape level in solving many sustainability challenges. Without counteracting the Forum's hitherto, collaborative multi-stakeholder approach with too much dominance by state actors, an institutional upgrading could be sought: either (1) by means of a strong political mandate from a group of vanguard states or even the entire community of states (e.g. via the General Assembly) to develop an action-guiding roadmap to strengthen the landscape perspective in national and international decision-making forums; or (2) by means of an official and financed mandate to develop an inclusive – i.e. co-created in this case on the basis of scientific and stakeholder-based expertise – status report on the contribution of the landscape approach to the achievement of the SDGs and other sustainability goals (Section 4.4.2).
- *Structural strengthening of 'glocal' cooperation in the UN system*: In addition to these two initiatives, there are also many starting points within the UN system for reforms to promote networked 'glocal' formats, which could be advocated by the German Federal Government and the EU. One conceivable option, for example, would be a 'UN Committee of Regions and Local Actors' attached to ECOSOC, analogous to the European Committee of the Regions, the EU's assembly of regional and local representatives. Within the framework of the EU, this body ensures that sub-national bodies such as cities, municipalities, regions or provinces, each with their own interests and identities, can also help to shape EU policy. Here, too, the aim of a corresponding UN committee would be to raise the cross-cutting perspective of regional interests and rural development into the negotiating forums of international politics. As a link between sub-national bodies and global, intergovernmental institutions, cooperation dividends can also be gen-

erated here by improving the application of the subsidiarity principle. In principle, the UN system also offers the possibility of strengthening the overall visibility and integration of the nine official UN Major Stakeholder Groups, each of which represents key (civil) societal groups (Farmers, Women, Non-Governmental Organizations, Local Authorities, the Scientific and Technological Community, Children and Youth, Workers and Trade Unions, Business and Industry and Indigenous People and their Communities). And the UN Safeguards for Local Action and Sustainable Land-Use Change proposed in Section 4.4.1.2 could also be used to structurally secure local perspectives and needs in the UN system.

4.4.4 Recommendations for action

In line with the examples of starting points for the further development of the international governance architecture elaborated in more detail in Sections 4.4.1.2, 4.4.2 and 4.4.3, the WBGU has formulated the following recommendations.

Convene a Global Land Summit

A Global Land Summit should be convened for 2025 as a joint conference of the Parties to all three Rio Conventions (Section 4.4.1.2). At the Global Land Summit, all issues relating to potential synergies in land stewardship should be jointly negotiated and then adopted by consensus for the respective conventions with the same wording, but formally separate. This would make it possible to generate a lot of attention and resources on a single occasion in order to manoeuvre the conventions towards a joint path. Outcomes of this summit might include:

- *Upgrading the Joint Liaison Group of the Rio Conventions and agreeing memoranda of understanding between the Conventions:* In the context of the Global Land Summit or independently of it, the work of the JLG should be upgraded with more personnel and funding, making it possible to establish permanent working groups. Memoranda of understanding should regulate common objectives and procedures not only for the convention secretariats, as is currently the case, but also for the COP bureaus and other organs of the Conventions.
- *Improving the mainstreaming of projects and programmes:* Joint standards for safeguards should be developed for mainstreaming instruments, and uniform requirements for environmental impact assessments of projects and programmes should be promoted. In particular, the inclusion of indirect land-use change is necessary and challenging here.

Using the CBD's post-2020 framework for more powerful mechanisms

The CBD's new strategic framework should be used not only to further develop compliance, but also to look at multiple benefits between different conventions. In the field of biodiversity and climate protection, the CBD's possible contribution to climate-change mitigation and adaptation should be realistic and formulated in a methodologically sound manner so as not to overburden the terrestrial ecosystems. At the same time, it should be recognized that successes in implementing the CBD are also contributions to climate-change mitigation and sustainable land stewardship.

Introducing two binding protocols on the conservation and sustainable use of biodiversity

The WBGU recommends the German Federal Government to work within the CBD to negotiate 'twin protocols' on the CBD's first two goals (the conservation and sustainable use of biodiversity): a Protocol on the Sustainable Use of Biological Diversity and a Protocol on the Protection and Conservation of Biodiversity, which would establish closely interlinked agreements on the conservation and sustainable use of biodiversity in the sense of synergistic multiple benefits. First, against the background of an integrated landscape approach, this should lead to a bundling and consolidation of the diverse decisions on these issues; second, it should contribute to institutional further development in view of the overarching SDGs; and third, it should secure a higher degree of commitment. This recommendation is highly ambitious in view of the foreseeably long duration of the negotiations and the substantive challenges involved. In terms of content, these protocols can build on multiple decisions and activities of the CBD: for the Protocol on Biodiversity Conservation on the Programme of Work on Protected Areas and the Aichi targets and criteria; for the Protocol on the Sustainable Use of Biodiversity, on the Addis Ababa Principles and Guidelines and the Forest Principles of the UNCED Conference.

Other recommendations for action for individual Rio Conventions from the analyses in Chapter 3

The comments on multiple-benefit strategies in various thematic areas have shown that there is also a need within the Conventions to assume responsibility for land ecosystems as global and local commons. Within the various multiple-benefit strategies, recommendations for action by the individual Rio Conventions have already been addressed in isolated cases, and are referred to again here (Sections 3.1.4.1, 3.2.5).

Section 3.1.4.1 demonstrated that, for all activities under the Paris Agreement, climate-policy targets, schedules and crediting structures for removing CO_2 from the atmosphere should be kept clearly separate from those aimed at avoiding CO_2 emissions (McLaren et al., 2019; Jeffery et al., 2020). Parties to the Paris Agreement should also follow this separation principle in their nationally determined contributions (NDCs). In the longer term, a separate international market for CO_2 removal as outlined in Article 6 of the PA would also be conceivable.

According to Section 3.2.5, the idea of synergies between conservation and use in protected-area systems should be introduced with greater emphasis into the processes of the CBD and other multilateral actors. More life should be breathed into the collaborations between the CBD and the 2001 International Treaty on Plant Genetic Resources for Food and Agriculture, as well as those between the CBD and FAO; the use of synergies and possible contributions of the global protected-area system to sustainable agriculture and the conservation of plant genetic resources should also be more clearly addressed. The guidelines on integrating protected areas into the landscape (CBD, 2018d) should be supported and further developed. In the CBD's post-2020 framework, the expansion and management of protected-area systems should be designed in such a way that biodiversity loss is prevented as effectively as possible, inter alia by placing greater emphasis on quality in the sense of the Aichi criteria. Ambitious, results-oriented targets should be agreed for all criteria that are measurable and can thus be implemented by means of SMART indicators. This should include an additional indicator aimed at determining whether the global protected-area system has the necessary (management and financial) resources at its disposal to achieve the set targets.

Combine responsibility architecture ‚glocally‘

In order to effectively address global environmental changes, local, rural and indigenous positions should not only be given a higher profile in international forums in certain situations; the role of their representatives as knowledge carriers, transformation actors and locally affected people should also be consistently strengthened and better integrated. To this end, among other things, the creation of their own network initiatives (e.g. along the lines of city networks such as C40) should be encouraged and supported, and the Global Landscapes Forum and its mandate further developed.

4.4.5 Research recommendations

Further develop scientific assessments on sustainable land stewardship

In view of the systemic relationship to the climate, biodiversity and food crises, the current state of scientific knowledge on global land stewardship should be determined by pooling knowledge from around the world and identifying the prerequisites for the success of a sustainable land-use transformation. To this end, on the one hand the synthesis potential of existing global reports should be used cooperatively for an overarching assessment (above all the IPBES, the IPCC, the SPI of the UNCCD, the GLO, the EAT-Lancet), and options for a separate mandate should be examined. On the other hand, local solutions and process knowledge for implementation at the landscape level should also be examined scientifically and processed in a globally coordinated assessment.

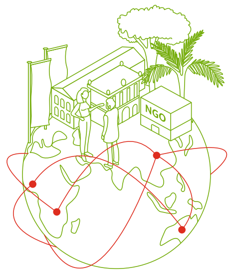
Identify options for ‚glocalizing‘ global sustainability policies

Being affected promotes involvement, which is why the diversity of actors in global sustainability policy is constantly growing – without institutional or procedural innovations taking account of this increased demand. A need for research arises here: Which mechanisms use and promote the polycentric character of global sustainability policy? How can multi-actor partnerships build both organizational and institutional bridges between increasingly networked policy levels, sectors and different spatial scales? Finally, how can local, decidedly rural and indigenous positions be (better) integrated into what are often primarily intergovernmental policy processes?

Develop regional transformation hubs for researching and testing an integrative land-use transformation in practice

The valuable approach of regional research and competence centres (e.g. BMBF, 2018) should be expanded in order to research and, with a practical orientation, test regional approaches to sustainable land stewardship in the systemic context of the crises of climate, biodiversity and food as transformative challenges (e.g. with reference to the multiple-benefits strategies, Section 3.3.4.2). The close networking of several such centres and their research findings generates valuable transfer knowledge for a global land-use transformation.

4.5 Three new multilateral cooperation alliances for promoting a global land-use transformation



The WBGU is convinced that – over and above existing international cooperation and coordination, which needs to be intensified – institutions need to be strengthened and overarching governance mechanisms developed in order to implement the guiding principles for sustainable land stewardship (Chapter 2). In order to develop a coherent, overarching and systemic form of governance that addresses the trilemma in an integrative manner and at the global level, the WBGU proposes a new governance mechanism: the establishment of multilateral cooperation alliances. They could (1) implement integrated landscape approaches across national borders as alliances of sub-national regions, (2) advocate a global land-use transformation as supranational alliances of globally networked states, or (3) protect valuable ecosystems as global conservation alliances in multi-stakeholder partnerships. All three types of cooperation alliance would make sustainable land stewardship their common task and promote an integrative landscape approach. Following the example of so-called 'club solutions', which have been suggested especially in climate-policy discussions in recent years, (Nordhaus, 2015), pioneer countries could lead the way and successively expand the circle of participating states and shared policies. Based on the vision of globally networked sustainable landscapes, a coherent and overarching form of systemic governance for land as global commons can be developed step by step, thus contributing to gradually overcoming the trilemma of land use outlined above (Section 2.2). All three alliances could help overcome existing national and international blockades, or at least provide incentives for overcoming them. Internally, the necessary transformative change can be vigorously supported by promoting corresponding pioneering activities (Section 4.1) and by the countries involved setting favourable framework conditions (Section 4.2). Mutual advantages can be generated in the joint network, and these can also trigger positive consequences and imitation effects in the current international network of states and in the existing institutional landscape. Such new, state-sponsored initiatives for sustainable land stewardship can set an example and lead to global awareness-raising and civil-society support for the protection of land and its functions.

The WBGU recommends the establishment and context-specific advancement of three categories of such cooperation alliances (Fig. 4.5-1), which are outlined below and subsequently presented in detail.

1. *Regional alliances for the cross-border implementation of integrated landscape approaches:* These alliances link sub-state regions which, as neighbours in a geographically coherent area, test and implement sustainable land stewardship in an integrative way across borders. In their internal relationship, the participating regions – usually supported by the respective higher level (federal state/province or nation state) – strengthen the landscape-specific implementation of multiple-use strategies (from cross-border protected areas to joint ecosystem-restoration projects to the regional cascade use of locally produced biomass), make a regionally integrated circular economy possible, and promote trade within the alliance in goods produced under sustainable land-use conditions. Externally, in close cooperation with the state level, they advocate a common trade policy oriented towards sustainability principles. Such regional alliances, which also draw economic benefits for their member regions from increasing integration, can build on historically evolved landscapes (e.g. Alpine countries), breathe new life into weak groupings (e.g. Mediterranean region) or generate fresh inspiration for regional integration (e.g. sub-Saharan Africa).
2. *Supranational alliances for a global land-use transformation:* Member states of these alliances do not necessarily share a contiguous territory; they can also be spread over different regions of the world. They jointly and forcefully represent a sustainability-oriented approach to land stewardship, as well as corresponding values and regulations. This kind of alliance is also focused on the conservation of global commons (climate, biodiversity, soils) and can achieve tangible joint benefits for its members across global regions through increasing integration. In this context, alliances between industrialized and developing countries and emerging economies can reciprocally strengthen the internalization of ecosystem services worldwide, e.g. by organizing intra-alliance trade accordingly, by direct financial support or by supranational law. Supranational alliances are created by pioneer states, but much of their attraction comes from the fundamental reciprocity of their policies.
3. *Global conservation alliances for ecologically valuable landscapes:* These are alliances of states and other stakeholders that join forces with the aim of preserving and restoring valuable ecosystems in third countries – which should also become

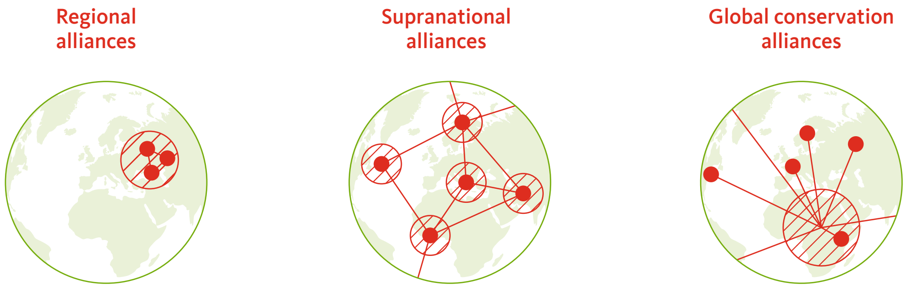


Figure 4.5-1
New cooperation alliances. Regional and supranational alliances, global conservation alliances.
Source: WBGU, graphics: Ellery Studio

members of the conservation alliance. The aim is to prevent ecosystem tipping points from being exceeded. Such conservation alliances are thus directly geared towards conserving global commons, particularly towards protecting and restoring important ecosystems and their services for the global community, e.g. landscape areas with valuable biodiversity or special sink functions. A conservation alliance can, for example, lease such areas jointly, thus stepping out of the often passive role of mere 'donor countries' and assuming joint responsibility together with other local stakeholders. Such a global responsibility initiative for a new togetherness can help overcome national blockades, but it should constitutively involve local stakeholders in integrated and empowering development concepts.

All three alliances should be open to new members and, if possible, be supported by a progressively growing group of regions and states. All three alliances should involve not only state actors but also other groups, e.g. NGOs and local groups, by endowing them with rights (e.g. partial local self-governance, consultation rights, legal protection) and obligations (e.g. participation or reporting obligations). In this way, adaptive and long-term-resilient solutions can be found for sustainable land stewardship by means of mutual exchange between the different stakeholders concerned (multi-stakeholder partnerships: SDG 17.16 and 17.17). Such involvement of non-state stakeholders also forms the backbone of a functioning integrated landscape approach. Only in this way can the interests of protection and use be reconciled, claims mutually recognized, and compromises and added values developed in practice and in a spirit of full equality (Box 2.3-3).

The three conceptually outlined types of cooperation alliances differ in terms of their geographical size, institutional structure and precise purpose, but they are not mutually exclusive. On the contrary, multiple-benefit strategies successfully tested in a regional alliance can, for example, also inspire and strengthen strategies within a conservation alliance. The institutional spectrum ranges from cross-border funding programmes (like Interreg Europe), to loose, informal multilateral alliances (e.g. similar to the G20), and to highly integrated alliances that, with a supranational structure, also transfer individual sovereign rights to a supranational institution (comparable to the European Coal and Steel Community, ECSC and the later EU). Although the strong leadership role and accountability of state actors is of great importance, the overarching vision is always the creation of strong multi-stakeholder partnerships (SDG 17) in which stakeholders from politics, civil society, business and academia contribute to sustainable development on an equal footing and in close association with local stakeholders, as well as incorporating specific landscape conditions.

In the following, the three cooperation alliances are described in practical terms, so that they can be taken up for implementation e.g. by the German Federal Government or the EU.

4.5.1 Regional alliances for the cross-border implementation of integrated landscape approaches

Landscape areas, i.e. areas in which certain common ecosystem and socio-technical conditions prevail ('structural regions'), are rarely located within a single national territory. Rather, prominent geographical landscapes such as river courses (e.g. the Nile), mountain ranges (e.g. the Alps), deserts (e.g. the Sahel) and maritime regions (e.g. the Mediterranean) have frequently been and still are the source of both inter-state conflicts and special cross-border cooperation efforts. Existing regional landscape conventions such as the Alpine or Carpathian Conventions, or intergovernmental collaborations such as the Danube River Protection Convention, can be a point of reference and incubator for these more ambitious cross-border regional alliances. Furthermore, the Interreg Europe programme, supported by the European Regional Development Fund, promotes cross-border, transnational and interregional cooperation not only at the national level but also with regional and local partners.

For the WBGU, sustainable land stewardship is an important motivation for developing new forms of regional cooperation among sub-state actors as well as for intensifying and renewing existing regional alliances. The purpose of regional alliances is to exploit the advantages of geographical proximity and of ecosystems that are shared by the participating regions in order to try out and consolidate sustainable land stewardship by means of integrated, cross-border cooperation in each region's socio-geographical landscape area. Also with a view to the need to adapt to climate change, there is a shared interest in conserving and improving local ecosystem services in landscape areas and making them more resilient. Sustainable agriculture, ecosystem-restoration projects, cyclical production and value creation, regional trade, joint regulation and the reciprocal assumption of responsibility can be implemented to advantage in a cross-border network. The initiative for regional alliances should come from and be endorsed by the respective regions themselves, but it can also be motivated and promoted by states – not least because, from the point of view of international law, initiating a regional alliance usually requires the support of the respective national governments. Implementation is essentially about developing and applying multi-benefit strategies (Chapter 3) not only in isolated cases within narrowly defined landscape areas or simply within national borders, but by exploiting joint synergies across borders. Thus, multi-benefit strategies – such as ecosystem restoration (Section 3.1), effective protected-area systems (Section 3.2), the diversification of agriculture (Section 3.3), changed dietary habits (Section 3.4) and timber-based construction within the framework of a responsibly designed cyclical bioeconomy (Section 3.5) – do not stop artificially at borders, but can be effectively put into practice across borders in line with the social and natural circumstances. Partnership-based planning within a regional network is a core instrument in this context, as it enables goal-oriented interaction between the respective given social and natural context and conditions. The conditions for the success of – and blockades affecting – a form of sustainability transformation designed in this way should be researched in parallel.

Setting up regional alliances

The basis for the cross-border regional alliances is a joint binding commitment by neighbouring regions to promote fully sustainable land stewardship within the alliance. Therefore, the promotion of sustainable products, production conditions and services in regional economic and resource cycles should be the core mission for the members of such an alliance. If there is strong support for the regional network by the national governments concerned, free internal trade and common sustainability standards for imports and exports that go beyond existing rules in world trade law can provide further incentives for cooperation.

In order to realize the medium- and long-term advantages of multiple-benefit strategies, the members in the transformation region should implement different instruments and initiatives that make a sustainable land-use transformation possible. These include the promotion of and a special role for innovative niche activities (Section 4.1), the creation of overarching incentives and framework conditions for transformative change by the sovereign authorities involved (Sections 4.2, 4.3), and support for coordination and cooperation on sustainable land stewardship in the context of international policy (Section 4.4). The cross-border transformation areas thus make it possible to establish large-scale real-world laboratories for effectively testing and implementing multiple-benefit strategies and conducive framework conditions in a regional network using a common set of instruments.

In addition, regional alliances offer an opportunity to pursue the following specific approaches:

- *Development of a sustainable circular economy in the regional landscape network:* One condition for the success of the global transformation towards sustainability is a successful change from linear economic activity with largely unchecked use and consumption of natural resources to a circular system of materials use involving a far-reaching decoupling of wealth creation from resource consumption and environmental damage. The transformation regions should therefore actively use and develop the advantages of the respective regional network to establish circular value creation. Considerable opportunities emerge here to effectively stimulate and implement the globally growing number of circular-economy strategies in one regional cooperation area. The advantages of spatial proximity are not only to be found in cycles that regionally integrate agricultural production and dietary patterns or organize re-use and re-purpose strategies among consumers. There are also opportunities for implementing a sustainable circular bioeconomy, for example with regard to the regionally integrated cascade use of biogenic raw materials (Box 3.5-2).

- *Further development of existing biosphere reserves into pioneers of integrative landscape areas:* Often, protection and sustainable use in a contiguous landscape area can only be meaningfully integrated by means of effective protected-area systems. A new way of working together in land stewardship has to prove itself above all where the sometimes contradictory claims for use by ecosystem conservation and land cultivation collide. If the sustainable integration of conservation and use succeeds at such hotspots, this task can also become the norm over wider areas. Biosphere reserves are already important centres for bringing this form of togetherness to life (Stoll-Kleemann and O'Riordan, 2018). The reserves have different zones: the core area and buffer zone are embedded in the transition area, which is already intended to function as an experimental area for model projects – for example for trying out economic and tourist uses "in harmony with nature" (CBD, 2010). Here, too, there are major societal conflicts, since such rules and zones can be perceived individually as a threat or a kind of expropriation. These defensive reflexes need to be actively turned around in the regional network and, building on the existing biosphere reserves, it must be shown that the demand for timber-based construction, the bio-economy, ecological agriculture or tourism, for example, can be reconciled with strong claims for conservation. By joint efforts and by forming strong multi-stakeholder partnerships on the ground, biosphere reserves are predestined to prove that strong conservation goals can be profitably reconciled with sustainable use (Section 3.2).
- *Establishment of regional innovation hubs ('special sustainability zones')*: In regional innovation hubs, the participating national, regional, municipal and non-governmental cooperation partners promote new models, financial incentives and rules to support a more sustainable form of land stewardship under special legal, economic or societal conditions and with the participation of the respective user interests. The establishment of these hubs is coordinated and supported by the entire alliance. In the context of the regional network, a close, cooperative exchange between such zones across different member states makes sense. Following and explicitly reversing the concept of special *economic* zones, the focus in the case of special *sustainability* zones is on the integrative cultivation of land under exceptionally conducive conditions. These can be overarching measures of regulatory, tax or subsidy policy, or just specific framework conditions for the implementation of individual multiple-benefit strategies. In many cases, this kind of cultivation can also contribute in particular to the restoration of areas (Section 3.1.2). A prominent case study that addresses many specific local challenges in the region and creates great multiple benefits is the 'green wall' in the Sahel, a flagship project of the African Union with, in the meantime, over 20 participating states (UNCCD, 2020). However, the core idea of addressing particular challenges with multiple-benefit strategies by making special joint efforts in a regional network can be inspiring in many places: from the many structural-transformation regions in the context of the global energy transformation (WBGU, 2018) to the restoration of more complex ecosystems in the world's major agricultural areas (from Brandenburg to the US Midwest). As real-world laboratories, these special areas should on the one hand be actively supported by intensive research cooperation; on the other hand, they should themselves be the object of comprehensive research (recommendations based on BMBF competence centres can be found in Section 3.3.4.2). By stimulating a wide range of pioneering activities, these areas themselves benefit; but the transformation experience they make also promotes change processes in the rest of the regional alliance and beyond.

Proving that multi-benefit strategies and an integrated landscape approach can be implemented cooperatively in a regional network involving local decision-makers and stakeholder alliances is key to successfully initiating and implementing a global land-use transformation. In addition, beyond regional alliances, there is also a need for worldwide, intergovernmental cooperation: this need can be met by the idea of a supranational alliance.

4.5.2
Supranational alliances for a global land-use transformation

Successively overcoming the land-use trilemma is of global importance: to mitigate climate change, to secure high-quality food supplies, to conserve local and global biodiversity, and to protect and restore soils worldwide (Chapter 2). Countries that recognize the need for such a global land-use transformation towards sustainable forms of protection and use, and wish to jointly promote them, should join forces and adopt shared, supranational organization forms (e.g. joint authorities) and rules for this purpose. The WBGU recommends this new type of inter- and supranational alliances in particular for the reciprocal implementation of a global land-use transformation. Politically and financially initiated by a small number of pioneer states, such alliances are intended to develop global appeal, grow in membership and successively implement sustainable land-stewardship practices.

Creation of supranational alliances

Such an alliance will ideally be made up of member states from different regions of the world, but it can also grow initially out of existing purely regional networks of states. The most prominent example of such classical, regionally oriented integration at the state level today is the EU, but examples of this kind of economically and politically motivated regional integration efforts exist in every region of the world (e.g. the South African Development Community SADC, the Andean Community and the Association of Southeast Asian Nations ASEAN), from which new globally networked alliances can emerge. In addition, existing coalitions, initiatives, action programmes and landscape-related agreements offer starting points and important nuclei for the development of such supranational alliances. For example, various alliances of committed states already exist in the context of the Global Partnership on Forest and Landscape Restoration, whose commitment could be bundled in a supranational alliance to form strong and binding policies for even more ambitious restoration projects.

The decisive added value compared to the status quo lies in the institutional and legal design of the supranational alliance. In principle, it is also possible – like the existing alliances – as a loose club of states. However, it unfolds its full effectiveness and impact – also by contrast to regional alliances and global conservation alliances – through the transfer of individual sovereign rights to a jointly established high-level administrative body (supranationality), as was set up in the EU and its predecessor alliances (Box 4.5-1). Supranational organization generates an internal commitment via shared laws, even across continents. This can provide a strong, state-supported institutional framework for long-term multi-stakeholder partnerships of state and non-state actors at the landscape level, both within and between the member states of this alliance. In order to increase the political and economic strength of the alliance from the outset, Germany should work to ensure that the EU as a whole promotes the establishment of such alliances for sustainable land stewardship on a global scale. Otherwise, Germany also could only initiate such an international alliance in cooperation with other willing European partners. In any case, the Global Land Summit to be convened in 2025 (Section 4.4.1) would be an appropriate stage for setting up such alliances.

By contrast to the proposal of a climate-policy club like that made by Nordhaus (2015), such an alliance of states does not focus solely on an integrated climate policy in its internal relations. Rather, it pursues common policies aimed at converging standards of land stewardship within the alliance. This task is far more complex than, for example, the introduction of a CO_2 price, as sustainable land stewardship must also take local and landscape aspects into account in an appropriate manner and be implemented individually. Creating inclusive and adaptive regulations for resilient landscapes should evolve as a standard model within these alliances; unsustainable land stewardship should be the exception.

Common standards should be set for sustainable land stewardship within the alliances (Section 4.2.2). Common, high sustainability standards above all for the sustainable production of and trade in agricultural products (e.g. fodder and foodstuffs; Sections 3.3, 3.4) can generate particular added value in a global network of developing countries, emerging economies and industrialized countries. Sustainable bioeconomy strategies can also be expected to yield sustainability-promoting returns on cooperation in the globally networked alliance of states through improved resource limitation, recirculation and cascade use (Section 3.5). The comparable design of these regulations would make it possible to dispense with restrictions on internal trade and avoid distortions of competition within the alliance. Free trade in sustainable products within the alliance would also make it possible to continue exploiting specialization advantages that persist even after the internalization of environmental scarcities and the adjustment of prices – or new advantages that may emerge in the course of this process. States that do not initially belong to the alliance would also have an economic incentive to join it because of the facilitated exchange of goods with and within the alliance.

The member states can also create uniform framework conditions to implement an integrated landscape approach in their sub-state regions and to productively network transnationally as knowledge networks. In doing so, they can create instruments at the alliance level to set up ambitious protected-area systems (wherever individual member states are located together regionally, also across borders) and to jointly promote and responsibly use biodiversity. They can also drive change towards sustainable food systems.

The following section gives some examples of relevant governance elements corresponding to the special structure and character of such alliances:

- *Pioneer alliances for sustainable global agricultural trade:* Reforms in global agricultural trade are a key lever for sustainable land stewardship (Section 4.2.5.2). A separate free-trade agreement between the states of the alliance can be implemented more simply

Box 4.5-1

Supranationality as an important driver: the example of the European Coal and Steel Community

To prevent further wars and create long-term peace, the governments of France, Germany, Italy, the Netherlands, Belgium and Luxembourg agreed to merge their coal and steel production in 1950. In the proclamation of 9 May proposing the founding of the European Coal and Steel Community (ECSC, 1952-2002), also known as the Schuman Declaration, former French Prime Minister and Foreign Minister Robert Schuman wrote: "World peace cannot be safeguarded without the making of creative efforts proportionate to the dangers which threaten it" (EU Commission, 2015a). The ECSC set up a supranational administration designed to enforce in the member states the production, trade and economic conditions (for coal and steel) that had been harmonized by the founding states, thus ensuring peace without encroaching on the territorial powers of the founding states.

In view of the current threats to the natural life-support systems, an effort similar to that made when the ECSC was founded is needed today.

A strong and ambitious core of founding states would also be conducive to the establishment of such supranational alliances. A more diverse community of states could form over time around such a nucleus of states with similar interests, as was the case with the ECSC. The founding states would form a stable coalition, set themselves ambitious goals, and establish binding rules for sustainable land stewardship. Internally, these goals and standards can be enforced by a common 'high' authority, which also forms the institutional framework of the alliance.

thanks to uniform standards for sustainable agricultural production; it can also lower barriers, e.g. customs duties, on trade in goods produced in a correspondingly sustainable manner. Furthermore, barriers such as border-adjustment taxes (Section 4.2.5.2) could be set up to hinder imports of non-sustainable agricultural goods from third countries into the alliance. In order to maintain compatibility with WTO law, these import standards should essentially aim only at alignment with the standards applicable to domestic producers and trading partners. A relevant example of a trade-policy initiative focusing on sustainability is currently being negotiated between New Zealand, Fiji, Costa Rica, Norway and Iceland. The planned Agreement on Climate Change, Trade and Sustainability (ACCTS) could bring decisive momentum into the process of further developing the trade regime (Zengerling, 2020:14). The ACCTS can represent a concrete starting point for the establishment of such an alliance in the WBGU's sense. In the alliance, however, in addition to the issue of trade, domestic policy-making would also play a crucial role.

- *Jointly implementing transparent and sustainable supply chains:* Sustainable production, transport and consumption conditions are of global relevance – not least because of the often global interdependencies and the material and commodity cycles. Especially the protection, consumption and sensible recycling of biomass are very relevant points of reference here. Legal requirements for sustainable supply chains are therefore not only a topic of discussion in Germany. A supply-chain law has already been introduced in France, for example. There are initiatives in various stages in numerous other states (including Germany), and a draft by the European Commission has also been announced at the EU level for 2021. An alliance is predestined to use its global supranational character as a sustainability advantage and to set common regulations for global supply chains that can form a global standard. Great opportunities lie especially in the binding integration of developing countries and emerging economies with industrialized countries (e.g. animal feed, wood, textile industry, etc.).
- *Driving a Green Deal forward globally:* For a long time there has been a call to initiate the necessary transformative change and to disseminate the ecological transformation of the industrial society by means of committed sustainability policies and correspondingly comprehensive investment programmes. In the EU, the European Green Deal proclaims an ambitious reform programme for European economic and environmental policy (Section 4.3). The core element is a European climate law that would commit the EU to reducing net emissions to zero by 2050. This momentum should be quickly seized upon and a similarly oriented Green Deal implemented by the commitment of the cross-continental alliance both within and beyond its own confederation of states.

The contributions to be raised to finance the alliance's tasks can be used for innovative research formats and special transformation laboratories in order to test and carry out – as in the model regions – the implementation of integrated landscape approaches under globally different conditions. The funds raised could also be used for activities outside the confederation of states in the spirit of a global conservation alliance. The development of international lease initiatives, such as those specified in the following Section 4.5.3, can be a powerful instrument in this context.

4.5.3
Global conservation alliances for ecologically valuable landscapes

Certain large-scale components of the biosphere – such as tropical rainforests – are, first, of particular importance for the function and stability of the Earth system and, second, vulnerable to relatively small changes in their growth conditions (e.g. temperature, precipitation) and structural parameters (e.g. connectivity). They have therefore been classified as tipping elements in the global environment (Lenton et al., 2019). Boreal coniferous forests and almost all coral reefs worldwide are also threatened by disruptive changes caused by anthropogenic climate change. Important drivers of environmental crises in general, and of land degradation in particular, can be attributed to the high demand for resources by industrialized countries and emerging economies (Section 2.1.2). The joint, cooperative conservation of these particularly valuable ecosystems from largely irreversible destruction is therefore a matter of urgency, but it is also a particular challenge (Drenckhahn et al., 2020:18).

Against this background, the WBGU proposes setting up global conservation alliances in which states – supported where appropriate by financially strong private actors – join forces to protect and restore such ecosystems of global importance. In the WBGU's view, a conservation alliance should assume responsibility for the protection or restoration of these ecosystems not only in terms of (project-related and time-limited) financing, but also by assuming proactive, creative responsibility for large areas and landscapes with valuable ecosystems in order to preserve their biological diversity and ecosystem services for the global community. In particular, the aim should be to ensure the urgently needed permanent basic funding for conservation and restoration areas (Drenckhahn et al., 2020:17) as well as the active involvement of local stakeholders (e.g. local decision-makers, resident farmers, indigenous peoples and nature conservationists) in order to implement ecosystem conservation on the ground in an integrative and context-related manner. Precisely because of their global importance, these ecosystems bear the characteristics of global commons whose conservation requires and deserves global cooperation (Buchholz and Sandler, 2020). Not only does the global, long-term value of these ecosystems exceed the short-term value of their destruction for local people; seen geographically, the capacity and the (historical) responsibility for the protection or the sustainable restoration and use of ecosystems also lie with the industrialized countries, whose resource-intensive production methods and lifestyles are at least partly responsible for the degradation of valuable ecosystems. By contrast, the ecosystems themselves are often located in countries which, due to economic (development) constraints, have little chance of providing for ecosystem conservation and, overall, bear far less responsibility for climate change and ecosystem degradation. To some extent, however, institutional deficits in these countries also stand in the way of effective ecosystem protection.

In line with the above-mentioned challenges of protecting these globally valuable ecosystems, a global conservation alliance should be underpinned by a broad concept of reciprocity. For example, the motivation of the industrialized countries and emerging economies in the alliance should be based on the understanding that (1) they share responsibility for the destruction of – or threats to – ecosystems that are relevant to the Earth system, and (2) the well-being of the population in their own national territory also depends on the long-term protection of these areas. They therefore act out of a duty of care for their own population and not as 'selfless givers'. In this sense, support for a global conservation alliance should not be seen as an alternative to their own decarbonization and conservation efforts but rather as complementary to them. Conversely, the states on whose territory the valuable ecosystems and available land are located can consider it part of their common but differentiated responsibility and capability within the meaning of Article 3 of the UNFCCC to contribute to the stabilization of the global Earth system by making terrestrial ecosystems and land suitable for restoration projects available within the framework of such initiatives.

Initiatives and funds that strengthen partnerships to conserve important ecosystems already exist and have existed in the past, e.g. the REDD+ climate-change-mitigation programme (Box 3.1-6), the failed Yasuní/ITT initiative (Box 4.5-2), or the BMZ's Legacy Landscapes Fund (BMZ, 2019). So far, these approaches have not been successful enough. This conclusion can be attributed, for example, to the observation that land-based climate change approaches, with only 3% of climate-change funding, are currently underfunded (CIFOR, 2018). New types of initiatives for the protection of globally valuable ecosystems are therefore needed precisely in order to prevent ecosystem tipping points from being reached.

The form in which protection and cooperation are implemented with the local policy-makers, businesspeople and population is not constitutive for a conservation alliance. The local conditions and the respective resources of both sides are decisive here. In principle, the activities of conservation alliances should meet the requirements of scalability, speed, and long-term

Box 4.5-2

Yasuní-Ishpingo-Tamboccha-Tiputini initiative

The Yasuní-Ishpingo-Tamboccha-Tiputini (ITT) initiative, announced by the government of Ecuador in 2007, can be considered a failed milestone in taking responsibility for the Ecuadorian rainforest and the world's climate. There were four main elements to the initiative (Sovacool and Scarpaci, 2016): (1) The extensive oil reserves (approx. 900 million barrels) in the Ishpingo Tambococha Tiputini (ITT) oil field within the Yasuní National Park were to remain entirely in the ground. This would also have prevented the deforestation of the rainforest growing within the park. (2) In return, Ecuador would have been partially compensated through international payments for not exploiting these oil reserves. (3) A fund, the Yasuní-ITT Trust Fund, was set up to pay for environment-protection measures, reforestation projects, energy-efficiency projects, social programmes, and research and innovation. (4) In addition, the Fund would have helped finance structural economic change through projects promoting renewable energy in order to increase Ecuador's independence from the extraction and sale of fossil resources. A treaty based on international law between donor countries and Ecuador was envisaged as the legal basis.

Originally, the payers (states, companies, but also private donors) were to acquire concrete property rights to the oil reserves, through which oil production could have been directly controlled. By contrast, as of 2008, the issuing of Yasuní Guarantee Certificates was envisaged as a *quid pro quo* for the financial assistance. These certificates were to be internationally tradable and would entitle the certificate holder to claim compensation from the Ecuadorian government if the latter were to exploit the oil reserves after all. The Yasuní ITT Trust Fund was set up in 2010 to manage revenues from donations and certificate sales; it was to be supervised by UNDP's Multi-Partner Trust Fund Office and managed by a committee of Ecuadorian government representatives, donor countries, and representatives of UNDP and civil society (Sovacool and Scarpaci, 2016). In financial terms, the proposal provided for total compensation of US$3.6 billion. This was to be disbursed by the international community to Ecuador over a period of 13 years in annual payments, starting in 2011 with US$100 million. Norway in particular (and for a while also Germany) showed great interest in the initiative, aware of the dilemma between urgently needed climate-change mitigation and environmental protection on the one hand and further resource extraction to secure trade interests on the other.

The initiative failed for several reasons. A major barrier proved to be concern on the part of potential donor countries (such as Germany) that supporting this initiative could set a precedent through which comparable claims might be made by other states with extensive fossil resource deposits for financial compensation for impending significant losses in the value of these resources in the course of climate-policy negotiations and the implementation of the Paris Agreement (financial compensation, 'stranded assets'). In addition to considerable domestic political pressure in Ecuador, the country's limited credibility in the field of climate policy also played a role, since parallel projects to further develop oil production, in some cases in the immediate vicinity of the Yasuní conservation area, would have been pursued and continued even if the initiative had been successfully implemented (Sovacool and Scarpaci, 2016). Nevertheless, the Yasuní ITT initiative can be seen as an important model for urgently needed stay-in-the-ground projects, especially in developing countries that see the extraction of these resources as one – or even the only – possibility for economic development.

horizons. Existing initiatives and approaches are often smaller-scale and have a shorter time horizon (e.g. project-based funding) or are slow in terms of implementation (REDD+).

Lease initiatives as a core tool of the conservation alliance

In view of the challenges involved in the protection of globally valuable ecosystems described above, the WBGU encourages considering lease initiatives as a new concept to generating fresh impetus in this way. Within the framework of such a lease, both sides – i.e. the lessee conservation alliance and the lessor states – assume joint and active responsibility for the protection of valuable ecosystems in a way that, in the WBGU's view, promises to meet the requirement of global cooperation described at the outset and the differing respective responsibilities and opportunities of both sides in the protection of valuable global commons. The aim of the lease is to place the leased areas under special protection, promote the regeneration of degraded areas, and protect and strengthen sustainable use and property rights for local and indigenous population groups, as inclusively and with as much participation as possible.

Using the form of a lease, the distribution of rights to (help) shape and monitor land use locally would differ from familiar instruments such as international compensation or subsidy payments in the sense of Payments for Ecosystem Services (PES, Box 4.2-1; Box 4.5-3). Even if the distribution of rights has to be defined in more detail in the necessary lease agreements, in the case of a lease the conservation alliance is given a much more active role in co-designing and implementing ecosystem conservation than in exclusively financial approaches; this is combined with a responsibility for the success of the initiative that goes beyond the financial dimension. For the lessors (states or private actors), the distribution of rights in the course of leasing can mean recognizing co-determination rights or even accepting restrictions on concrete (sovereign) rights (Box 4.5-3), but it can also offer greater and more long-term (financial) security and development prospects through the more active involvement of the lessee alliance.

The constitutive elements of a lease initiative must always include the maximum possible active involvement of local and indigenous actors and their knowledge, as well as an assurance of local, subnational and, where possible, national co-determination rights. A lease initiative aims to lead to inclusive working together and to establish long-term stable multi-stakeholder partnerships to prevent the emergence of 'neo-colonialist' lease initiatives or initiatives being perceived as such. Where possible, lessons should be learned in this context from the experience gained with REDD+ and the Yasuní initiative.

Such influence on territories that are usually located in developing countries and emerging economies must always be exercised with the greatest sensitivity to history (especially colonialism and imperialism) and be accompanied by an acceptance of responsibility on the part of the drivers of ecosystem destruction (e.g. glocal production, demand and trade patterns; Sections 3.3-3.5, 4.2, 4.3). Clear mechanisms should ensure that the lease system is not abused as a form of 'land grabbing' with all the related conflicts (Box 3.3-4). In view of the socio-economic consequences of land grabbing, the purchase or lease of land in other states is already regarded in critical literature as a form of neo-colonialism: "Huge areas of the world are being taken over by foreign powers, but they are no longer using military force – they are waving chequebooks, which in today's world can be an even more powerful weapon" (Branford, 2011:81). As a lease initiative involves a limited restriction of state sovereignty, structuring it might impinge on an extremely sensitive area of the respective state – sensitive because state sovereignty is central and intrinsic. It is therefore highly relevant how the proposal is received by those states and inhabitants who are to lease out parts of their territory, i.e. what associations it would arouse. In this context, control over the structuring of the instrument by the country receiving the money (country ownership) is an important concept that is familiar from the work of the Green Climate Fund. This can be taken into account from the outset by actively involving the recipient countries and local actors as contracting parties themselves or as important stakeholders in shaping the rights and obligations in the lease contracts. However, the power imbalance between the contracting parties, which is based on differences in financial and economic strength as well as political influence, cannot be completely avoided and should therefore always be limited by means of broad participation formats, at least within the framework of the multi-stakeholder partnership. In exceptional cases where there is a lot of political resistance at the national level, it would also be conceivable to include in the conservation alliance only local and subnational actors from the areas to be protected.

Procedure and possible contract contents of a lease initiative

The first step is identifying a suitable ecosystem with globally valuable ecosystem relevance. Recourse to scientific expertise and globally relevant facts, e.g. from the IPCC and the IPBES, would be an authoritative reference. Potential lessor states could be called upon to make offers, as Ecuador did in the case of the Yasuní-ITT initiative (Box 4.5-2).

Where possible, the leased areas should not be limited to a narrowly defined ecosystem, for example a forest; rather, they should always include adjacent landscapes, i.e. integrate a mixture of ecosystems with valuable ecosystem services, an agricultural landscape and settlements. This makes it possible to carry out an integrated development of the region in line with the integrated landscape approach and to address local drivers of ecosystem degradation more directly. A procedure should be envisaged where an integrated development plan is jointly drawn up to guide the activities of both contracting parties for the area; it should include protection and (re)construction as well as economic options for the livelihood of the population living in the affected and adjacent regions. The procedure should be based on local and regional self-determination within planetary guard rails. Optimum use should be made of existing infrastructures, e.g. created through participation in REDD+. In addition, the rights of local resident groups must be taken into account; they must also be involved – ideally in the sense of local self-government.

In the spirit of a kind of reciprocity that goes beyond financing, the obligations of the lessee alliance should also include the responsibility to combat drivers of land degradation, e.g. imports of fodder and timber that lie within the sphere of influence of the contracting parties themselves, for example through fiscal and trade policy, public procurement and improved standards. To underline the idea of reciprocity, the group of lessee states could give priority to trade in products from the lessor state or from the territory concerned, wherever this is compatible with international trade law (Section 4.2.5.2; Zengerling, 2020).

Periodic monitoring of implementation (e.g. every two years) would document progress and problems. Accordingly, targeted interventions could be made for readjustment, either by adjusting the support measures or by reducing the lease payments. In addition, it also makes sense to regularly adapt the development plan with the involvement of local actors. Dealing with conflicts on the ground or violations of newly established protected areas, for example through illegal slash and burn, is especially challenging. The enforcement of the conservation regime should therefore be regulated in

Box 4.5-3

Legal design options for a lease initiative

From a legal point of view, the structure of a 'lease' raises various questions. Structural options for a lease initiative are therefore outlined in the following.

Lease under international vs. private law and servitude vs. easement

In the most comprehensive form of a lease under international law, the lessor state transfers territorial sovereignty – i.e. the right to perform sovereign acts in a certain territory – to the lessee state. This arrangement is very rarely to be recommended, since responsibility is thus transferred unilaterally to the lessee state and the lessor state relinquishes sovereign rights. It is possible to limit this legal status under international law to individual sovereign powers and rights of use. In this case, it is a servitude. A lease under private law, which is also possible between states if the lessor state has ownership over the land to be leased, is governed by the respective legal system chosen for the arrangement (e.g. the international lease agreement continues to be subject to the legal system of the lessor state applicable in the leased area). In German law, a lease under private law obliges the lessor, for example, to grant the lessee the use of the leased object, including the use of any income (section 581(1) of the BGB). In the case of an easement (section 1018 of the BGB), the agreement only relates to a partial right of use of the property. A prerequisite for private-law leases would be, in particular, clarified land rights. This can be a crucial challenge.

In the case of a servitude or easement, however, it is difficult to determine in the context of sustainable land stewardship what such partial rights should be directed at. Servitudes are agreed in particular for the transfer of fishing rights in foreign territorial waters. The right to fish in foreign territory is transferred. However, this does not yet ensure sustainable implementation. With regard to the protection of ecosystems, the servitude could be directed at the right to decide on the sustainability of cultivation or changes in land use. This limitation would preserve the status quo of land ownership and would only give the lessee state the right to decide on future land-use changes. However, this does not prevent illegal land-use change (e.g. slash-and-burn). A survey of the status quo of land use would also be necessary, ideally via a cadastre, in which ownership rights could also be clarified.

Whether a project is to be handled under international law or private law depends largely on what the contracting parties want. Ownership of the area to be leased is likely to be the decisive factor as to 'whether' a lease initiative comes to fruition: in the case of fragmented (private and state) or unclear ownership, it is hardly reasonable to expect the lessee state to conduct separate negotiations with each stakeholder. In this case, the international-law approach is preferable. However, if there is one private or public owner of a large area of land (e.g. religious communities), the lessor can be clearly identified. Large-scale solutions probably require the involvement of the state with territorial authority, or at least that of regional administrations. If necessary, the consent of the respective parliament must then be obtained. In addition, a combination of international-law and private-law agreements can be examined when it appears to make sense in order to satisfy all interests. For example, it would be conceivable for states to sign a contract on 'whether' a lease can go ahead, thus overcoming any legal hurdles that may exist in the lessor state. The lease of the area itself (the 'how'), could then be governed by private law, would not rely on sovereign rights, and could include private landowners.

the contract, as should legal-protection options for the local population.

Conflict regulations must also be agreed between the contracting parties. A long-term lease contract and the regulation of termination conditions are recommended. In particular, successor governments on both sides would have to be prevented from terminating the agreements without cause. Incentives to prevent this can also be created by structuring the rents. The level of the rent is on principle subject to contractual freedom and depends on the specific areas to be protected. The optimal solution, however, is for payments to be as close as possible to the lessors' opportunity costs, so that the limited financial resources of the lessee alliance can be used as effectively as possible (Box 4.5-4). About €1,000 per km^2 or payments of €4 billion per year are proposed for the core funding of African protected areas by an EU biodiversity alliance (Drenckhahn et al., 2020:17). The transfer of territorial-management rights to the global conservation alliance is likely to require additional payments.

4.5.4 Recommendations for action and research

Existing negotiation forums for a global land-use transformation such as the Rio conventions are indispensable, but they need to be further strengthened, and new forms of cooperation are needed to enable rapid progress to be made. The WBGU therefore recommends the establishment of new cooperation alliances by like-minded states and subnational regions. The Federal Republic of Germany has a special responsibility: together with the EU and other willing pioneer countries, it can play a leading role in such initiatives for a global land-use transformation:

- *Regional alliances for the cross-border implementation of integrated landscape approaches (Section 4.5.1):* Regions should cooperate more closely institutionally as neighbours to make cross-border land uses possible, e.g. by means of multiple-benefit strategies. Regional alliances of sub-national regions can, for example, establish regional circular economies and value chains, further develop existing

Box 4.5-4

Rent and payment structure

In addition to the legal structure, the appropriate design of international payment systems for ecosystem conservation and restoration raises questions: (1) What is the basis for calculating the payments and, accordingly, how high should the payments be? (2) Are payments to be made in advance or subsequently, and are they possibly subject to the implementation of certain agreed criteria for measuring the project's success?

The problem of asymmetric information (principal-agent problem) between donor and recipient regularly plays a key role in deciding on payment mechanisms for ecosystem conservation or certain ecosystem services (Section 4.2.1). In the case of a lease initiative, however, this is already partially addressed by the transfer of the lessee's rights of intervention and co-determination, depending on the form of the lease and the contract. In general, the lease payment and the legal form are subject to the free contracting rights of the lessee and lessor. Due to the heterogeneity of local conditions, only some guidelines can be given here on designing the financial aspects.

In order to make the most effective use of the conservation alliance's limited funding budgets, the payments or the rent should be as close as possible to the lessor's opportunity costs. Opportunity costs reflect economic and other benefits that the lessor could derive from the area in question in the absence of the lease initiative. Lease contracts that do not offset these opportunity costs continually offer incentives for the lessor to terminate the lease and make alternative use of the leased lands.

However, it proves to be problematic that the level of opportunity costs is usually only known to the lessor, making it difficult for third parties to estimate; these costs depend on numerous local factors, especially in questions of land management, and are thus (geographically) very heterogeneous. This applies both in the case of compensation or subsidy payments for more sustainable land use, as in the case of PES approaches (Section 4.2.1), and in the case of a lease initiative. However, in the case of the lease initiative, the transfer of rights of intervention and co-determination raises the question of additional opportunity costs for which separate compensation is expected. Depending on the ownership structures in the area concerned, it is also conceivable that the lessor state, if it cannot derive any direct economic benefit from the area itself, for example, may claim financial compensation solely for the transfer of co-determination rights, while the opportunity costs of more sustainable land use are incurred downstream with the question of implementing land-use changes on the ground and involving local communities. The Yasuní-ITT initiative is an exception with regard to the opportunity costs and the level of payments, since Ecuador demanded compensation only for the oil deposits beneath the national park, and this could be assessed comparatively directly (Box 4.5-2).

The different distribution of management and co-determination rights compared to purely financial compensation or subsidy systems suggests an adjustment in the payment structure, for example compared to the performance-based payments that are characteristic of REDD+; these are not paid out until after the project objectives have been successfully implemented. In the case of a lease initiative, the transfer of intervention and co-determination rights means that less importance is attached to the motive of creating stronger incentives to implement the contractual goals by means of downstream payments that are dependent on agreed success criteria. However, the continuity of lease payments also provides an incentive for the lessor to meet the obligations entered into under the lease so as not to jeopardize future payments.

Another argument in favour of making the lease payment before the actual implementation of the initiative's objectives is that the structuring and co-determination rights are also transferred in advance. Such a change in the payment structure towards upfront financial payments also entails a different distribution of risks and/or responsibility for the implementation of the contractual objectives between the lessee and the lessor, which may well have advantages for the lessor. Unlike in the case of performance-based payments, the lessor does not have to make advance payments and is no longer exposed to risks of force majeure (e.g. storms) in the implementation of the contractual objectives. This gives the lessor state more certainty about the amount and receipt of the financial transfers, which could represent an important part of the compensation for the transfer of rights to lessee states, especially in the case of risk-averse states. Under certain circumstances, it would also be conceivable to combine (slightly reduced) lease payments with debt relief conditional on nature-conservation targets being met (debt-for-nature swaps) for lessor states as part of the lease initiative.

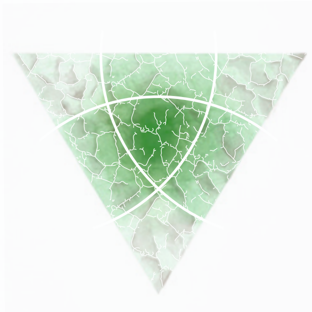
The lessees or donor state(s), in addition to paying rent, would also have to earmark funds for administrative and economic support for the implementation of the lease objectives on the ground. In principle, this is already inherent in the direct assumption of responsibility for the implementation of the contractual objectives. As far as possible, local organizations and authorities should be encouraged to get involved – also international organizations with years of experience of working in the relevant regions (UNEP, GFC or, for Germany, GIZ, KfW).

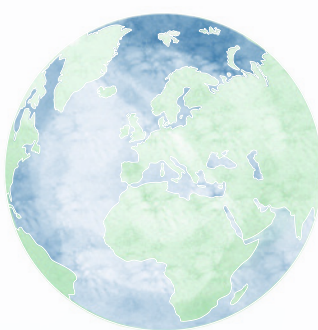
The necessary financial resources for a lease initiative could come from a variety of sources. It is conceivable that contribution payments by the states within the framework of one of the alliances outlined in Section 4.5 – or revenue from border-adjustment mechanisms – could contribute to financing such initiatives. In this context, financing requirements resulting from a broad shift towards more sustainable land use within the lessee states themselves should also be taken into account. To prove that the lessee alliance really is taking on more responsibility, steps should be taken to ensure that environmental or development-policy budgets and funding commitments it has made in the UN context are not simply reallocated, but that the lessee states really do take on new, additional tasks for global cooperation (keyword: 'additionality' in the UN context).

biosphere reserves into the forerunners of integrative landscape areas, and set up regional innovation hubs for sustainable farming methods.

- *Supranational alliances for a global land-use transformation (Section 4.5.2):* The purpose of supranational alliances is to bring together states that jointly pursue a sustainable approach to land stewardship and agree common values and regulations, e.g. common production standards. Member states of these alliances can be spread over different regions of the world. They become effective through the transfer of specific sovereign powers to the alliance (following the EU model), which can be enforced by alliance institutions vis-à-vis the member states. Supranational alliances can form a pioneer alliance for sustainable global agricultural trade, jointly implement transparent and sustainable supply chains, and effectively advance a Green Deal worldwide.
- *Global conservation alliances to protect and restore valuable ecosystems (Section 4.5.3):* These alliances of states and other – also private – stakeholders join forces with the aim of preserving and restoring valuable ecosystems in third countries that should also become members of the conservation alliance. A conservation alliance can, for example, jointly lease such areas, enabling its members to step out of the often passive role of mere 'donor countries' and assume joint responsibility together with other local stakeholders.

FOR A **GLOBAL TRANSFORMATION OF LAND USE**





SYSTEMIC INTERRELATIONS AS A KEY TO GLOBAL SUSTAINABILITY

SYNERGISTIC INTERACTION: FROM SEPARATION TO INTEGRATION

SOLIDARITY-BASED ASSUMPTION OF RESPONSIBILITY

1
From conflict and competition to multiple benefits

2
From destruction to the conservation and restoration of terrestrial ecosystems

3
Use the integrated landscape approach as an orientation mark

4
Enable and strength-en the assumption of responsibility along entire value chains

5
Promote the transformation of land use through effective global governance

Key messages for a global land-use transformation 5

Where does international sustainability policy stand at the beginning of the 2020s? The answer is sobering. This report appraises the situation and reveals an urgent need for action by many government ministries (e.g. Environment, Education and Research, Agriculture, Development Cooperation) to adopt a new approach to land stewardship.

- It looks as if the climate-protection goals of the Paris Agreement can only be reached if, in addition to decarbonizing the global economy, more areas of land are used to extract carbon dioxide (CO_2) from the atmosphere. However, this not only offers opportunities, it also involves considerable risks.
- The global food system is in crisis. The security of food supplies is under threat for a quarter of humanity, and another quarter suffers from unhealthy overconsumption or a faulty diet. At the same time, the environmental damage and other external effects caused by industrial agriculture threaten our natural life-support systems, despite all past efforts – from the 'Green Revolution' of the 1960s and 70s to the EU's Common Agricultural Policy.
- Biodiversity is experiencing a dramatic, human-induced mass extinction worldwide, the scale of which has been compared with the great geological extinction events of the past. This also greatly reduces the capacity of ecosystems to contribute to climate regulation and food security.

All this is happening in a situation where multilateralism is in deep crisis and the COVID-19 pandemic is making things even more difficult. The President of the European Commission, Dr Ursula von der Leyen, put it in a nutshell in her State of the Union Address to the European Parliament on 16 September 2020: "There is no more urgent need for acceleration than when it comes to the future of our fragile planet."

The diverse demands made on land for the purposes of climate-change mitigation, food security and biodiversity conservation are already in competition with each other today, and land degradation will have a negative impact on all three aspects in the short or long term. The scarcity of land as commons and the no-longer-tenable conflicts of use over terrestrial ecosystems show that there is an urgent need for a 'transformation of land use towards sustainability' in which the amount of land needed for climate-change mitigation is always calculated with biodiversity conservation and food security in mind. In this report, the WBGU presents political design options for sustainable land stewardship. It uses examples to show how combinations of conservation and diverse uses in the landscape can generate multiple benefits so that competition can be overcome. To this purpose, the WBGU develops examples of multiple-benefit strategies for the protection and restoration of ecosystems, for agriculture, nutrition and the bioeconomy – strategies that are transformative because they are scalable and suitable as 'game changers'. In addition, the report proposes effective instruments for governance involving both change agents and the proactive state, the EU, international institutions (including the UNFCCC, CBD and UNCCD) and new, international cooperation alliances.

Only a global 'land-use transformation towards sustainability' can simultaneously meet the interdependent demands of climate-change mitigation, the conservation of ecosystem services and biodiversity, and food security in the context of equitable land stewardship. Land is a global commons: humankind must assume responsibility for land in order to attain sustainability; it must discharge this responsibility nationally and enforce it internationally. The focus should be on halting the destruction of terrestrial ecosystems and on investing massively in their conservation and restoration. Globally sustainable land stewardship is a prerequisite for compliance with planetary guard rails and for meeting the UN Sustainable Development Goals (SDGs). The key strategies and governance requirements set out by the WBGU in this report can be characterized by the terms *systemic, synergistic* and *solidarity-based*.

- *Systemic interrelations as a key to global sustainability:* A wide variety of interactions characterize the interplay between, on the one hand, land use and land degradation and, on the other, climate change, greenhouse-gas emissions and sinks, the loss and degradation of ecosystems and biodiversity, the exploitation of biogenic resources, and the increasingly critical state of the food systems. Fragmented and unsustainable land management leads to multiple conflicts concerning its protection and use, and to competition for land. The WBGU therefore urges a systemically founded, sustainable approach to land stewardship, which is an important key to the Great Transformation towards Sustainability. Ecosystems and their diverse services are essential foundations for human life and economic activity and deserve to be at the centre of attention. For this, telecouplings (remote effects) on land-use changes and land degradation – e.g. by material cycles or the world trade in agricultural goods – must also be taken into account.

- *Synergistic interaction – from separation to integration:* In selected thematic areas (ecosystem restoration and conservation, agriculture, nutrition, bioeconomy), the WBGU has developed five examples of multiple-benefit strategies for protecting and sustainably using areas of land, which contribute to a wide range of synergies and, overall, to sustainable land stewardship. In many cases, focusing on monofunctional land uses leads to competition between protection and use. A sustainable land stewardship that simultaneously enables climate-change mitigation, biodiversity conservation and food security, requires multifunctionality and synergies both on areas of land and in the landscape. This is the only way to achieve multiple benefits overall and to overcome the trilemma of climate-change mitigation, biodiversity conservation and food security. The WBGU therefore recommends multiple-benefit strategies for sustainable land stewardship that combine and realize several aims in one and the same landscape. For example, the focus should be simultaneously on expanding and upgrading systems of protected areas (to cover 30% of the Earth's surface), on accelerating land restoration, diversifying agriculture in different parts of the world, and changing dietary habits. Using timber in construction can combine climate-change mitigation, sustainable biomass production and a responsibly limited use of biogenic resources.
- *Solidarity-based assumption of responsibility:* Multilateral policy approaches are indispensable for implementing overarching strategies for a transformation of land use at all spatial levels of governance – from local, national and European to international. Land as a global commons requires actors at all levels to assume responsibility. International institutions, e.g. the three Rio Conventions UNFCCC, CBD and UNCCD, whose activities relating to land are currently not sufficiently coordinated, need more solidarity-based cooperation, scientific support across topics, and better stakeholder involvement. Furthermore, new multilateral alliances should be forged in order to promote the Great Transformation towards Sustainability before it is too late. Above all, they should bring together countries that are responsible for a particularly large proportion of global resource consumption.

These convictions form the background to the following five core messages and key recommendations for action based on them. They summarize the essence of the multiple-benefit strategies relating to five thematic areas (Chapter 3) and the five governance proposals (Chapter 4). More detailed recommendations for action and research can be found in the individual sections of Chapters 3 and 4. The 'Overview of the recommendations' section that follows this Chapter 5 presents a condensed form of the recommendations for action and research.

1. From conflict and competition to multiple benefits

Multiple forms of competition between the protection and use of land, in combination with diverse conflicts of interest, threaten sustainable land stewardship and create a trilemma between the use of land for climate-change mitigation, biodiversity conservation or food security. Ecosystems provide multiple services (e.g. CO_2 storage, diversified agricultural use), which should thus form the focus of synergistic, scalable multiple-benefit strategies. The WBGU's core recommendations in this regard are as follows:

- *Work towards a combination of several goals in implementing sustainable land-stewardship strategies:* At the same time, special attention must be paid to expanding and upgrading protected areas, accelerating the restoration of land, diversifying industrial agriculture in various parts of the world, changing food systems and strengthening a sustainable bioeconomy. In other words, these issues should be addressed in an interministerial and inter-agency manner at both the national and the international level.
- *Strengthen multiple benefits using several instruments:* A combination of climate-change mitigation, stimuli for sustainable biomass production and a responsibly limited use of biogenic resources is possible in some areas, e.g. in timber-based construction. This should be strengthened even more than before through the coordinated linking of e.g. sustainable raw-material strategies, regulation and deregulation, as well as changes in standards, certification, promotion of circular and cascade uses, price incentives, and research and development geared to sustainability effects.

2. From the destruction to the conservation and restoration of terrestrial ecosystems

Curbing and reversing the increasing rate of land degradation and ecosystem destruction should rank much higher on the political agenda. A radical change of direction is needed towards nature conservation, restoration, sustainable forms of agriculture and control of global biomass use. Ecosystem services and the costs of their degradation must become more visible and assessable. The WBGU's core recommendations in this regard are as follows:

- *Promote the conservation and restoration of terrestrial ecosystems with real commitment:* This is not only a crucial prerequisite for maintaining biodiversity, it also makes an important contribution to climate-change mitigation by reducing GHG emissions and creating CO_2 sinks. These approaches must be combined with a consistent decarbonization of the energy sector and industry in particular, but also of other sectors.
- *Gear mainstreaming towards the integration of conservation and the sustainable use of land:* Essential systemic interrelations and synergies should always be an integral part of deliberations across all ministries and agencies. Efforts to protect terrestrial ecosystems must consistently also develop sustainable forms of use from the outset, and sustainable use always means implementing conservation at the same time – especially in order also to address blockages at an early stage.
- *Promote the greening of agriculture in the spirit of a 'transformation of agriculture':* Greater emphasis should be placed on diversified, multifunctional production systems to bring about both the necessary shift away from industrial agriculture in the EU and a sustainable increase in the productivity of subsistence agriculture in developing countries (especially in sub-Saharan Africa). Such systems preserve soil quality in the long term, which is the basis for food production and also strengthens climate-change mitigation.
- *Systematically monitor the production and use of land-based biomass:* Land use for the purposes of the bioeconomy should be documented as completely as possible on a global, but spatially differentiated level, supported by modern digital technologies (monitoring, extended indicator systems). The results should be used to support conservation and use prioritization, as well as appropriate pricing, or for the prevention of externalities in production and biomass use.

3. Use the integrated landscape approach as an orientation mark

An approach to land stewardship that relates to the whole landscape takes into account competing demands such as conservation and use, incorporates local knowledge, and supports several sustainability goals through a combination of different multiple-benefit strategies and participatory governance. Within the framework of sustainability-oriented spatial planning, equal consideration is given to different ecosystem types and to different forms of use (e.g. agricultural land, woodland and forest, protected areas, grasslands, wetlands, peatlands, coastal zones). The integrated landscape approach implements the sustainability goals with concrete action and also aims to contribute to overcoming global challenges through the governance or mediation of land-use competition. People should be placed at the centre of such efforts and special attention paid to gender. The WBGU's core recommendations in this regard are as follows:

- *Strengthen integrative multiple benefits in agriculture:* As part of an integrated landscape approach, sustainable agriculture should seek to reconnect crop cultivation with livestock production and to close nutrient cycles. Other objectives include nature conservation and the creation of carbon sinks.
- *Combine top-down with bottom-up approaches to kick-start the agricultural transformation:* In order to stimulate bottom-up initiatives on the application of know-how and empowerment for integrated land cultivation, farmers also need publicly driven top-down stimuli aimed at sustainable land stewardship and diversified production systems. These should thus be given a decidedly ecological orientation through existing funding channels such as the EU's Common Agricultural Policy (CAP) or the Input Subsidy Programmes of the countries in sub-Saharan Africa.
- *Promote integrated approaches to spatial planning and ecosystem policy:* The integrated landscape approach should be incorporated as a guiding principle and concept into planning activities and national planning law. To this end, aspects such as biodiversity conservation, climate impacts and other ecosystem functions should be given greater weight in spatial planning. The planning proposals should be supported by an overarching system of coordinated requirements and incentives for the sustainable management of agricultural land and land for forestry and nature conservation.

4. Enable and strengthen the assumption of responsibility along entire value chains

By interacting with the production side, the consumers of land-based resources and products can strongly influence whether land is used in an ecologically and societally sustainable manner. The WBGU therefore also highlights proposed solutions on the demand side aimed at constraining drivers of problematic land use. The objective here is to encourage more people – and via demand-induced market processes also companies that consume biomass – to live up to their responsibility as consumers for our ecosystems. To this end, the scarcity of biomass and ecosystem services should be reflected in prices and use priorities, and resources should be used responsibly (cascade and cyclical use). As a community of states with a particularly high level of responsibility for global resource consumption, the EU can play a key role in driving forward the Great Transformation, also in terms of actor behaviour. The WBGU's core recommendations in this regard are as follows:

- *Strengthen growing societal commitment and pioneering behaviour:* There are already many different initiatives that are committed to the concerns of climate-change mitigation, changing dietary habits and biodiversity conservation and that, furthermore, want to use circular approaches to reduce the consumption of resources. These approaches should be strengthened and consistently used for land-based policies at all levels ranging from the local to the global. Above all, powerful corporations and lobby groups should be convinced that they should make a significant contribution to sustainable land stewardship as pioneers of the transformation and no longer obstruct it.
- *Transform global food systems and dietary habits:* Both should be equally geared to human health and the conservation of ecosystem services. Above all, it is essential to stimulate changes in consumer behaviour with a reduced consumption of animal products and a diversification of the food system in the course of an agricultural transformation. In addition to an education offensive and the consistent implementation of nutrition guidelines that conform to the Planetary Health Diet, components of such a transformation include a reform of the European CAP (e.g. better remuneration for ecosystem services), a corresponding design of development cooperation and the internalization of external costs.
- *Fully reflect ecological costs in prices for food and biogenic resources:* In order to inform consumers, influence their consumption behaviour and ensure that they pay a share of environmental costs, the services provided by ecosystems and the costs of their degradation must be fully reflected in the prices of food and other biogenic resources, and appropriate framework conditions must be established for this purpose. For example, hitherto neglected external costs of climate change and environmental degradation should be systematically documented by research and internalized by appropriate measures (certification, taxation, financial support). Social hardships related to price increases should be taken into account and cushioned wherever appropriate.
- *Shape the bioeconomy responsibly:* In order to make the consumption of globally scarce biomass more sustainable, approaches are needed to limit its use and to set priorities according to the type of use. Taking the conservation of biodiversity and natural carbon reservoirs into account, a hierarchy in the use of biomass should give first priority to food production and only then to materials and specific energy-related uses, preferably those where carbon is stored or where there are no other climate-friendly alternatives. To this end, consumption-reduction targets should be defined, the sustainability requirements for biomass production should be strengthened parallel to its material uses, and non-bio-based climate-change-mitigation strategies should be pursued.

5. Advance land-use transformation through effective global governance

As part of the global commons, terrestrial ecosystems and their services depend on all stakeholders assuming broad responsibility, and this requires multilateral governance approaches. Effective governance measures based on up-to-date, multidisciplinary scientific evidence can be essential levers for transformative change, but their synergies and clout need to be strengthened. The proactive state has a key role to play here. Sustainable land stewardship can only be achieved by assuming responsibility that is strategically networked in multiple ways. The WBGU's core recommendations in this regard are as follows:

- *Shape the EU's Common Agricultural Policy as a transformation instrument:* The EU should go beyond incremental improvements, especially in the course of a transformative reform of the CAP after 2020, and provide radical new stimuli in conjunction with the European Green Deal. Direct effects on the conservation and promotion of biodiversity can be achieved through agri-environmental and climate measures. Regulatory policy should prevent excessive inputs of nutrients and pesticides into the surrounding ecosystems. The CAP should be geared much more consistently than hitherto to remunerating ecosystem services. In the medium term, its transformation into a Common Ecosystem Policy (CEP) should be pursued in which ecosystem services are remunerated in an overarching system on all land areas, instead of only on agricultural land.

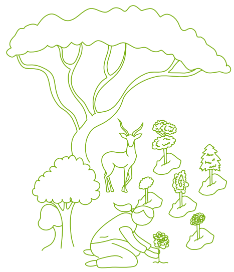
- *Strengthen change agents:* Individual actors who, in their roles in civil society, science or business, advocate land-use transformation by trying out new ideas, practices or business models should be supported in their transformative actions by publicizing existing individual activities or civil-society initiatives, networking them and providing them with resources (funds, premises).
- *Promote multi-stakeholder partnerships for the coexistence of conservation and sustainable use:* States, civil society and academia should work together with local actors and communities to implement local, regional and cross-border transformation laboratories for sustainable-integrative land practices, and receive targeted political support. The various options for strengthening global-local policy processes involving the landscape level should be explored, including trade-policy standards and, where appropriate, incentives for sustainable land stewardship.
- *Introduce sustainability standards for all internationally traded biomass:* Building on existing sustainability standards (e.g. on the use of biomass for energy generation, sustainable timber production, agricultural products produced in a fair way), harmonized certification and verification obligations should be extended to all biomass types and origins and better enforced by means of independent monitoring and effective sanctions. These obligations should be treated as decisive criteria or preconditions for trade facilitation and the conclusion of trade agreements, also in order to raise international awareness of the problem. In addition, sustainability impact assessments of trade flows should be consistently made in conjunction with approaches to strengthen resilience in agricultural trade.
- *Create strong stimuli by convening a Global Land Summit:* In order to sensitize the international community to the urgency of the upcoming tasks of global land-use transformation, institutions such as the Rio Conventions (UNFCCC, CBD and UNCCD) should cooperate more and be better supported by scientific assessments. On this basis, a Global Land Summit initiated by Germany can play a key role in instigating the integrated land-use transformation for climate-change mitigation, biodiversity conservation and for halting land degradation – and in boosting the transformation's global impact.
- *Strengthen international cooperation and enforcement with cooperation alliances:* The WBGU proposes the establishment of new interregional, supranational and global alliances that motivate like-minded states to take on more joint responsibility for sustainable land stewardship. Driven by states as initiators, they should act in an agile and decisive manner, linking top-down with bottom-up initiatives and also involving the private sector and other stakeholders. It is a matter of working vigorously in solidarity for a global 'land-use transformation' and closing gaps in governance that have existed up to now, for example to preserve CO_2 sinks and particularly valuable ecosystems.

In conclusion, in relation to the goal of resolving the trilemma of unsustainable land use, this report offers multi-benefit strategies for five thematic areas, five related governance approaches, and five overarching key messages. The WBGU's vision of a global land-use transformation towards sustainable land stewardship is essentially shaped by the following strategic perspectives: First, the integrated landscape approach should serve as an orientation mark to make it possible to merge policies on climate-change mitigation, biodiversity conservation and food security on the ground. With the help of multiple-benefit strategies and taking into account the WBGU's normative compass, competing interests can be mediated with the support of participatory governance. Second, telecouplings (long-distance effects), for example via world trade, must be taken into consideration in the policies as drivers of unsustainable land stewardship. Third, terrestrial ecosystems and their services should be explicitly regarded and treated as global commons whose protection, restoration and sustainable use require complementary initiatives for the assumption of responsibility at all levels, from the local to the supranational.

Overview of the recommendations

Multiple-benefit strategies

Ecosystem restoration: make land-based CO_2 removal synergistic



Measures for removing CO_2 from the atmosphere are no substitute for a massive reduction of CO_2 emissions with the aim of cutting emissions to zero. However, in order to achieve the climate-protection goals of the Paris Agreement, additional measures for the removal of CO_2 from the atmosphere are hardly avoidable, although they involve considerable uncertainties depending on the method, scope and effectiveness of implementation and may potentially increase the pressure on land (Section 3.1).

The restoration of degraded terrestrial ecosystems is by and large a promising approach for removing CO_2 from the atmosphere and can simultaneously generate additional benefits for biodiversity and food security. Rewetting and restoring peatlands has great potential for preserving very specific biological communities and for storing CO_2 sustainably. While projects for the afforestation of hitherto unwooded areas must be critically and individually appraised, the site-specific reforestation of deforested areas can open up sustainable additional potential for reducing CO_2. It can also provide opportunities to contribute to local economic sectors or directly to human food supplies by establishing or creating agroforestry systems. In view of the forthcoming UN Decade on Ecosystem Restoration, the multiple-benefit strategy of 'restoring degraded terrestrial ecosystems' should have particular political appeal.

In order to support the restoration of degraded land worldwide and to encourage innovative progress in this field, the WBGU recommends stepping up national and international research on the costs, feasibility and permanence of ecosystem restoration and the potential global land area that is available for the purpose. The many possible multiple benefits of low-risk ecosystem-based approaches like the restoration of degraded land should be exploited at an early stage.

Recommendations for action

Removal of CO_2 from the atmosphere

- *Make a clear distinction between climate-policy goals on CO_2 emissions reduction and on CO_2 removal from the atmosphere:* When setting climate-policy targets and designing time plans and accounting structures, a clear distinction should be made between reducing CO_2 emissions and removing CO_2 from the atmosphere. Net emission targets or climate-neutrality targets should, if at all, only be formulated if the assumed contributions of CO_2 emissions reductions and CO_2 removal respectively are explicitly stated; otherwise, the chances of achieving the climate-protection goals might be jeopardized.
- *Strategically plan the application of approaches to CO_2 removal from the atmosphere and limit their sustainability risks:* The sustainable options for CO_2 removal should be scientifically sounded out at an early stage, sustainably limited and strategically coordinated with plans for CO_2 emissions reduction and the sustainable use of biomass and ecosystems.
- *Implement ecosystem-based approaches to CO_2 removal at an early stage with a view to multiple benefits:* National regulations and international funding programmes should without undue delay realize the potential of ecosystem-based approaches to CO_2 removal as proven, low-risk and cost-effective methods.
- *Create multilateral financing systems for sustainable CO_2 removal:* Sustainable, separate targets for CO_2 removal require independent financing mechanisms, such as international transfer payments, possibly also an independent market-based incentive system.
- *Create state financing systems for sustainable CO_2 removal:* As a contribution to national climate-change mitigation, CO_2 removal should also be supported at the national level through appropriate regulation and financing, e.g. via payments for ecosystem services or in the form of an auction mechanism. In this context, the advantages and risks of individual approaches to CO_2 removal should always be taken into account.

Restoration of degraded terrestrial ecosystems

- *Massively increase and promote ecosystem-restoration measures worldwide:* Achieving the goal set by the Bonn Challenge to restore 350 million hectares of global terrestrial ecosystems by 2030 requires a massive increase in and acceleration of restoration measures. The focus should be on restoring degraded, originally near-natural forests rather than creating plantations.

- *Significantly expand the area target for restoration:* The target formulated in the Bonn Challenge corresponds to about 2% of the Earth's terrestrial surface. This area target should be significantly expanded and should address not only reforestation but also wetlands and grasslands – especially since the goal of designating 30% of the Earth's surface as protected areas has to be supported, inter alia, by restoration measures.
- *Considerably expand the Global Partnership on Forest and Landscape Restoration:* The number of states that have committed themselves to carrying out restoration measures within the framework of the Global Partnership on Forest and Landscape Restoration should be considerably expanded – on condition that plantations and monocultures are excluded. To this end, Germany should form coalitions with other EU countries to provide financial and logistical support especially to developing countries. So-called global cooperation alliances can provide an institutional framework for achieving these goals at the global level.
- *Increase support for non-governmental organizations and civil-society initiatives:* Support programmes should be set up specifically for civil-society initiatives and NGOs that implement restoration. These need more financial support, especially in the form of start-up funding and to cover their personnel costs.
- *Combine COVID-19 crisis-management programmes for developing countries with sustainable land use:* Support for the world's least developed countries – for example in the case of the COVID-19 pandemic – should combine economic objectives with sustainable land-use practices and the protection of terrestrial ecosystems. The G20 could set the political framework for this.
- *Design financing mechanisms with sustainability in mind:* In order to successfully promote ecosystem-restoration measures, it is necessary to take into account the complexity of the topic and the long-term horizon of implementation. Accordingly, funding programmes should be designed for the long term and not only initiate the process of restoration, but also accompany it for its entire duration.

Research recommendations

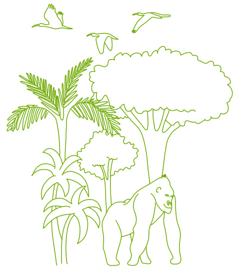
Removal of CO_2 from the atmosphere

- *Examine sustainable methods and the potential of CO_2 removal from the atmosphere:* More precise assessments of sustainable, technically and socio-economically feasible potential are needed before independent targets for CO_2 removal from the atmosphere can be strategically planned and formulated. Alternative development paths, synergies and conflicts between different approaches should be examined as well as country-specific advantages and disadvantages.
- *Develop suitable governance and financing structures:* The interaction between existing climate-policy structures and new, yet-to-be-created mechanisms should be examined in detail.
- *Use government funding to specifically research and develop a broad portfolio of methods and circumspectly accelerate their marketability:* Incentive structures, funding models, political framework conditions and business models should be researched in order to quickly but circumspectly benefit from the sustainable potential of both established and new technologies.

Ecosystem restoration

- *Assess more precisely the sustainable potential of restoration measures:* Further research is needed in order to be able to better assess (sustainable) potential areas of land that are suitable for the restoration of forests, wetlands and grassland ecosystems, how big they are and where they are situated, while taking into account land-use competition and conservation requirements.
- *Boost the development of indicators for degradation and restoration and increase monitoring capacity:* There is an urgent need to develop indicators that are at least comparable for measuring the degradation of terrestrial ecosystems and for restoration. To this end, corresponding monitoring networks should be strengthened and, where none exist, new ones established. Monitoring by field observation should be complemented by remote sensing methods.

Expand and upgrade protected-area systems



Effective, well connected systems of protected areas form the backbone of ecosystem conservation and are a decisive prerequisite for defusing the global biodiversity crisis and maintaining ecosystem services that are essential for humans and nature alike (Section 3.2). Preventing the further degradation and destruction of ecosystems also benefits climate-change mitigation by avoiding CO_2 emissions and preserving natural carbon reservoirs. The value and conservation of the ecosystems inhabited by Indigenous Peoples and Local Communities (IPLCs) is of key importance here since a large proportion of them are as yet untouched by intensive forms of cultivation.

Protected-area systems are characterized by the fact that their priority goal is the effective conservation of ecosystems and biodiversity. Protected areas that use zoning – i.e. division into areas with different combinations of conservation and sustainable use – allow the coexistence of valuable nature with human activities compatible with biodiversity conservation. Multiple benefits for food security can be realized in these protected areas, e.g. by allowing sustainable forms of use in certain zones, which can even be a prerequisite for biodiversity conservation.

The WBGU recommends expanding terrestrial systems of protected areas to cover 30% of the Earth's land area while consistently applying internationally agreed quality criteria, and proposes this goal for the post-2020 framework of the Convention on Biological Diversity (CBD). A significant increase in the funding of nature conservation is an important prerequisite for this. The WBGU also recommends the further development of ecosystem conservation in line with the multiple-benefit strategy.

Recommendations for action

- *Internalize the benefits of ecosystem services and biological diversity:* National governments should consider how to improve the internalization of ecosystem services and biological diversity in their societies and economic and financial systems (e.g. regulatory law, financial incentives).
- *Including and realizing synergies:* In addition to the top-priority protection goals, the other dimensions of the trilemma should also be borne in mind, checked for possible synergies and, in the landscape context, integrated more closely into the management plans of protected areas. This idea should also be introduced with greater urgency in the multilateral processes of, for example, the IUCN, the CBD, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and the United Nations Development Programme (UNDP), and should be implemented more strongly in development cooperation.
- *Strengthen protected-area systems in the post-2020 framework of the CBD:* The WBGU supports the CBD's goal of putting 30% of the global land area under protection, but warns against restricting the negotiations to land-area targets. The existing Aichi quality criteria for protected areas must not be watered down under any circumstances. Protected-area systems should be more closely linked to restoration, and compliance regulations should be tightened.
- *Improve the management of protected-area systems:* Development-cooperation projects should prioritize the potential for improvement within existing protected-area systems in line with the CBD quality criteria. Further success factors include digitally supported monitoring and the supervision of rules on use and management.
- *Improve the integration of the protected-area systems into the landscape:* In line with the concept of an integrated landscape approach, there should be improved connectedness both among the protected areas and with the surrounding land areas. In order to strengthen the landscape's ecosystem diversity and improve the supply of locally relevant ecosystem services, an integrated landscape approach should address areas of land both inside and outside protected areas.
- *Support Indigenous Peoples and Local Communities:* In order to safeguard the conservation effect of regions inhabited by IPLCs, the focus is initially on recognizing and formalizing the IPLCs' traditional rights and traditional knowledge not only at the UN level but also in national contexts. The participation of IPLCs in the expansion and management of protected areas should be improved on this basis.
- *Strengthen the financing of protected-area systems:* Industrialized countries should make greater use of their financial capacity, where possible in combination with private financing, to expand and upgrade protected-area systems both at home and in developing countries. This should be flanked by support for effective management systems and the economic development of surrounding regions (with the aim of reducing the opportunity costs of ecosystem conservation).

Research recommendations

- *Increasingly use participatory research approaches:* Participatory research approaches to the establishment, management, local acceptance and, in particular, expansion of protected-area systems should be used more frequently and greatly strengthened in line with their importance.
- *Strengthen socio-ecological research on protected areas:* The role of protected-area systems with regard to sustainability in the overall socio-ecological system (e.g. also health, human well-being) should be studied more closely.
- *Examine the quality of the protected-area systems:* The WBGU recommends increasing research investment in global databases on the state of ecosystems, threatened species and protected areas (e.g. degradation, threats, protected-area downgrading, downsizing and degazettement, or Indigenous and Community Conserved Areas). There should also be increased investment in additional data sets on the status of interconnections between protected-area systems, on their integration into the landscape, and on the coverage of critical ecosystem services and other effective area-based conservation measures.
- *Promote monitoring and citizen science:* Research on improved indicators and the monitoring of quality criteria of protected-area systems is recommended, as are research collaborations with developing countries to expand and support monitoring and data analysis. The considerable potential of citizen science should be better exploited by providing targeted support.
- *Research the financing mechanisms of protected-area systems:* Data on existing and necessary funding for protected-area systems is still insufficient and should be improved, e.g. as part of the World Database of Protected Areas. Building on this, more research should be conducted into the effectiveness of different financing mechanisms.
- *Study the influence of telecouplings:* There should be close study of the impact of telecouplings on protected-area systems (e.g. as a result of increased pressure of use and intensified competition for land use) and of measures addressing these telecouplings.
- *Research and strengthen the role of Indigenous Peoples and Local Communities:* Available data on regions inhabited and managed by IPLCs (e.g. global cartography, knowledge of governance methods, biodiversity and effectiveness of conservation) should be improved and the relationship between biological, cultural and linguistic diversity more closely studied.

Diversify agricultural systems

Agriculture has a formative influence on land stewardship in many parts of the world (Section 3.3). It is the foundation of food security, but today it endangers soils, the climate and biodiversity – both in the form of industrial agriculture and in the form of subsistence agriculture practised on resource-poor small farms.

While industrial farming systems tend towards uniformity and over-fertilization, resource-poor subsistence farms tend to be under-fertilized. In both cases, this leads to inefficiencies and the degradation of soils. One leads to considerable environmental externalities, the other to increased land conversions. Both destroy biodiversity. While a number of developing countries (above all in Africa and India) cannot secure their food supply with subsistence farming, in countries where industrial practices dominate, agriculture and dietary habits have become more and more decoupled, leading to further externalities.

For both forms of agriculture the WBGU recommends a transformation towards ecologically intensive, multifunctional production systems in which efficiency gains are achieved primarily by promoting ecosystem services, thus overcoming the trilemma of land use. Within the framework of this transformation, the focus is on people and on a greening of agriculture.

This report focuses on the EU and sub-Saharan Africa, as these regions are the main priorities of German and EU agricultural and development policy. In both cases, the WBGU recommends multi-benefit strategies towards diversified farming systems – leading to the greening of EU agriculture and to a sustainable increase in productivity for sub-Saharan Africa's agriculture – combined with a systematic adaptation to climate change for both forms. Furthermore, trade in agricultural products, which will remain an important factor, should be consistently geared towards resilience and sustainability.

Recommendations for action

Greening the EU's industrial agriculture and realigning the Common Agricultural Policy after 2020

- *Push for the reform of the EU's Common Agricultural Policy in the direction of environmental and climate policy:* Today's area-based direct payments should be transformed into payments for environment-related and ecosystem services. Regulatory policy or possibly an incentive tax should be used to reduce excessive nutrient and pesticide inputs. 'Dark green' agri-environmental and climate measures should be further developed, even though this involves more administrative work. Monitoring of the planned national strategy programmes for the implementation of the Common Agricultural Policy (CAP) should be increased. In the medium term, the CAP should be integrated into a more comprehensive system that also promotes ecosystem conservation outside of agricultural land.

- *Recouple agricultural sectors and close nutrient cycles:* Greater efforts should be made to boost and reward the recoupling of crop production with animal husbandry (enabling the closure of nutrient cycles), improvements in the efficiency of nutrient use and the recycling of nutrients (especially phosphorus), the creation of carbon sinks and/or the protection of natural carbon reservoirs, and the formation of humus.
- *Promote the development and implementation of digitalization in agriculture:* The development and implementation of technical innovations for sustainability, e.g. precision farming, should be promoted in order to realize a transformation in agriculture towards diversified, multifunctional and sustainable farming systems. Precision farming makes it possible to optimize inputs of fertilisers, pesticides and water. Attention should be paid here to adapting technical innovations to diversified and small-scale systems and not to promoting large-scale agriculture.
- *Promote participation, counselling, education and training:* To achieve a transformation of land use towards sustainability, it is essential to involve and consult a wide range of stakeholders. Education and training programmes should provide information on diversified agricultural production systems and agri-ecological practices, explain the aims and requirements of agri-environmental programmes better and encourage participation. Inter- and transdisciplinary methods should be used to develop and design an innovative ecological transformation.

Agricultural development in sub-Saharan Africa

- *Channel funds for agri-ecological measures via existing government subsidy programmes:* Input Subsidy Programmes (ISPs), which are already in place in most African countries, are suitable channels for financing sustainable productivity improvements in sub-Saharan Africa's agriculture and for adapting to climate change. The programmes should be given a financial boost and, in a similar way to the EU's CAP, a second pillar could also be created for the ISPs in order to more systematically combine yield-increasing with agri-ecological measures. This requires coordination and joint implementation of the national adaptation programmes in the respective environment ministries and the subsidy programmes in the agriculture ministries.
- *Recognize the additional work required to restore the soil as a key success factor and give financial support:* For a successful restoration of the soils it is essential to provide temporary financial support not only to pay for materials but also to cover the enormous additional work input. Otherwise, there is a considerable risk that farmers and livestock herders will not be able to persevere for the several years required for this transition, since the majority of them already live and work close to subsistence level.
- *Encourage new agreements between farmers and livestock herders:* New agreements for the co-management of land use in semi-arid regions by farmers and livestock herders could stabilize ecosystems and be facilitated by development-cooperation experts within the framework of the integrated landscape approach. For the Sahel countries in particular, this would also represent active peace-building work.
- *Halt food losses:* Food losses during grain storage in sub-Saharan Africa amount to about a third of annual consumption per person. It is possible to end these losses using relatively simple means, for example by storing the grain in sacks and municipal storage facilities and managing it jointly using e-voucher systems. Joint management would also allow longer storage and enable farmers to sell some of their produce at higher prices at a later stage rather than at low prices immediately after harvest.

Trade

- *Promote sustainability in trade through certification and labels of origin:* The design and implementation of certification schemes (e.g. Fair Trade, the 'Bio-Siegel' organic seal, FSC) and protected labels of origin should be improved and, where appropriate, new schemes developed (e.g. climate labels for agricultural products) to promote sustainability. Regional trade agreements should proactively adopt the development of guidelines for voluntary eco-labelling programmes from the planned Agreement on Climate Change, Trade and Sustainability (ACCTS).
- *Promote sustainability in trade through supply-chain management:* Approaches to cooperation in the field of supply-chain management should be expanded and fleshed out to promote sustainability in trade. Cooperation can be made easier by shortening and unbundling international value chains in the agricultural sector.

- *Strengthen resilience to shocks and food crises:* Only a small number of net exporting countries supply a large number of net importing countries, and most developing countries, specifically in sub-Saharan Africa, are becoming increasingly dependent on food imports. Resilience – i.e. the capacity to robustly withstand shocks, climate-change impacts and food crises – should be increased through diversified (especially agri-ecological and 'climate-smart') measures, through a new fund under the Economic Partnership Agreement, e.g. for a sustainable increase in the productivity of a climate-resilient agriculture in sub-Saharan Africa, and through Aid for Trade measures for sustainable products.

Research recommendations

Sustainable land use in sub-Saharan Africa

- *Involve local researchers and practitioners in research projects on development cooperation:* In addition to young African academics, experienced practitioners should also be given a stronger role in research projects. Research questions should be identified jointly, and the research implemented in cooperation with 'Green Innovation Centres', which are part of German development cooperation.
- *Research to regain the original yield capacity of degraded soils:* The mechanisms involved in accelerating the regeneration of degraded soils (restoration) are not yet fully understood. Supplementary research projects on this subject are therefore recommended because it can be decisive whether, for example, restoration measures enable soils to regain their original yield capacity after only three years or only after ten years – or never.
- *Research ecological intensification measures and the determinants of successfully disseminating the measures:* There is a need for research to identify ecological intensification measures and their dissemination, especially in semi-arid regions. The research should investigate how yields can be increased in the long term by strengthening ecosystem services and how suitable soil-conservation techniques can be effectively disseminated.
- *Optimize financing mechanisms for sustainable land management:* When new financing mechanisms or modalities are used to benefit land users in sub-Saharan Africa, e.g. with the help of a second pillar in the ISPs, accompanying and experimental research projects could help identify the most successful formats and channels.
- *Investigate conditions for the successful dissemination of diversified agricultural systems:* Despite numerous development-cooperation projects, suitable soil-conservation techniques and diversified agricultural systems often spread slowly and not continuously in sub-Saharan Africa, i.e. they are only applied to a part of the land area or are repeatedly suspended. Research should be conducted to determine whether there are other success factors besides the need for advice and broad-based financial support.

Greening the EU's industrial agriculture and the Common Agricultural Policy after 2020

- *Promote research on the effects of (the reform of) the CAP:* Indicator systems for analysing the effectiveness of the CAP (output, impact and result indicators) should be further developed. These should also be used as a basis for future reforms of the CAP and its instruments.
- *Step up research on agri-ecological approaches and practices:* Research and innovation policy should concentrate on developing agri-ecological approaches, their acceptance by farmers and their effects on agricultural production systems (e.g. the role of incentive mechanisms, institutional preconditions).
- *Initiate new methods, approaches and ways of modelling for the agricultural sector:* In order to understand the complexity of change processes in the agricultural sector, citizen science and transformation research (real-world laboratories, living labs or experiments), multi-actor models and methods of spatial and landscape planning should be further developed.
- *Use digitalization for sustainability:* In precision farming, intelligent machines should be developed that are also adapted to smaller field sizes and/or diversified production systems. Digital innovations should also be modulable, circular and reusable or recyclable, and should enable the sustainable management of ecosystems.

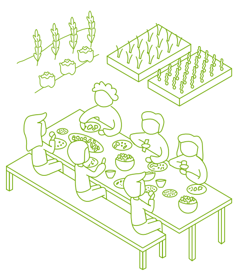
Trade

- *Improve the methodology of sustainability analyses in (agricultural) trade:* Methods for *ex-ante* evaluations of regional trade agreements should be further developed. In addition, climate-relevant import and export flows, as well as important terrestrial ecosystems and economic drivers of land degradation, should be identified and quantified at the regional level. Furthermore, proposals should be developed on what instruments can be used to address these drivers.
- *Research ways to improve the effectiveness of certification, labels of origin and supply-chain management:* Further research is needed to better understand the impact of different certification schemes

and labels of origin on sustainability (primarily also on the environment). The effects of the expansion of supply-chain management and supply-chain legislation should also be empirically researched.

- *Promote research into the role of trade in food security:* The effects of trade on food security should be researched more intensively. The interests of developing countries and emerging economies should be taken into account and questions on the design of development cooperation included.
- *Strengthen resilience research:* (Climate-) risk analyses and long-term analyses of the effects of shocks on land use and productivity levels and on farmers' adaptation behaviour (e.g. with regard to the application of agri-ecological and climate-smart measures) should be promoted to improve assessment of the effects of shocks (e.g. the COVID-19 pandemic) and to strengthen the coping capacities of affected stakeholders.

Move ahead with the transformation of diets heavy in animal products in industrialized countries



The dysfunctionality of global food systems is one of the drivers of the land-use trilemma (Section 3.4). Above all, diets heavy in animal products in industrialized countries – and also among the growing middle classes in emerging economies and developing countries – are exacerbating land-related problems for climate and biodiversity protection and making sustainable food security more difficult. Significant potential for alleviating this problem lies in changing dietary habits. In Europe, a corresponding shift in values away from factory farming towards lower levels of meat consumption is already evident. The transformation of dietary habits emerging here can be decisively promoted by making consistent changes to framework conditions, establishing sustainability-oriented standards and creating corresponding incentives for business and consumers.

Recommendations for action

Consistently make sustainable nutrition the norm with guidelines that are in line with the Planetary Health Diet (PHD)

- *Recommend dietary guidelines aimed at sustainability:* The PHD's guiding principle is that a proportion of daily meals should contain fewer animal products, especially red and processed meat. This should be laid down by the corresponding institutions (e.g. by the BZfE for Germany) as a principle for new dietary guidelines and also recommended by the Federal Government.
- *Offer meals based on the PHD in communal catering:* Because of its special exemplary function, a dietary guideline based on the PHD should be offered in the short term as a basis for menus in public communal catering. Implementation should be initiated and further developed by corresponding transformative research.
- *Enforce the principle of sustainable procurement in publicly funded catering:* For all publicly funded catering (conference catering, buffets at public events, etc.) sustainability should be consistently strengthened and menus following the PHD established as standard.

Support the trend towards a diet low in animal products and gear dietary biographies towards sustainability

- *Publicize and support the many initiatives targeting the goal of sustainable diets:* Sustainability-oriented civil-society initiatives aimed at changing dietary attitudes should be networked and promoted, e.g. by initiating umbrella organizations, staging forums or sponsoring prizes.
- *Sustainably influence dietary biographies at an early age:* Especially in educational institutions, PHD-based dietary guidelines should apply in the short term not only in communal catering. In addition, they should be included in the curriculum to further promote the already measurable change in societal values.

Encourage consumers to practise sustainable dietary habits

- *Promote the pricing-in of environmental externalities and cut subsidies:* At present, sustainable solidarity-based dietary habits among consumers are not encouraged by prices that reflect the societal costs of nutrition or by an availability of corresponding choices. The pricing-in of environmental externalities should be promoted, especially on the production side, in order to create appropriate price signals.
- *Promote the development of a consumer-oriented information system for labelling environmental externalities:* Dietary habits are geared towards individual target systems, so that information about the environmental impact of a product, for example through labelling in the form of seals, cannot do justice to all consumers. An information platform and corres-

ponding apps on the environmental externalities of food should therefore be developed to maximize consumer information.

- *Introduce a 'sustainable food supply' certificate:* A 'sustainable food supply' certificate should be introduced for the retail trade. The certificate could, for example, be linked to compliance with the basic principles of the PHD or to ensuring that at least 50% of the food is offered with well-prepared information on environmental externalities. Such a certificate could be conceived by private initiatives and further developed and issued with the support of public institutions.
- *Introduce and promote a 'sustainable catering' certificate Europe-wide:* The emerging trend of vegetarian and vegan restaurants should be encouraged. To this end, information on the environmental externalities of each dish should be made available and a restaurant label developed and introduced to certify that a PHD-compliant turnover target has been reached.
- *Launch an initiative to place warnings on advertising for unhealthy foods:* The overconsumption of animal products can in some cases be harmful to health. The same applies to other food categories such as products that are rich in sugar or fat. A societal discourse should be initiated on the extent to which advertising for such products might include information or even warnings. Such a project should be promoted throughout Europe.

Promote 'healthy trade' nationally and internationally

- *International trade and investment agreements should take impacts on the diets of populations into account:* The Principles for Responsible Investment in Agriculture and Food Systems developed by the Committee on World Food Security safeguard food security and the right to adequate nutrition and should be consistently implemented. This applies in particular to regional and bilateral trade agreements which offer investors particularly strong protection.
- *Use trade as an engine for achieving sustainable and healthy nutrition:* Agricultural trade makes it possible to supply urban populations in particular with a wide range of sustainably produced agricultural products. Trade also has indirect effects since the commercialization and export of agricultural products generates income that contributes to food security, particularly for the rural population. Aid for Trade measures can specifically promote this.

Research recommendations

Transformative research to strengthen sustainable dietary habits

- *Promote sustainable dietary habits with real-world laboratories at educational institutions:* Ideas on the introduction of new PHD-based dietary guidelines or PHD-compliant meals could be developed and tested at universities and schools in the form of real-world laboratories.
- *Study the potential of sustainable offers in the catering industry:* Together with actors from catering (e.g. the German Hotel and Restaurant Association) and civil society, research should be carried out to find out how diets can move closer to the PHD in this field, too, and what kind of information services can meaningfully assist guests in their efforts to eat sustainably.
- *Encourage the transformative development of needs-based information services on sustainable consumption:* Current product seals do not adequately reflect individual information and orientation needs. One solution might be to set up online information portals where users can make choices according to criteria based on their individual information needs and are offered corresponding product recommendations. The German Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (WBAE) at the Federal Ministry of Food, Agriculture and Consumer Protection (BMEL) recommends the creation of such an open-access database which would support the development of a 'digital ecosystem for more sustainable nutrition' (WBAE, 2020). The development of such information systems is only possible as part of a broad-based research programme involving a wide spectrum of civil-society actors.
- *Engage in transformative research into sustainable prospects for meat and milk:* Using participatory research methods, a concept for a sustainable future of animal husbandry and animal-food production should be explored and discussed with actors primarily from rural regions. The aim could be to lay the foundations for a citizens' report on the subject of 'future prospects for meat and milk'.

Extend existing research programmes in the field of nutrition to include sustainability aspects

- *Add research on sustainability to the Nutrition Research Competence Cluster:* The BMBF's Nutrition Research Competence Cluster and the EU programme 'A Healthy Diet for a Healthy Life' are prominent in the field of nutrition research, but focus almost exclusively on the health aspect. The WBGU recommends adding further sustainability aspects. Actors such as the BMEL, the BMU, the Federal Centre for Nutrition and the German Institute of Human Nutrition should be involved.

- *Research the effects of political consumption and alternative forms of nutrition:* The emergence of a wide range of initiatives in the field of sustainable nutrition is also an expression of political consumption and indicates that nutrition as a form of expression is particularly important. Implications (collective effectiveness, experience of self-efficacy, diffusion potential) should be investigated in a social-science research programme looking into effects on individual quality of life and societal impacts.
- *Research the effect of and reference to dietary guidelines:* The extent to which whole areas of different nutritional locations or even individual institutions or associations (e.g. student unions, canteens) specifically conform to dietary guidelines is largely unknown. A corresponding review aimed at more accurately assessing the effectiveness of dietary guidelines would also be helpful in view of a reorientation towards the PHD.
- *Optimize methodology for quantifying food waste and its potential:* Quantifying food waste is currently a methodological problem. This should be taken into account in future research projects, especially since prominent sustainability strategies are based on reducing food waste.
- *Initiate international research cooperation on the future of nutrition:* Existing research activities on sustainable nutrition should be systemically geared towards all the trilemma dimensions and have an international orientation. The diversity of dietary habits worldwide should be systematically assessed according to their impacts on health and sustainability. A corresponding research programme and collaborations should be initiated.

Shape the bioeconomy responsibly and promote timber-based construction

The use of materials or energy from biomass in a bioeconomy offers a wide range of options for replacing emissions-intensive processes and fossil resources (Section 3.5). However, the growing demand for land for biomass production is increasingly competing with the land requirements for food security and biodiversity conservation. In order to design a bioeconomy based on sustainable land use, it is therefore necessary to create a framework limiting the use of biomass and setting priorities according to types of use. Taking the conservation of biodiversity and natural carbon reservoirs into account, a hierarchy in the use of biomass should give first priority to food production and only then to materials and specific energy-related uses. Preference should be given to uses in which carbon is stored, or for which there are no other climate-friendly energy alternatives. In this report, the WBGU therefore focuses on the example of boosting methods that use wood instead of cement and steel in construction. Timber as a building material offers effective possibilities for long-term carbon storage, but it should come from site-specific sustainable forestry. The use of by-products from agriculture and forestry for materials or energy can also contribute to economically sustainable development and food security, especially in developing countries and emerging economies.

Recommendations for action

Construction with timber

- *Proclaim a global 'Mission for Sustainable Construction' together with international partners:* This mission should strategically link the development and large-scale implementation of sustainable (timber-based) construction methods to a sustainable supply of resources, involve state actors as well as business, science and civil society, and develop global strategies on sustainable resources and building-material use. The mission would form the framework for all subsequent recommendations on timber-based construction.
- *Develop global strategies on sustainable raw materials and the use of building materials:* The partners involved in the mission should work together to identify which technologies and raw materials from which sources can make the construction industry more sustainable worldwide. The strategies should be developed iteratively on the basis of research into feasible raw material scenarios as well as new building materials and construction methods. In doing so, this must take into account land-use and biomass requirements for food, environmental protection and climate-change mitigation, as well as regionally different conditions in terms of resources and demographics.
- *Strengthen the supply of sustainable raw materials and the pricing of environmental costs in conventional construction in parallel:* The internalization of environmental costs (e.g. higher effective CO_2 prices for cement and steel, environmental regulations for sand) makes sustainable construction more attrac-

tive relative to conventional construction. It creates incentives for material efficiency and reuse, but also increases demand for biogenic materials, so that it should be combined with a roadmap for the massive expansion of primary forest protection, forestry certification and raw materials monitoring.

- *Strengthen education and further training for sustainable building:* In order to establish all stages of the value chain of sustainable construction worldwide, also in rural areas, the necessary knowledge must be disseminated (e.g. information on materials, construction methods, standards and certification, recycling options). A greater number of practice-oriented, inexpensive engineering and dual-training courses and advanced training in sustainable construction should be offered, and not only by industry associations.
- *Establish timber-based construction in industrialized countries – adapt regulations, promote a circular economy and sustainable public construction:* Building regulations, i.e. norms, standards and regulatory law, which often still put sustainable timber-based construction at a disadvantage, should be adapted in its favour, putting it on an equal footing with conventional construction, also in cases of renovation aimed at upgrading energy performance. This also applies to specifications and standards for promoting circular-economy approaches. The public sector should itself build exclusively sustainably and/or with wood, and in this way proactively contribute to the international dissemination and monitoring of sustainability standards in forestry.
- *Sustainable construction in developing countries and emerging economies: develop regional, sustainable building materials and construction industries:* Especially countries that require a lot of new construction or have a lot of potential for sustainable resources should be supported in the production of sustainable building materials and in the planning, construction, maintenance and reuse of regionally adapted sustainable buildings. Support should be provided to collaborations between local farmers and foresters, construction companies and R&D institutions, and linked to local investment and international trade programmes.

Bioeconomy as a whole

- *Take ecosystem conservation and the finiteness of sustainable resources seriously as preconditions of the bioeconomy:* In bioeconomy strategies, the increased use of biogenic resources and corresponding innovation funding should be explicitly linked to preconditions on ecosystem conservation, particularly to responsible land stewardship and biomass use according to specific priorities and within planetary limits. This also includes quantified, binding targets for reducing biomass consumption. Further key points are a system of binding sustainability requirements, financial incentives and raw-materials monitoring for all produced and traded biomass, as well as the consideration of distribution effects caused by changes in prices for land and biomass.
- *Fully exploit non-bio-based climate-friendly alternative technologies and adapt current biomass uses:* In order to save fossil resources without increasing demand for biomass, the main methods used should be to reduce demand, improve efficiency and use non-bio-based low-emission technologies. ‘Freed up’ biomass and land should be used primarily for the conservation and restoration of ecosystems, and only then for applications where there is a lack of low-emission alternatives or where carbon remains stored in the long term.
- *Give preference to the use of efficiency-enhancing innovations and encourage reuse:* Preference should be given to bio-based innovations and principles, such as efficiency-enhancing technologies, circular and cascading uses, above all to protect ecosystems by reducing the demand for raw materials. Existing approaches in Germany and the EU should increasingly include biomass to reduce the overall demand for primary raw materials despite the substitution of emission-intensive raw materials by biomass.
- *Embed the transition to a sustainable bioeconomy into societal transformation:* Using democratic pressure to initiate further transformation processes, (global) environmental protection and civil society, for example, should be more strongly represented in the Federal Ministry of Food and Agriculture’s Bioeconomy Council, which was reorganized in 2020. Education and training should also take on board critical perspectives on the bioeconomy. German and EU bioeconomic strategies should be synchronized with fundamental agricultural and economic-policy strategies and the programme for the yet-to-be-developed ‘new European Bauhaus’ (von der Leyen, 2020).

Research recommendations

Construction with timber

- *Improve the knowledge base and scenarios on sustainably available biogenic raw-material potential for the construction industry:* The development of a strategy for transforming construction worldwide requires the detailed documentation and forecasting of raw-material potential (e.g. timber, bamboo, papyrus). This includes production and use, substitution possibilities, ecological limits and the effects of climate change. Corresponding research on sustainable construction should be embedded into assessments of potential for the bioeconomy as a whole.

- *Further develop sustainable building materials and construction methods as well as their standardization and certification:* Research requirements relate to different biogenic materials (based on coniferous or deciduous wood, bamboo, papyrus), other non-biogenic but climate-friendly materials (clay bricks, natural stone), as well as low-emission cement. Sustainable construction methods based on such materials should take into account greenhouse-gas emissions over the entire life cycle, durability, 'reparability' and the flexible usability of buildings, and the reuse of components or materials. Institutes for construction research should be integrated into the 'Mission for Sustainable Construction' and be more strongly networked internationally.

Bioeconomy as a whole

- *Improve the documentation and forecasting of biomass supply and demand:* Monitoring biomass uses as well as supply and demand forecasts should be refined in order to analyse trade-offs between types of use, land availability and biomass production potential, while taking biodiversity and food security into account. This also applies, for example, to regional analyses of the potential of agricultural by-products or marginal farmland for the non-food bioeconomy with a view to diversifying small farmers' incomes.
- *Promote applied research specifically on sustainability-oriented areas of application and technologies of the bioeconomy:* Research and technology funding should increasingly focus on approaches that extend the 'reach' of the limited amount of biomass available. This includes research and development on reuse and recycling possibilities, efficiency potential and non-bio-based alternatives to energetic 'bridge-technology' applications of biomass. Process technologies for efficient bio-refineries should be further developed, as should biomass production by artificial photosynthesis and aquaculture.

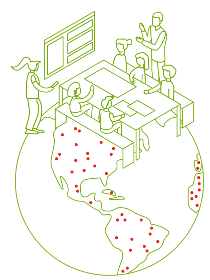
The implementation of the multiple-benefit strategies

The examples of multiple-benefit strategies presented above form building blocks for implementing the transformation of land use towards sustainability. This is best done within the framework of the integrated landscape approach, which represents more than the negotiated parallel coexistence of different land uses. The aim here is to achieve a synergistic integration of different uses – and thus also to defuse the trilemma of land use. This will require more flexible forms of planning and governance to cross existing administrative boundaries. In addition to transdisciplinary cooperation, iterative, adaptive management and continuous learning over long periods of time are also needed. However, the implementation of the multiple-benefit strategies to enable a global land-use transformation towards sustainability also requires the creation of suitable framework conditions and incentive systems through global governance.

Transformative governance for solidarity-based land stewardship

As part of the global commons, terrestrial ecosystems and their services depend on all actors assuming broad and solidarity-based responsibility. The multiple-benefit strategies offer starting points for important changes, but a global land-use transformation is a challenge that goes far beyond individual multiple-benefit strategies.

Change agents: empower actors to take responsibility



Solidarity-based consumption habits that are sensitive to the scarcity of terrestrial ecosystems are becoming increasingly widespread. In the meantime, there are numerous examples of change agents trying out new sustainable, land-related protection and use practices (Section 4.1). In order to broadly promote such pioneering activities and solidarity-based consumption, support and financial resources should be provided for networking and visibility. Across the board, appropriate framework conditions should be created to ensure true prices for land-based consumer goods as well as for educational opportunities in schools, training and further vocational education.

Recommendations for action

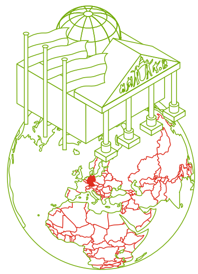
- *Promote trustworthy information provision by the state:* Consumers need information they can trust for individual decisions and actions. Lacking or contradictory information demoralizes committed consumers. It is helpful if the state consistently advocates alternatives, especially to overcome old (i.e. inappropriate in terms of sustainability) consumption practices. By consistently exercising its control functions (taxation, supply restrictions, quotas, etc.) the state also underlines its right to lay down general societal standards.

- *Make pioneers visible and provide resources for networking:* Individual actors who, in their roles as part of civil society, science or business, advocate land-use transformation by trying out new ideas, can be supported in their transformational actions by publicizing existing individual activities or initiatives, networking them and providing them with resources (e.g. funds, premises).
- *Promote sustainable education in schools, training and further education:* Education is a general prerequisite for inclusion in a changing society, for understanding problems and for developing personal norms of action. Education is also important as a resource for obtaining information (knowledge about alternative products) and the critical examination of information sources – or knowledge of trustworthy information sources. Beyond school education, the mainstreaming of new practices requires the adaptation of training plans (e.g. in the construction trade, catering) and the rapid availability of training opportunities.
- *Promote gender equity as a cross-cutting issue of land-use transformation at the federal political level:* To ensure that the German government's contribution to the global transformation of land use is gender-equitable and successful, the political mainstreaming of gender equity should be promoted; in particular, structural power differences and drivers of gender inequality in Germany and its institutions should be reduced. Economic and political inclusion are central to this. They could be promoted through gender-sensitive social policy, political and economic representation based on gender parity and anti-discrimination training for management personnel.

Research recommendations

- *Promote interdisciplinary research into the nexus of gender and environmental issues and develop multilateral indicators involving monitoring:* With the aim of strengthening the 2030 Agenda and the Rio Conventions by means of gender-environment indicators and appropriate monitoring, existing drafts (such as UN Environment and IUCN, 2018) should be built upon, taking into account not only women but also other discriminated groups. The issue of gender equity in OECD countries requires more scientific attention, not least in the context of the European Green Deal. Social-science approaches, such as feminist political ecology, can make an important contribution here and should be promoted more widely.

Proactive state: create framework conditions for solidarity-based land stewardship



The challenge for governments lies in developing a consistent system of different instruments (e.g. price incentives, voluntary and mandatory sustainability standards, spatial planning, subsidies, etc.) to support a land-use transformation not only for change agents but also for society as a whole, and to remove barriers (Section 4.2). States should ensure that both those who use the land and those who consume products produced on the land take into account the negative impacts of their actions on ecosystems and that their positive contributions to the protection or enhancement of ecosystems and their services are rewarded in society. Proceeding from a large number of partial, sectoral regulations, a system of coordinated instruments should therefore be developed that is as comprehensive as possible in terms of areas, (sectoral) biomass uses and actors, especially when demand for new uses of land and biomass is greatly increasing, e.g. as a result of higher CO_2 prices. Furthermore, particular challenges for nation-state action lie in enforcing these domestic requirements on land stewardship also at the international level (e.g. through free-trade agreements or border-tax adjustments), in order to prevent international displacements of unsustainable modes of behaviour and thus indirect land-use changes caused elsewhere. These challenges also involve identifying and cushioning distributional effects of government action and the land-use transformation in general.

Recommendations for action

- *Further develop indicators for and the monitoring of sustainable land stewardship and biomass use:* In order to document goals and strategies at different levels of governance, existing systems of sustainability indicators (e.g. on biodiversity, ecosystem services and resource consumption) should be supplemented and improved. Transparent monitoring should be strengthened at all levels of governance, e.g. through a shared open-data ecosystem that also involves citizen science.
- *Improve selected partial management approaches:* Existing instruments – ranging from voluntary certification and financial incentives to legal require-

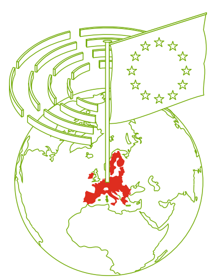
ments (e.g. relating to land use for nature conservation or groundwater protection, bans on pesticides) – should be improved on a scientific basis and consistently enforced in the interests of sustainable land stewardship. States should live up to their role-model function, e.g. in public procurement, as land and forest owners or as building contractors.

- *Develop a consistent system from partial, sectoral management approaches:* Sustainable land stewardship requires a combination of financial incentives and mandatory sustainability standards that are harmonized and extended across sectors. Existing partial regulatory and incentive instruments should be transferred into such a consistent overall system on a scientific basis.
- *Apply integrated landscape approaches in planning and land-use allocation:* The integrated landscape approach and, in particular, the possibility of using existing planning instruments such as spatial planning to plan and designate multifunctional land uses, should be integrated as a model and guiding concept into national planning law and planning activities.
- *Review trade-policy decisions more intensively with regard to their implications for land and ecosystems:* The sustainability impact of trade-policy decisions, particularly the conclusion of free-trade agreements, should be carefully examined at an early stage. On this basis and with public participation, effective regulations and control mechanisms should be sought and already decided upon during the negotiation process.
- *Back-up frameworks for sustainable land stewardship within existing possibilities of trade law:* Domestic frameworks for sustainable land stewardship should also be applied to imports. This alignment should primarily use cooperative approaches such as negotiations on regional free-trade agreements and for promoting trade in goods and services that are verifiably sustainable. However, particular countries linked by free-trade agreements should, where appropriate, make use of border-tax adjustment measures that are also possible in trade law vis-à-vis third countries.
- *Promote sustainable land stewardship through trade-law reforms:* The possibilities of countries to enforce sustainable framework conditions in their foreign-trade relations should be strengthened, for example by specifying and expanding the exceptions under World Trade Organization (WTO) law. In addition to a new understanding on trade barriers and an expansion of WTO review mechanisms, initiatives should be taken and supported to reduce harmful subsidies and promote trade in verifiably sustainable goods and services (including organic farming products and technologies for renewable energies, recycling or energy efficiency).
- *Anticipate and address distributional effects – reform subsidies, tax land rents:* Comprehensive regulatory frameworks for sustainable land stewardship lead to distributional effects as a result of existing ownership structures, land scarcity and the character of many land-based products as basic services. These effects should be evaluated at an early stage and cushioned by accompanying instruments.

Research recommendations

- *Empirical research on the impact, gaps and success factors of instruments for sustainable land stewardship:* The systematic evaluation of existing certifications, financial incentives and conditions is a prerequisite for the further development and expansion of the instruments. The evaluation of the instruments should be regularly bundled by an international panel of experts and recommendations for action derived from them.
- *Explore the potential and compatibility of multiple-benefit strategies:* Realistic global, regional and national scenarios for the coordinated use of multiple-benefit strategies should be developed and their respective contributions to mitigating the trilemma of land use determined.
- *Assess the distributional effects of political frameworks on sustainable land stewardship:* The effects of new framework conditions on land ownership and prices, and the prices and availability of foodstuffs and biomass, broken down by actor group, must be scientifically identified and quantified at an early stage on the basis of better data in order to address their distributional effect.

A transformation of land use as part of the European Green Deal



The European Union (EU), as a legal community of shared values across a largely interconnected territory, is particularly well suited for testing a land-use transformation over a large area. In this sense, the European Green Deal can be used to advance not only climate neutrality by 2050 but also a transformation in land use towards sustainability (Section 4.3). The EU also bears particular international responsibility because of the high demand for land outside of the EU induced by its relatively high consumption of resources. This can be taken into account primarily through its trade policy. The key policy for a European land-use transformation is the EU's Common Agricultural Policy (CAP). Within the EU, funds are needed not only for the greening of agriculture but also for sustainable forestry, for the establishment and expansion of protected-area systems, for restoration and the development of land-based approaches to CO_2 removal, as well as for other objectives, all of which have an impact on the quality, protection and use of land. In order to establish uniform framework conditions and funding conditions for all these concepts of land use and protection, the CAP should in future be further developed into a Common Ecosystem Policy (CEP).

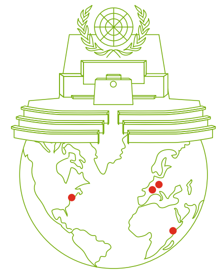
Recommendations for action

- *Transform the Common Agricultural Policy into a Common Ecosystem Policy in the medium term:* The CAP should be integrated into a CEP which provides for uniform funding conditions for sustainable land stewardship, incorporating agriculture, forestry and even urbanization. In this way, activities that lead to the avoidance of detrimental land-use changes or to the preservation of ecosystem services can be rewarded in a uniform system.
- *Strengthen sustainability standards for products that have an impact on land stewardship outside the EU:* Sustainability standards like those that already apply to the promotion of bioenergy and biofuels should be extended to other uses of biomass and made compulsory. The Renewable Energies Directive II should be supplemented by further ecological and social criteria. The ongoing revision of the EU Timber Regulation should lead to it being strengthened and tightened up where possible, in particular as regards material certification requirements.
- *Develop a quantified target for resource consumption in the EU:* In line with its climate-policy objectives, the EU should develop concrete, quantified targets for reducing its overall consumption of natural resources and lay these down as overarching goals for the circular economy. A sub-target should limit the use of biomass.
- *Gear an EU strategy for CO_2 removal towards restoration and diversified farming systems:* As part of its long-term strategy under Article 4 of the Paris Agreement, the EU should explore on a scientific basis what contributions in the form of CO_2 removal are sustainably feasible and coordinate the different approaches to CO_2 removal. It should clearly distinguish CO_2 removal from its CO_2 emissions-reduction strategy and focus in particular on low-risk, ecosystem-based approaches as part of a broad-based ecosystem policy.
- *Use EU foreign-trade policy as an instrument for taking responsibility for global land-use transformation:* The EU should make the sustainable stewardship of land a key issue in the negotiations on future – and the reform of existing – trade agreements. It should furthermore use its trade-policy clout to integrate the protection of global commons more fully into WTO regulations and promote the development and production of sustainable goods and services by reducing relevant trade barriers. Unilateral actions at its external borders should be further pursued and explored in line with the objectives of EU environmental policy.

Research recommendations

- *'Farm to Fork' – the importance of the Planetary Health Diet for European agriculture:* There should be research into the impact of changing dietary habits inspired by the PHD on European agricultural production structures.
- *Reduction of resource consumption as a political goal:* There are few concepts for the goal of reducing resource consumption or for related indicators; there is a need for research in this area.
- *A European roadmap for CO_2 removal from the atmosphere:* In addition to the necessary further technical development, there is a great need for research into the sustainable feasibility of the various possible approaches to CO_2 removal in the EU, and into their synergies and trade-offs in the course of their interaction. Linked to this, more research should be conducted on effective governance and financing mechanisms for the separate documentation of CO_2 emissions reduction and CO_2 removal. Sustainability risks and distribution issues between member states should also be comprehensively addressed.

Strengthen existing international cooperation and coordination of land stewardship



Numerous international organizations, institutions and conventions under international law are working on the global land-use transformation. The WBGU focuses here on cooperation under the Rio Conventions, on scientific appraisals of land use, and on the potential for increasingly 'glocal' interlinkage (Section 4.4).

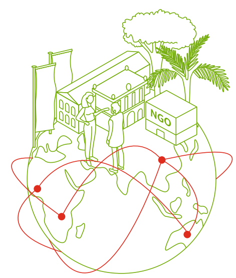
Recommendations for action

- *Convene a Global Land Summit:* A Global Land Summit should be convened in 2025 as a joint conference of the parties to all three Rio Conventions. In this way, a lot of attention can be generated and many resources made available to develop a common vision for sustainable land stewardship. This cooperation should be supported by upgrading the Joint Liaison Group, the link between the three conventions. Joint standards for safeguards should be developed for mainstreaming instruments, and uniform requirements for environmental impact assessments should be promoted.
- *Use the CBD's post-2020 framework for more powerful mechanisms*: Successes in implementing the Convention on Biological Diversity (CBD) also contribute to climate-change mitigation and sustainable land stewardship. As milestones, the WBGU recommends negotiating and implementing an ambitious post-2020 framework programme and further developing compliance. The CBD's contribution to climate-change mitigation and adaptation should be realistic and formulated in a methodologically sound manner so as not to overburden the land sector.
- *Negotiate two binding protocols on the conservation and sustainable use of biodiversity:* In the CBD, the WBGU recommends binding protocols (1) on the conservation and (2) on the sustainable use of biodiversity (as twin protocols: Protocol on the Sustainable Use of Biological Diversity and Protocol on the Conservation of Biological Diversity).
- *Combine the architecture of responsibility 'glocally':* In order to effectively address global environmental changes, local, rural and indigenous positions should not only be given a higher profile in international forums to some degree; rather, their role as knowledge carriers, transformation actors and locally affected people should be consistently strengthened and better integrated. To this end, among other things, the creation of their own network initiatives (e.g. along the lines of city networks such as C40) should be encouraged and supported, and the Global Landscapes Forum and its mandate should be further developed.

Research recommendations

- *Further develop scientific assessments on sustainable land stewardship:* The synthesis potential of the existing global progress reports should be used for an overarching assessment, and options for a separate mandate should be considered. In addition, local solutions and process knowledge for implementation at the landscape level should also be scientifically examined and processed in a globally coordinated assessment.
- *Identify options for 'glocalizing' global sustainability policies:* One important task is to integrate hitherto under-represented groups of actors into the diversifying global sustainability policy. Options and conditions for the success of strong multi-actor partnerships (SDG 16) in an increasingly polycentric governance architecture should be identified scientifically and co-creatively with practice partners.
- *Develop regional transformation hubs for researching and testing an integrative land-use transformation in practice:* The valuable approach of regional research and competence centres should be expanded to research and, with a practical orientation, test regional approaches to sustainable land stewardship in the context of systemic references to the crises of climate, biodiversity and food as transformative challenges.

Three new multilateral cooperation alliances for promoting a global land-use transformation



Existing forums for a global transformation of land use are indispensable. To enable rapid progress, they need to be strengthened and, in addition, new forms of cooperation set up. The WBGU therefore recommends the establishment of new cooperation alliances by like-minded states and subnational regions (Section 4.5).

- *Regional alliances for cross-border implementation of integrated landscape approaches:* Regions should cooperate more closely institutionally as neighbours to make cross-border land uses possible, e.g. in the form of the proposed multiple-benefit strategies. Regional alliances of sub-national regions can, for example, establish regional circular economies and value chains, further develop existing biosphere reserves into forerunners of integrative landscape areas, or set up regional innovation hubs for sustainable farming methods.
- *Supranational alliances for a global land-use transformation:* The purpose of these globe-spanning supranational alliances is to unite countries that want to jointly pursue sustainable land stewardship and sign agreements on common values and regulations to achieve this aim, e.g. common production standards. Member states of these alliances can be spread over different regions of the world. They become effective by transferring specific sovereign powers to the alliance, following the EU model.

These powers can be enforced vis-à-vis the member states by alliance institutions. Such supranational alliances can form pioneering alliances for sustainable global agricultural trade, jointly implement transparent and sustainable supply chains, and effectively advance a Green Deal globally.

- *Global conservation alliances to protect and restore valuable ecosystems:* These alliances of states and other – also private – actors join forces with the aim of conserving and restoring valuable ecosystems in third countries, which should also be members of the conservation alliance. Conservation alliances can, for example, jointly lease such areas and, in this way, move beyond the often passive role of being mere 'donor countries' and inclusively assume joint responsibility together with local actors.

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Glossary

7

2030 Agenda for Sustainable Development
was unanimously adopted by the UN General Assembly in 2015. With the 2030 Agenda, the global community set itself 17 goals (→ Sustainable Development Goals, SDGs) for socially, economically and ecologically sustainable development. The 17 goals apply equally to all countries. They range from eradicating global hunger to strengthening sustainable consumption and production and to climate-change-mitigation measures. The 2030 Agenda is not binding under international law.

Afforestation
is the conversion into forest of an area of land that was not previously forested.

Agrobiodiversity
is the → biodiversity that maintains elementary functions, structures and processes of agricultural → ecosystems. It includes the diversity and variability of animals, plants and microorganisms at the level of genes, species and → ecosystems.

Agroecology
links traditional-local empirical knowledge with scientific findings. The aim of agroecology is a socio-ecological transformation of the entire → food system from production to consumption. The antithesis of industrial agriculture, agroecology aims at small-scale, diversified farming systems and focuses on optimizing nutrient cycles, boosting → ecosystem services and resilience (IAASTD, 2009).

Agroforestry
includes both traditional and modern land-use systems where trees are cultivated alongside crops and/or livestock-production systems in agricultural environments (FAO, 2015a).

Anthropocene
means the 'age of humankind' and is partly derived from the concept of geological ages like the Palaeocene or the Holocene. The term was coined in 2000 by Nobel prize winner Paul Crutzen together with Eugene Stoermer and refers to a geological era in which the impacts of human activities on the environment have reached a global dimension. This leads to – in some cases considerable – changes in → ecosystems, even to the extent of their destruction. The most important changes caused by humans also include climate change and ozone-layer depletion in the Antarctic (Crutzen and Stoermer, 2000).

Biodiversity
→ Biological diversity

Bioeconomy
is the generation, exploitation, use and conservation of biological resources, processes, principles and systems in order to provide products, services, procedures and knowledge in all sectors of the economy. A sustainable bioeconomy requires responsible management of the totality of globally used and unused terrestrial and marine → ecosystems within → planetary guard rails, which sustains and protects the natural life-support systems, the societal inclusion of all people, *Eigenart* (individuality) and diversity, and thus human dignity.

Biological diversity
"means the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic → ecosystems and the ecological complexes of which they are part; this includes diversity within species and between species, and of → ecosystems" (CBD, 1992: Article 2).

Biomass
refers to "the mass of non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms in a given area or volume" (IPBES, 2018a).

Bonn Challenge
is a global initiative launched in 2011 by the International Union for Conservation of Nature (IUCN) and Germany, and later extended by the New York Declaration on Forests, to restore 350 million hectares of the world's deforested and degraded land areas by 2030. In the first phase, 150 million hectares of degraded forest land was to be restored by 2020 (Bonn Challenge, 2020).

Carbon capture and storage (CCS)
refers to technical processes for capturing CO_2 from waste-gas streams that stem from fossil- or biomass-based energy generation or industrial processes and storing it in geological formations.

Carbon reservoir
→ Carbon sink

Carbon sink
refers to a reservoir that temporarily or permanently absorbs and stores carbon. The term should not be confused with a carbon reservoir. While a reservoir (or store) can also be static, meaning it contains a certain amount of carbon, sinks are dynamic, meaning they are reservoirs whose stored carbon is growing, e.g. young forests.

Cascade use
refers to multiple uses of a raw material or product in which "a raw material is processed into a final product and this final product is used at least once more either for material or energy purposes" (UBA, 2017a). The raw-material intensity and thus, as a rule, the environmental intensity of the value added can be improved by passing the same raw material through several use phases and different functions, and by recycling it comprehensively.

Citizen science
"involves the active participation of citizens at various stages of the research process in the humanities, natural sciences and social sciences. Participation ranges from generating questions and developing a research project, to data collection, scientific evaluation and the communication of research results" (Bonn et al, 2016).

COVID-19
is an infectious disease that can be caused by the coronavirus SARS-CoV-2. It was first described in Wuhan, China in 2019 and developed into a pandemic in 2020. COVID-19 is an acronym for 'Coronavirus Disease 2019'.

Decarbonization
describes the transition process from high-carbon energy sources (coal) to less carbon-intensive (oil and natural gas) and increasingly to CO_2-emissions-free energy generation (solar, wind and hydroelectric power).

Desertification
is → land degradation in arid, semi-arid and dry sub-humid areas.

Dietary habits
are the habitual choices that an individual or culture makes when choosing food. Every culture and every person has food preferences or taboos. These can be due to personal taste or for ethical reasons (e.g. sustainability, animal welfare). Dietary habits and choices play a significant role in quality of life, health and life expectancy (Journal of Childhood Obesity, 2020).

Digitalization
refers to the development and application of digital and digitalized technologies that dovetail with and augment all other civilizational technologies and methods.

Diversified farming systems
comprise agricultural production methods that, by increasing the number of crop species in the form of spatial mixing or successive crop rotations, minimize production risks, improve adaptation to climate change, strengthen → ecosystem services, conserve genetic diversity, recouple crop production with livestock farming, and thus also promote a varied diet.

Ecological intensification
aims to maximize productivity while strengthening and maximizing the use of → ecosystem services.

Ecosystem
"means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (CBD, 1992: Article 2).

Ecosystem restoration
is a measure aimed at enabling the substantial recovery or rewilding of a once existing → ecosystem that has been degraded or destroyed. However, restoration does not mean returning to a kind of original or ideal state. Rather, it is about sensibly designing the management of terrestrial → ecosystems and keeping it within sustainable limits, while at the same time making a contribution to climate-change mitigation and adaptation. Examples of restoration are → reforestation,

the rewetting of peatlands and the rehabilitation of grassland ecosystems.

Ecosystem services

denote the benefits that humans derive from → ecosystems. There are 18 ecosystem services, which are categorized as regulating, material, non-material (Table 2.1-1). In this report, the terms 'ecosystem services' and 'nature's contributions to people' (NCP) are used largely synonymously.

External costs

are costs that are incurred outside of a system under consideration (Feess and Günther, 2018), e.g. social or environmental costs caused by an actor's activities, but do not have to be borne directly by that actor and are not taken into account in the actor's decisions.

Food security

is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (CGIAR, 2020).

Food system

comprises the totality of activities from the production to the consumption of food. This includes the services from upstream and downstream sectors of agriculture, as well as the environmental, societal and economic impacts of these activities. The climate and biodiversity crises are greatly influenced by the food system or themselves influence the system.

Global governance

encompasses the overall system of institutions, public and private actors, formal and informal governance processes, as well as binding and voluntary regulatory instruments for dealing with global sustainability problems (Pattberg and Widerberg, 2015).

Great Transformation towards Sustainability

is, according to the WBGU (2011), a comprehensive societal change towards sustainability involving a restructuring of national economies and the global economy within → planetary guard rails in order to avoid irreversible damage to the Earth system and → ecosystems and the effects this would have on humanity.

Ground rent

is an economic rent paid for land, which is a scarce commodity. An economic rent is when more is paid for a good than the amount required to provide it. As a biological system, land is either productive in itself (even if productivity can, in some cases, be increased by humans) or available solely as building land, depending on its location; however, the amount of land that can be used economically, e.g. for agriculture or building, is limited (geographically, administratively or, in the long term, ecologically). Therefore, the use of land, after deducting other costs of labour and capital, or its lease, can yield scarcity rents; these are called ground rents. The level of private ground rents, which are often highly concentrated, is greatly influenced by public action (e.g. infrastructure, spatial planning). Taxing these rents is often considered particularly efficient (Stiglitz, 2015; Mattauch et al., 2018; Schwerhoff et al., 2020), as it hardly changes the overall supply of land.

Humus

refers to the totality of the finely decomposed organic matter of a soil. The living organic matter consists of plant roots, soil animals and microbial biomass, while the dead organic matter is formed by the chemical and biological decomposition of organic residues (NN, 2008).

Industrial agriculture

is characterized by the large-scale, highly mechanized (digitalized) intensive cultivation of high-yielding crop varieties with narrow crop rotations, factory farming and the use of large quantities of inputs from outside of the farm, i.e. decoupled from the farm (→ mineral fertilizers, liquid manure, pesticides). Within the framework of value chains, it is geared towards processing, sales and exports. High levels of capital investment, specialization and standardization are further characteristics of this form of agriculture.

Integrated landscape approach

→ Landscape approach, integrated

Land degradation

refers to a worsening of the state of terrestrial ecosystems caused by direct or indirect human-induced processes, including anthropogenic climate change. The meaning of land degradation is broader than that of → soil degradation, as it also encompasses all negative changes in the capacity of the → ecosystem to provide goods and services (e.g. biological, water-related, land-related, social; van Diemen et al., 2019).

Land degradation neutrality (LDN)

"is a state whereby the amount and quality of land resources necessary to support → ecosystem functions and services and enhance → food security remain stable or increase within specified temporal and spatial scales and → ecosystems" (UNCCD, 2015). LDN was included in the catalogue of → Sustainable Development Goals (SDG 15.3) in 2015.

Land management, sustainable
is "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (FAO, 2020).

Landscape approach, integrated
is a design concept comprising ecological, spatial-planning and governance aspects. At its core is the compatibility of competing forms of land use as well as the interests and – in some cases culturally influenced – values of stakeholders in the ecological and cultural context of the landscape.

Land-use transformation, global
according to the WBGU, this refers to the necessary global transformation of land stewardship and terrestrial → ecosystems towards sustainability.

Mineral fertilizer
is often also called artificial fertilizer; are substances for application in fields and crops and is produced by chemical synthesis (ammonia synthesis, Haber-Bosch process) using fossil fuels. Mineral fertilizers usually consist of nitrogen, phosphorus and/or potassium. Their application in the field is intended to increase the growth rate and productivity of plants. Mineral fertilizers do not contain carbon (Eurostat, 2019).

Monoculture
is the cultivation of the same crop in pure culture, i.e. without any simultaneous mixing with other crops and without staggered crop rotation.

Multiple-benefit strategies
are examples of strategies proposed by the WBGU which, in the context of land use, target several concomitant benefits and can contribute to defusing competition for the use of land.

Negative emissions
refers to the deliberate removal of CO_2 or, where appropriate, other greenhouse gases from the atmosphere by human activities, i.e. in addition to the removal that occurs through natural carbon-cycle processes.

Net primary production
describes the amount of carbon that → ecosystems accumulate through photosynthesis, minus the carbon released by plant respiration.

Organic farming
is a system alternative to conventional and → industrial agriculture. A key element is the closing of nutrient cycles by using the farm's own fertilizers and feedstuffs, by placing limitations on livestock concentration and/or by observing crop rotations. → Mineral fertilizers and synthetic chemical pesticides are not used in organic farming, and yields are 5–25% lower than in conventional farming, depending on crop type, location and management. The higher product prices are justified by this fact and by the higher labour input.

Payments for ecosystem services (PES)
are aimed at financially rewarding the promotion or maintenance of → ecosystem services according to the advantages and benefits derived by third parties or the general public. Their area of application is correspondingly broad and includes the conservation, → restoration and sustainable use of → ecosystems.

Pesticides
are chemical substances that are toxic for undesirable organisms such as insects (insecticides), rodents (rodenticides), fungi (fungicides) or plants (herbicides).

Planetary guard rails
are quantitatively defined damage thresholds which, if breached, would have intolerable or even catastrophic consequences. They are scientifically deduced, but always contain an evaluating component. One example is the climate-protection guard rail, according to which an increase in the global mean temperature by more than 2°C above the pre-industrial level should be prevented. Sustainable development pathways do not breach these guard rails. The approach is based on the realization that it is hardly possible to define a desirable, sustainable future in terms of a state to be achieved. It is, however, possible to agree on the definition of an area that is recognized as unacceptable, and which society wishes to avoid. Compliance with the guard rails is a necessary, but not sufficient, criterion for sustainability.

Planetary Health Diet (PHD)
is a nutrition portfolio developed by the EAT-Lancet Commission (Willet et al., 2019) that is consistent with sustaining the natural life-support systems and human health. The Planetary Health Diet is flexible in that it provides guidelines for different food groups which

together represent optimal nutrition for human health and environmental sustainability. It consists largely of vegetables, fruit, whole-grain products, pulses, nuts and unsaturated oils, contains a small to moderate amount of fish and poultry, and little or no red meat, processed meat, added sugars, refined grains or starchy vegetables.

Proactive state
is a state that creates framework conditions which comprehensively promote innovation for sustainable development, and which demand and support the assumption of responsibility by all actors. In doing so, it should perform its function in such a way as to promote consultation, co-determination and participation opportunities for civil society.

Protected area
"is a clearly defined geographical space, recognized, dedicated and managed through legal or other effective means, to achieve the long-term conservation of nature with associated → ecosystem services and cultural values" (IUCN, 2008).

Reducing Emissions from Deforestation and Forest Degradation (REDD+)
is the forest conservation and afforestation programme under the UN Framework Convention on Climate Change. REDD+ aims to reduce emissions from deforestation and forest degradation and to promote forest conservation, sustainable forest management and the enhancement of forest carbon stocks in developing countries.

Reforestation
is the conversion of an area of land that was previously forested back into forest.

Smallholder agriculture
includes arable farming, livestock farming, forestry and fishing; it is typically family-based and uses predominantly family labour; the family derives a large but variable proportion of their income from this work. Arable plots are smaller in size, and crop rotations are typically wider (diversified), as some of the farm's own feed is used (HLPE, 2013).

Soil degradation
is the permanent or irreversible alteration of the structure and functions of soils resulting from physical and chemical or biotic pressures that exceeds the resilience of the respective systems. The most widespread form of soil degradation is soil erosion, i.e. the removal of soil by water and wind or tillage.

Sustainable Development Goals (SDGs)
→ 2030 Agenda

Sustainable Land Management (SLM)
→ Land use, sustainable

System of protected areas
is a system made up of → protected areas. According to Aichi Target 11 of the Convention on Biological Diversity, it should meet the following criteria: it should be (1) effectively and equitably managed, (2) ecologically representative, (3) well connected, and (4) integrated into the wider landscape.

Telecoupling
are remote effects that refer to socio-economic and ecological interactions over large distances. It encompasses the long-distance exchange of information, energy and matter (e.g. people, goods, products, capital) at different geographical, temporal and organizational levels. In agriculture, for example, the high demand for soybeans or palm oil in the EU is met by cultivation in the producer countries such as Brazil and Indonesia, and this involves high environmental costs. Agricultural production there leads to high levels of environmental damage due to inadequate enforcement of environmental regulations.

Trilemma of land use
according to the WBGU, this refers to competition over land use that arises between the needs of climate-change mitigation, food security and the conservation of → biological diversity. The trilemma arises when one of the three crises can only be managed at the expense of the other two. → Land degradation has a negative impact on all three aspects in the short or long term. Reversing the trends of the increasing destruction of terrestrial → ecosystems and → land degradation is therefore a *sine qua non* for defusing the land-use trilemma.

Zoonoses
are diseases that are transmitted from animals to humans.

Rethinking Land in the Anthropocene: from Separation to Integration

Only if there is a fundamental change in the way we manage land can we reach the targets of climate-change mitigation, avert the dramatic loss of biodiversity and make the global food system sustainable. The WBGU proposes five multiple-benefit strategies illustrating ways of overcoming competition between rival claims to the use of land. These should be promoted by five governance strategies, especially by setting suitable framework conditions, reorienting EU policy and establishing alliances of like-minded states.

“The German Advisory Council on Global Change’s recent report, ‘Rethinking Land in the Anthropocene: from Separation to Integration’, makes it abundantly clear that we need a fundamental change in how we manage the land to limit climate change, reverse biodiversity loss and create sustainable food systems. Healthy land is finite, but changes in consumer and corporate behaviors, combined with better land use planning and management, can help meet the demand for essential goods and services without compromising land resources. This report presents a clear path toward climate change mitigation, ecosystem protection and food systems sustainability through better land management.”

Ibrahim Thiaw, Executive Secretary of the United Nations Convention to Combat Desertification (UNCCD)

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