PBL Netherlands Environmental Assessment Agency

INSIGHTS FROM GLOBAL ENVIRONMENTAL ASSESSMENTS

LESSONS FOR THE NETHERLANDS

Paul Lucas, Timo Maas and Marcel Kok

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Insights from Global Environmental Assessments: Lessons for the Netherlands

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Corresponding author
Paul Lucas [paul.lucas@pbl.nl]

Authors
Paul Lucas, Timo Maas and Marcel Kok

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Insights from Global Environmental Assessments

Synthesis of Global Environmental Assessments

Challenges surrounding global environmental change feature prominently in international discussions and global conventions and agreements, such as the 2030 Agenda for Sustainable Development, the Paris Agreement and current discussions on a new global biodiversity framework. The Netherlands has committed itself to these conventions and agreements and thereby to achieving their goals and targets. Global Environmental Assessments, such as those produced by the Intergovernmental Panel on Climate Change (IPCC), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the United Nations Environment Programme (UNEP) organise existing scientific information on environmental issues in a format that is useful for the decision-making process. However, as such assessments generally have a global focus, their results are not directly applicable in a national context (e.g. here the Netherlands). In addition, many assessments have different thematic foci while also overlapping in some areas, which raises the question of what common messages arise from the assessments.

At the request of the Dutch Ministries of Foreign Affairs and of Infrastructure and Water Management, this study synthesises five environmental assessments, published between 2017 and 2019 (Table 1), and draws lessons for both domestic and foreign Dutch sustainable development policies. The focus of the synthesis is on three environmental challenges that are central to the assessments (i.e. climate change, land degradation and loss of biodiversity and ecosystem services) and related Dutch policy agendas addressing sustainability transitions: (i) the national climate agreement; (ii) the government vision on agriculture, nature and food; and (iii) the government-wide programme for a circular economy. Policy lessons drawn from the five assessments are linked to lessons from recent PBL publications to inform Dutch policymakers in support of their efforts to further develop and implement these national policy agendas and contribute to achieving the internationally agreed environmental goals and targets.

Table 1

Main characteristics of the five assessments

	Global Land Outlook: first edition	Global Warming of 1.5 °C	Global Environment Outlook 6	The Global Assessment Report on biodiversity and ecosystem services	Global Resources Outlook 2019
Environ-mental focus	Land and land degradation	Climate	Air (incl. climate), biodiversity, oceans, land and freshwater	Biodiversity and ecosystem services	Climate, air, water and biodiversity
Requested by	Secretariat of the United Nations Convention to Combat Desertification (UNCCD)	25th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC)	First session of the United Nations Environment Assembly (UNEA-1)	Second session of plenary meeting of the Intergovern-mental Science–Policy Platform on Biodiversity and Ecosystem Services (IPBES)	Second session of the United Nations Environment Assembly (UNEA-2)
Coordination	UNCCD	Intergovern-mental Panel on Climate Change (IPCC)	United Nations Environment Programme (UNEP)	IPBES	International Resources Panel (UNEP-IRP)
Link to global conventions and agreements	UNCCD; 2030 Agenda for Sustainable Development (Agenda 2030)	UNFCCC; Paris Agreement; Agenda 2030	Various Multilateral Environmental Agreements; Agenda 2030	United Nations Convention on Biological Diversity (CBD); Strategic Plan for Biodiversity 2011–2020; Agenda 2030	Agenda 2030

A unanimous call for urgent action

While the five assessment reports focus on different areas of sustainable development, they all convey a clear and unanimous message of urgency in addressing global environmental change. Over the last few decades, global environmental change, such as climate change, land degradation and loss of biodiversity and ecosystem services, has increased, and for some issues even accelerated (e.g. species extinction and loss of coral cover on reefs). Energy systems, food and agricultural systems and resource extraction and processing are largely responsible for these changes, driven by an increasing demand for energy, food and materials. Impacts can already be observed and disproportionately affect poor communities and vulnerable groups worldwide. Furthermore, high-income countries have increasingly outsourced their footprint to middle- and low-income countries.

The assessments show that, without additional effort, environmental changes may be expected to continue, resulting not only in many internationally agreed environmental goals and ambitions remaining unmet, but also increasing the risks to human well-being and achieving the Sustainable Development Goals (SDGs). Under full implementation of the nationally stated climate mitigation ambitions (NDCs) the global mean temperature is set to increase by around 3 °C above pre-industrial levels by 2100 (the Paris Agreement aims for well below 2 °C), business-as-usual scenario projections show a continuation of land-use change and loss of soil organic carbon (SDG3.2 aims for Land Degradation Neutrality), and even scenarios with low population growth, effective international cooperation and a policy orientation towards sustainable development, show a continuation of the decline in biodiversity and ecosystem services (the vision of the Strategic Plan for Biodiversity 2011–2020 is that biodiversity is valued, conserved, restored and used wisely).

The assessments conclude that a clear break with current trends is required and that the coming decade is crucial for initiating the required transitions — the Decade of Action called for by the United Nations. Not only because the SDGs have to be achieved by 2030, but also to create the right conditions for achieving the long-term ambitions of, for example, the Paris Agreement and the forthcoming post-2020 Global Biodiversity Framework. The assessments further conclude that acting now is often less expensive and intrusive than cleaning up later. The challenges arising from delayed climate action include greater overall impacts for people and nature, rising costs, the lock-in in carbon-emitting infrastructure, stranded assets, and diminished flexibility in future response options, while at some point the Paris Agreement goal might even become impossible to achieve. In terms of nature, once lost, some ecosystem services are irreplaceable (e.g. wild pollination), while for others replacement through built infrastructure can be extremely expensive (e.g. coastal mangroves for flood protection).

Targeting the root causes of environmental degradation

The assessments show that achieving many of the goals the international community has agreed upon is still possible but that this requires fundamental changes in the technological, economic, social and political factors underlying the drivers of unsustainable development. These changes are considered unprecedented, far-reaching, systemic and structural, and need to take place rapidly. Commonly they are referred to as transformative change, transformation, or transition. This message is not new but the timeframe in which to make these changes and achieve internationally agreed environmental goals is shrinking, along with the flexibility in response strategies.

To enable these fundamental changes, the assessments stress that policies should address not only the systems or activities that directly impact the environmental (e.g. energy production and use, agriculture, resource extraction and processing), but also their indirect drivers, or ‘root causes’. These indirect drivers include consumption patterns, population growth, inequality, international trade, technological innovation and finance systems, which are embedded in societal values, behaviour and governance. Successful interventions have to go beyond traditional environmental policies and include mainstreaming environmental concerns throughout the various policy-making domains.

The assessments highlight the need to refocus the currently predominant well-being paradigm based on material consumption and economic growth, to reflect the much wider set of aspects that affect people's well-being. In practice, this could be spurred by developing new ways of measuring progress (i.e. beyond GDP) and integrating these into decision-making processes to strengthen the balancing act of achieving social, environmental, and economic objectives. To stimulate more sustainable choices in production and consumption along the whole supply chain, they further stress the need to reform or remove environmentally harmful subsidies and modify the financial and non-financial incentives for consumers, business and governmental organisations, including in international trade.

Addressing interlinkages between environmental challenges

Climate change, land degradation, and loss of biodiversity and ecosystem services are highly interconnected. Not only do they reinforce each other and share similar root causes, the available solutions also make them closely intertwined. A broad range of behavioural, technological and management measures are put forward in the assessments, many of which are already available. While achieving the internationally agreed goals requires measures in all of these categories to be taken, different portfolios face different implementation challenges and have different potential synergies and trade-offs across environmental challenges and, more broadly, sustainable development as well. A shift away from resource-intensive lifestyles (e.g. reduced meat and dairy consumption, reduced energy demand, and low material consumption) is emphasised as highly synergistic across various environmental and human development objectives. Other highlighted measures with strong synergies include improving resource efficiency, air pollution control and land and ecosystem restoration. Conversely, the assessments discuss trade-offs between sustainability objectives associated with specific technologies. Most notably they point to land-based climate mitigation measures (e.g. the use of bioenergy with or without carbon capture and storage, and afforestation and reforestation) and related competition with other land uses, such as food production and biodiversity. Furthermore, they point to agricultural intensification that, if not done sustainably, could increase water and nutrient use with attendant environmental impacts.

How synergies and trade-offs manifest themselves, in practice, depends to a large degree on aspects specific to the implementation context, including the extent to which issues are mainstreamed to provide cross-cutting options and possible win-wins. The assessments generally do not specify these aspects in any detail but provide only overall considerations. In general, seizing on synergy and avoiding or mitigating trade-offs requires greater policy integration and coherence, and policy interventions that address systems (e.g. energy system, food and agriculture system) rather than individual environmental concerns. A long-term vision grafted onto principles of robustness and resilience will help to align policies throughout different sectors and systems, the various tiers of government and different types of actors, while creating space for adaptivity and policy experimentation.

Technology versus changing consumption

Compared to earlier assessments, the five covered in this study pay much more attention to the contribution of changing consumption patterns (i.e. a shift away from resource-intensive lifestyles) towards achieving environmental goals. Consumption change has strong synergies with achieving environmental and well-being objectives. Furthermore, there is wide recognition in the assessments that certain technologies come with significant trade-offs. The scale and urgency of the transformations required to achieve the internationally agreed environmental goals means that both technology (new and existing) and consumption change are required. Portfolios of measures may differ in their relative emphasis on the two, reflecting underlying assumptions and preferences about what contributes to human well-being, as well as in how to address intra and inter-generational equity.

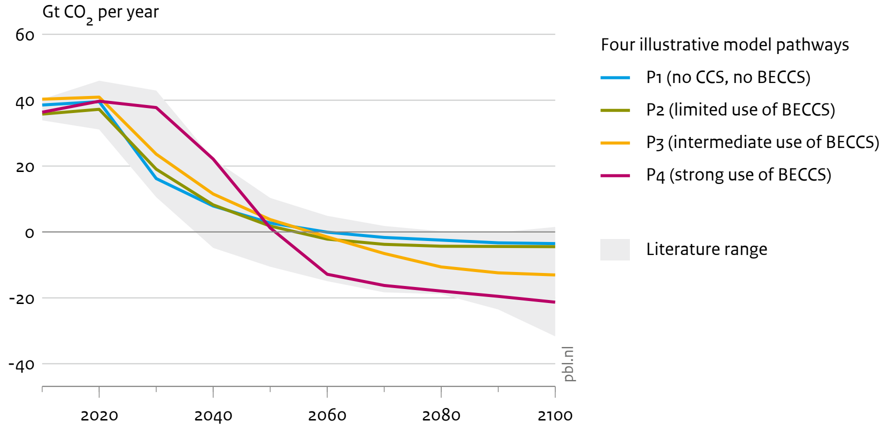
Portfolios with a strong emphasis on technology require a relatively modest change in material consumption, and thereby people's well-being paradigm, but risk techno-optimisation and narrowing the solution space available to future generations. Such portfolios include technologies that face multiple feasibility constraints, including economic and technological, as well as social acceptability (e.g. carbon capture and storage, onshore wind and bio-industry). Several technologies are also associated with trade-offs with other sustainability objectives when deployed on a large-scale (e.g. bioenergy).

Conversely, portfolios with a strong emphasis on changing consumption patterns are less reliant on uncertain technologies but require relatively major changes in current well-being paradigms. Specifically, they imply that current generations with a large environmental footprint must change their consumption significantly to reduce environmental pressures and create space for future generations, as well as for people in middle- and low-income countries to develop further. While behaviour and lifestyle-related measures have led to emission reductions around the world, policies that successfully modified dietary choices remain limited and globally the demand for meat is still increasing.

Balancing near-term climate action with long-term deployment of carbon dioxide removal

The timing of emission reductions to achieve the Paris Agreement's objective of keeping the global mean temperature at well below 2 °C greatly affects the need for consumption change and technological innovation, respectively. The underlying governance decision centres around rapid near-term action versus large-scale carbon dioxide removal (CDR) later this century (Figure 1). More lenient emission reductions in the short term will require very rapid reductions later in the century, followed by the large-scale removal of carbon dioxide emissions from the atmosphere to compensate for excess emissions earlier in the century. The CDR technologies discussed in the assessments include bioenergy in combination with carbon capture and storage (BECCS), afforestation and reforestation, soil carbon sequestration and other land conservation, restoration and management options, enhanced weathering of minerals, direct air carbon capture and storage (DACCS), and ocean fertilisation.

Figure 1
Net anthropogenic CO_2 emissions in pathways limiting global warming to 1.5 °C



Source: IPCC Global Warming of 1.5 °C

These technologies differ widely in terms of maturity, potential and risks, while several technologies have significant impacts on land, energy, water and nutrients when deployed on a large scale. For example, BECCS and afforestation and reforestation require land and therefore compete with other land uses, negatively impacting food security and biodiversity. The restoration of natural ecosystems and soil carbon sequestration do not require land-use change and can have co-benefits, such as improved biodiversity, soil quality and local food security. A mix of CDR options can reduce negative impacts and increase the likelihood of limiting global warming to 1.5 °C. Effective governance is needed to limit trade-offs and ensure the permanence of carbon storage in terrestrial, geological and ocean reservoirs. If large-scale CDR deployment is to be limited, or even avoided, deeper near-term emission reductions are required, combined with more pronounced consumption changes (including reduced energy demand, reduced food waste and reduced meat and dairy consumption).

More attention for land governance

Many environmental challenges centre on land, and achieving many of the internationally agreed environmental goals will depend on how land is managed, used, protected and governed. Competition for land globally was a new theme discussed in assessments 10 years ago. The assessments discussed here conclude that global pressures on land have further intensified and without additional effort will continue to increase, with causes and consequences spilling over national borders. This increase is primarily driven by the growing demand for land-based products (e.g. food, wood, bioenergy), exacerbated by land degradation and climate change. At the same time, many of the solutions put forward in the assessments to address environmental change require land, including for land-based climate mitigation (e.g. bioenergy, afforestation and reforestation), for the conservation of land, biodiversity and ecosystem services, and for nature-based solutions. Sustainable intensification, agro-ecological approaches and limiting or changing agricultural demand (reduced meat and dairy consumption, reducing food losses and waste, and limiting biofuel demand) are put forward as broad strategies to reduce pressure on land, while all of these face significant implementation challenges when applied on a large scale. To address the multiple claims on land the assessments specifically discuss integrated landscape and spatial planning approaches for the protection, management and restoration of land. Restoring agricultural and natural areas contributes to achieving multiple societal objectives, such as ensuring food and water security, climate mitigation and adaptation, as well as resilience and improved livelihoods. Overall, the continued pressure on land requires that more attention be devoted to land governance at local, national and international levels, especially in regions where this is currently underdeveloped. The attention devoted to land in the assessments is not reflected in global governance in the same way as it is for climate change and biodiversity loss.

Lessons for the Netherlands

In the Netherlands, too, environmental problems are systemic and persistent. Despite policy efforts undertaken and progress made, greenhouse gas emission levels are still high, livestock farming is reaching its ecological and social limits, biodiversity is under great pressure, and the use of raw materials is causing significant environmental pressure. The Netherlands' nitrogen surplus is among the highest in the EU, while the Netherlands scores the lowest on environment-related SDGs. Furthermore, Dutch consumers have a relatively high and, for some indicators, growing environmental footprint with large environmental impacts abroad, including outside the EU. The Netherlands' nitrogen crisis has shown the urgency of improving the sustainability of the food and agriculture system, while the COVID-19 pandemic and the related green recovery discussion shows that a systemic approach to tackling environmental challenges is warranted.

Based on the key insights of the assessments, some overall lessons can be drawn to strengthen Dutch policy agendas addressing sustainability transitions: (i) the national climate agreement; (ii) the government vision on agriculture, nature and food; and (iii) the government-wide programme for a circular economy. Overall, the visions and policy targets of the three agendas require further elaboration, with clear policy choices on long-term and transboundary effects. The three agendas could put more emphasis on policy coherence between the agendas, transboundary effects, consumption change, and equity and inclusiveness (both nationally and internationally). Finally, combining international cooperation with national action and more active use of the concept of overall well-being and the SDGs in national policy-making can increase effectiveness and help improve coherence between the three policy agendas, with other sustainability objectives and with international policy efforts.

Make clear policy choices on long-term and transboundary effects

The shrinking solution space for addressing global environmental change underlines the need for a clear long-term vision and related policy choices on long-term and transboundary effects. As part of discussions on strengthening climate and energy policy, a discussion could be started, both within the EU and internationally, on if and how much CDR would be desirable. If CDR is to be widely used, criteria could be defined under which it is considered acceptable. Furthermore, this requires the timely development and deployment of these technologies. If large-scale CDR deployment is to be limited while still aiming for a global mean temperature increase of well below 2 °C, the 2030 reduction target has to be tightened, and a shift away from resource-intensive lifestyles will become more important to deliver medium-term emission reductions.

The policy targets for the vision on agriculture, nature and food, and on the circular economy require further elaboration to steer their respective transitions. Progress towards more sustainable agriculture requires more specific political choices about what values agriculture should serve and what nature is desired. Recent ambitions to halve the Netherlands' ecological footprint and fully achieve the EU Birds and Habitats Directive, both by 2050, offer guidance. For the circular economy the interim target of halving the use of primary abiotic resources by 2030 requires further development. This includes deciding whether it also applies to fossil fuels, applying a footprint approach to provide insight into total resource use in the whole value chain (including environmental pressures abroad) and taking a production and a consumption perspective, as both provide relevant entry points for policy. The current focus on aggregate material input will not necessarily reduce environmental impact and supply security risks, which is the underlying rationale of the government-wide programme.

Increase policy coherence across the three agendas

Greater coherence and integration across the three policy agendas is warranted.
An integrated policy approach, as called for by the assessments, does not necessarily mean one overall decision-making process cutting across all agendas but rather requires dedicated processes where significant cross links may be expected. This includes ensuring that policy choices on trade-offs are made explicit and that synergistic implementation is promoted. Entry points to coherence are the indirect drivers, or 'root causes', of environmental change, including lifestyle and behaviour, international trade and finance. Coherence could also be sought through shared challenges, such as around biomass and land use.

Integrate external environmental footprints in the agendas

Addressing the Dutch environmental footprint beyond national borders in the three policy agendas can help to recognise environmental pressures abroad and avoid burden shifting. The government's new ambition to halve the ecological footprint of Dutch consumption by 2050 needs to be made more concrete before coherent polices can be formulated and implemented. Addressing external environmental footprints requires that responsibilities for environmental and social issues in sourcing areas outside the Netherlands are integrated into environmental policies. Instruments include certification schemes and area-based approaches, as well as greater transparency of supply chains. Reducing environmental footprints requires both production-related measures as well as changes in consumption patterns.

Place more emphasis on consumption change
The three policy agendas could put more focus on changing consumption patterns (e.g. reducing meat and dairy consumption and lowering material consumption). Consumption changes are highly synergistic with various environmental and human development objectives and can help to reduce dependence on technology. However, they require behavioural changes and overcoming the 'throw-away culture', which is challenging as it requires that people change their worldview and notions of a good quality of life. As consumption patterns are largely determined by social routines and changes in routines do not happen overnight, policies addressing consumption change should start sooner rather than later.

Specifically address equity and inclusiveness
As transitions inevitably involve 'winners' and 'losers', successful transitions require navigating equity and inclusiveness considerations, both domestically and internationally. This includes the fair distribution of costs and benefits (within and between countries), as well as ensuring societal support. The Dutch tradition of ex ante evaluation of the effects of policies on different socio-economic groups can be used more implicitly in further developing the policy agendas. Furthermore, the Netherlands could include considerations concerning 'fair' shares when defining national policy ambitions regarding natural resource use (e.g. land, biodiversity, materials).

Combine international cooperation with national action
The global systemic problems targeted by the three policy agendas require international cooperation. Successful cooperation contributes to effectiveness, equity, efficiency and ensuring a level playing field, as well as combining smaller countries' market power. The Netherlands can take a proactive role in strengthening policies in the fields of international trade and finance in the European and global context. A leading role in international environmental cooperation can only be credibly claimed when combined with serious national action. In the context of development cooperation, considering national policies in conjunction with transformations in developing countries could help to improve policy coherence.

Make more use of the concept of overall well-being and the SDGs
The concept of overall well-being ('*brede welvaart*') and the SDGs could be more actively used in all phases of policy-making. Together, they provide a framework that integrates the social, economic and environmental aspects of sustainable development, a vision for the medium term, and a shared global language on sustainable development. More active use can help to improve coherence across the three policy agendas, with other sustainability objectives and with international policy efforts. Furthermore, achieving the SDGs by 2030 could provide an important step towards achieving the 2050 ambitions on energy and climate, food, agriculture and nature, and the circular economy.

FULL RESULTS

1 Introduction

Challenges relating to global environmental change feature prominently in international discussions and global conventions and agreements, including the 2030 Agenda for Sustainable Development (UN, 2015), the Paris Agreement (UNFCCC, 2015), the Strategic Plan for Biodiversity 2011–2020 (CBD, 2010), the United Nations Convention to Combat Desertification (UNCCD, 1994) and the current discussions on the new post-2020 global biodiversity framework. Together with a range of other agreements and conventions, they form the international policy framework. The Netherlands has committed itself to these conventions and agreements and thereby to achieving their goals and targets.

Global Environmental Assessments (GEAs) are designed to provide policymakers with a knowledge base to address global environmental challenges. For that purpose, they map the current state of the global environment, assess progress towards achieving the internationally agreed environmental goals, analyse the consequences of alternative future developments for people and the planet, explore pathways, solutions and policies for achieving the goals, and indicate research and knowledge gaps to be addressed.

Since the adoption of the 2030 Agenda in 2015, a range of new environmental assessments have been published, many under the flag of the United Nations. However, as these assessments generally have a global focus, the results are not directly usable on a national or regional (EU) scale. They thus require translation to national circumstances to help policymakers draw policy consequences. In addition, many assessments have different thematic foci as well as overlaps, which raises the question of what the common messages are across the assessments. At the request of the Dutch Ministries of Foreign Affairs and of Infrastructure and Water Management, this study synthesises the results of recent assessments and, based on these insights, reflects on Dutch sustainable development policies, both national and foreign.

Ten years ago, PBL conducted a similar study, drawing lessons from four major GEAs that were published in the period 2007–2008 (Kok et al., 2009; PBL, 2008). Based on the new round of assessments, the current study focuses on internationally agreed environmental goals on climate change, land degradation and loss of biodiversity and ecosystem services, linked to national policy programmes around energy and climate, food, agriculture and nature, and the circular economy. More specifically, it discusses policy lessons in the light of three agendas prominent in Dutch environmental policy — the National Climate Agreement, the government's vision on agriculture, nature and food, and the government-wide programme for a circular economy.

The following five assessments are included in this study:
1. Global Land Outlook: First Edition, published by the United Nations Convention to Combat Desertification (UNCCD, 2017a);
2. Global Warming of 1.5 °C, a special report published by the Intergovernmental Panel on Climate Change (IPCC, 2018);
3. Global Environment Outlook 6: Healthy Planet, Healthy People, published by the United Nations Environment Programme (UNEP, 2019a);
4. Global Resources Outlook 2019: Natural resources for the future we want, published by the International Resource Panel of the United Nations Environment Programme (IRP, 2019);
5. The Global Assessment Report on Biodiversity and Ecosystem Services, published by Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019).

These assessments were all either directly or indirectly requested and funded by the international community, including the Netherlands, and were published in the period 2017-2019.[1] Researchers from PBL Netherlands Environmental Assessment Agency were involved in four of the five assessments, coordinating several chapters for the Global Environment Outlook 6, providing major scenario input for the Global Land Outlook and the Global Assessments Report on Biodiversity and Ecosystem Services, and acting as contributing or lead authors in Global Warming of 1.5 °C and the Global Assessment Report on Biodiversity and Ecosystem Services.

This report does not aim to be exhaustive. It provides only a snapshot of the extensive discussions on the current state of the environment. Furthermore, challenges surrounding freshwater and oceans have not been addressed, while several other issues have only been touched upon without going into detail. Nevertheless, this report has attempted to synthesise the main policy lessons and related dilemmas to strengthen Dutch sustainable development policies, both nationally and internationally. Appendix A provides an overview of the main conclusions of the individual assessments.

The study is subdivided into three blocks:
1. How were the different assessments produced (Chapter 2)? How have they formalised their respective science-policy interface, what functions do they fulfil for policy-making, and how did they explore future developments?
2. What were the key insights of the assessments in relation to energy, food and agriculture, and resource extraction and processing, in relation to achieving internationally agreed goals on climate, land and biodiversity? Is the world on track to meet these environmental

[1] The assessments integrate results from earlier assessments, including IPCC's fifth assessment report, the IPBES assessment report on land degradation and restoration, and regional assessment reports by IPBES and GEO6. More recent assessments, such as the IPCC special report on climate change and land and the IPCC special report on the ocean and cryosphere, were published after the synthesis of the assessment results was completed and therefore are not included.

goals (Chapter 3), and which global response strategies were identified to achieve the goals (Chapter 4)?

3. What lessons can be derived for Dutch sustainable development policies (Chapter 5)? To what extent have the insights offered by the assessments already been included in Dutch policy agendas on energy and climate, agriculture, food and nature, and the circular economy? And what lessons can be drawn to further develop and implement these agendas and contribute to achieving internationally agreed environmental goals. These lessons build on recent PBL publications that discussed specific aspects of the Netherlands' three policy agendas.

2 The assessments in context

Science plays an important role in much of environmental policy-making, for instance, through a better understanding of specific environmental problems or by developing effective policy interventions. However, science is not a single coherent body of work. There is a myriad of scientific communities each analysing different areas of environmental problems or approaching these problems from different perspectives. Addressing environmental issues generally requires a combination of knowledge from many different scientific communities. GEAs are an effort to synthesise the state-of-the-art of fragmented scientific knowledge to provide insight into scientific agreement (and disagreement) on how to respond to policy-relevant questions. They aim to improve the quality of decision-making without being policy prescriptive.

In this chapter, we discuss what GEAs are and how they are produced, focusing on the five assessments that formed the basis for this study (Section 2.1). Section 2.2 considers how the various assessments have formalised the science-policy interface while Section 2.3 provides an overview of the different functions they fulfil. Finally, Section 2.4 looks at how they have addressed the future, with a specific focus on the scenarios they used.

2.1 The five assessments

In GEAs, experts compile and organise existing scientific information on environmental issues in a format that is useful for the decision-making process (Jabbour and Flachsland, 2017; Mitchell et al., 2006). Rather than attempting to move the 'frontier' of scientific knowledge on an environmental issue, they serve to *re*-present the current state of the science (including uncertainty/confidence limits) in a manner that is relevant to policy-making. In this sense they operate at the 'interface' of science and policy-making.
In practice, most GEAs are large reports in which peer reviewed and openly accessible grey literature is reviewed and assessed for its evidence base, generally accompanied by a Summary for Policymakers (SPM) containing the key messages of the study judged to be most policy relevant. Nonetheless, the process by which these reports are produced and the activities that are organised in parallel are seen to be at least as important (Bakkes et al., 2019).

In recent decades, there has been significant growth in the number of environmental assessments published, in part because many international treaties prescribe their production (National Research Council, 2007). Furthermore, the processes followed by GEAs have evolved over time. With the IPCC often considered a flagship example of a successful GEA (Hulme and Mahony, 2010), many subsequent assessments have adapted the IPCC principles and procedures, such as nomination and selection procedures for authors and review editors, peer review processes, and government-approved summaries for policymakers. Studying the 40-year history of GEAs more generally, Jabbour and Flachsland (2017) concluded that the way assessments are conducted strongly relates to how they are embedded in political and institutional processes. They highlight the increasing complexity of the GEA process — with more authors and more scientific material to review — as well as their apparent shift away from problem analysis towards identifying and assessing (potential) solutions. GEAs have successfully put environmental problems on the political agenda, both nationally and internationally, and now place greater emphasis on exploring solutions to these problems, including in their scenario analyses (see also Van Vuuren et al., 2012).

The current study is based on five major assessments published between 2017 and 2019:

- *Global Land Outlook: first edition* (GLO), published by the Secretariat of the United Nations Convention to Combat Desertification (UNCCD, 2017a). The report focuses on the status and outlook of land globally, and more specifically of land degradation and its impacts. It further discusses response pathways to reduce unsustainable land use and manage the increasing pressure on land, and contribute to the related objectives of poverty reduction, food and water security, biodiversity conservation, climate change mitigation and adaptation, and sustainable livelihoods.
- *Global Warming of 1.5 °C* (IPCC1.5), published by the Intergovernmental Panel on Climate Change (IPCC, 2018). This Special Report focuses on the impacts of global warming of 1.5 °C compared to 2 °C and discusses response strategies to stay below a 1.5 °C increase this century relative to pre-industrial levels, in the context of sustainable development and poverty eradication. The report builds on the IPCC fifth assessment report, published in 2014, and subsequently published relevant research.
- *Global Environment Outlook 6: Healthy Planet, Healthy People* (GEO-6), published by the United Nations Environment Program (UNEP, 2019a) This report provides an overview of how the global environment is changing and how people and their livelihoods are affecting and are affected by environmental changes. Furthermore, it analyses the effectiveness of past environmental policy, and discusses possible pathways towards achieving the environmental dimension of the Sustainable Development Goals (SDGs) and goals set out in Multilateral Environmental Agreements (MEAs).
- *Global Resources Outlook 2019: Resources for the future we want* (GRO), published by the International Resource Panel of the United Nations Environment Programme (IRP, 2019). The report examines the impacts of the use of natural resources on the environment and human well-being, as well as how they could be managed more sustainably.
- *The Global Assessment Report on Biodiversity and Ecosystem Services* (IPBES GA), published by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019). This report examines the current status, historical and projected trends for biodiversity and nature's contributions to people, as well as possible pathways to conserve, restore and sustainably use nature, while simultaneously meeting other global

societal goals. The assessment builds on the IPBES assessment report on land degradation and restoration, and four regional assessment reports published in 2018.

These five assessments all examined global environmental change in the context of sustainable development. The GLO and GRO followed less strict rules in their assessments than the IPCC, IPBES and UNEP in terms of admissible literature, primary research, the author team and the review process (see Section 2.2). Nevertheless, they are generally regarded as assessments and occupy clear niches in the global assessment landscape (see Maas et al., 2020). Table 2.1 provides an overview of the focus of each of the assessments, how they are linked to conventions and multilateral agreements, and how they were produced.

2.2 Production processes

To be effective at the science-policy interface, GEAs have to conform to two sets of standards. They must be of use to policymakers/decision-makers (governments, private sector, NGOs and civil society) by answering their questions without advocating a particular political message, a combination often denoted as policy relevant but not policy prescriptive. Furthermore, they must follow the standards by which the scientific community separates 'facts' from 'hypotheses'.

Three criteria are widely considered to be crucial for effective GEA processes: relevance, credibility and legitimacy (Cash et al., 2003; Mitchell et al., 2006). These criteria can be operationalised in different ways. For GEAs in general these strategies can be summarised as follows (van der Hel and Biermann, 2017):

- *Relevance*: whether the assessments are demand-driven and provide the necessary information to answer the right questions at the right time. In GEAs this is achieved by the scientific and user communities co-designing the scope of the assessments, and subsequently comprehensively assessing the scientific and other literature.
- *Credibility*: the scientific adequacy of the assessment. GEAs generally focus on the peer reviewed scientific literature but, where appropriate, may also include grey literature and indigenous and local knowledge. Furthermore, GEAs employ an extensive expert and government peer review process.
- *Legitimacy*: the degree to which different values, interests and beliefs are respected. GEAs generally seek balance in the scientific disciplines, geographical representation, and gender of the scientists involved in the assessment, and increasingly this extends to the representation of different knowledge systems.

Meeting these criteria can be challenging. The strategies GEAs tend to follow can be difficult to put into practice, and increasingly so; for example, the ever-growing body of scientific literature to be assessed represents a corresponding increase in the volume of work for GEA authors (Jabbour and Flachsland, 2017). But, more importantly, different stakeholders may have different interpretations of what these criteria encompass precisely, whether they are

Table 2.1

Main characteristics of the five assessments

	Global Land Outlook: first edition	Global Warming of 1.5 °C	Global Environment Outlook 6	The Global Assessment Report on Biodiversity and Ecosystem Services	Global Resources Outlook 2019
Environmental focus	Land and land degradation	Climate	Air (including climate), biodiversity, oceans, land, and freshwater	Biodiversity and ecosystem services	Climate, air, water and biodiversity
Requested by	UNCCD Secretariat	UNFCCC COP21	UNEA-1	IPBES-2 Plenary	UNEA-2
Coordination	UNCCD	IPCC[3]	UNEP	IPBES[4]	UNEP-IRP
Type of report	Regular product to-be	Special Report	Regular product	Regular product to-be	Regular product to-be
Link to global governance	UNCCD; 2030 Agenda	UNFCCC, Paris Agreement; 2030 Agenda	Various MEAs; 2030 Agenda	CBD, Strategic Plan for Biodiversity 2011-2020[1]; 2030 Agenda	2030 Agenda
SDGs addressed	SDG target 15.3	Focus on SDG 13; synergies and trade-offs of climate mitigation and adaptation measures with the other 16 SDGs	SDGs linked to five thematic areas5 from the perspectives of well-being (SDGs 2, 3, 6 and 7) and natural resources (SDGs 6, 11, 13, 14 and 15)	Direct and indirect links between nature's contribution to people and the 17 SDGs	SDGs 8.4, 12.1 and 12.2 linked to essential material needs (SDGs 2, 6, 7 and 9) and natural and social capital (SDGs 13, 14, 15 and 17)
Scope	The importance of land for human well-being and the extent, severity, drivers and impacts of land degradation now and in the future. Policy options for more sustainable land management and management of trade-offs	The impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways in the context of strengthening the global response to the threat of climate change, sustainable development, and poverty eradication	The state of the global environment and human health. Effectiveness of current and past environmental policies. Possible pathways and solutions to achieve the environmental dimension of the SDGs and other internationally agreed environmental goals	The status of and trends in biodiversity and ecosystem services. How these relate to achieving the Aichi targets and the SDGs. Plausible pathways and policy interventions leading to sustainable futures	Historic and future trends in extraction and use of natural resources globally and impacts on the environment. Recommendations aimed at supporting innovations to address environmental challenges and improve sustainable consumption and production
Type of research[2]	Literature assessment (P-R and grey) + scenario development	Literature assessment (P-R)	Literature assessment (P-R and grey)	Literature assessment (P-R, grey and indigenous and local knowledge) + scenario development	Literature assessment (P-R and grey) + new scenario development
Author selection	Partner institutes selected by UNCCD Secretariat based on their expertise	Nominated by member states and observers, selection by Bureau	Nominated by governments and other main stakeholders, selection by UNEP Secretariat	Nominated by member states and observers, selection by Multidisciplinary Expert Panel	Panel Members appointed by UNEP Secretariat, recommendations from panel members and member states
Type of review	Expert review, governmental review	Expert review, governmental review	Expert review, governmental review	Expert review, governmental review	Expert review
Government approval	-	SPM approved by the member states	SPM approved by the member states	SPM approved by the member states	-
Reception	Launched at UNCCD COP13	'Timely completion' *welcomed* at UNFCCC COP24	*Welcomed with appreciation* at UNEA-4.	*Welcomed* at CBD SBSTTA-23	Welcomed at UNEA-4

[1] Progress towards the goals and objectives of other MEAs related to biodiversity with a global scope (CMS, CITES, Ramsar, UNCCD, WHC and IPPC) was also assessed but in much less depth;

[2] P-R = peer reviewed;

[3] founded by UNEP and WMO;

[4] collaborating with UNEP, UNDP, UNESCO and FAO and other non-UN partners.

indeed the right criteria, and what is the best strategy for achieving them. A notable example of a recurring debate in this context is whether the SPMs should be government-approved (as is the case in many GEAs) to increase the relevance of the assessments, or whether such a procedure detracts from their credibility. In the following paragraphs we discuss how the five assessments dealt with the three criteria.

Relevance: linkage to global environmental governance

All five assessments were directly or indirectly requested by the international community, i.e. demand-driven, strongly supportive of relevant environmental conventions (e.g. United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification (UNCCD)) and associated agreements (e.g. the 2030 Agenda for Sustainable Development, the Paris Agreement, the Strategic Plan for Biodiversity 2011-2020). In most cases, to differing degrees, the assessments were co-designed and co-produced by the scientific and user communities. IPCC1.5 and GRO were produced by UN bodies which have been specifically mandated in the wider UN system to create assessment reports (UNFCCC and UNEP-IRP, respectively). IPBES GA was produced by an independent intergovernmental process (IPBES) with a UN body providing administrative support (UNEP) and GEO-6 was published under the auspices of the UN body for coordination on environmental matters (UNEP). The GLO is different in the sense that it is a strategic communications publication and platform largely produced and launched by the UNCCD Secretariat itself.

Some of the assessment reports have long-standing histories and can be seen as new iterations in a regularly recurring assessment process. This is especially true for the IPCC which published its first report in 1990 and is currently working on its sixth assessment report due to appear 2022, and GEO which has a 25-year history and recently published its sixth Global Environment Outlook (Bakkes et al., 2019). The IPCC1.5 report is not part of the regular assessment cycle of the IPCC but was a special assessment requested at UNFCCC COP21. Its prominence in terms of media attention and position in international climate politics prompted the decision to include this special report rather than the 'regular' but older fifth assessment report in the present study. The other three assessments were the first of their kind focusing specifically on biodiversity and ecosystem services (IPBES GA),[2] land (GLO) and natural resource use (GRO), however, follow-up reports can be expected. IPBES was founded only relatively recently (2012) and the report selected was its first global assessment. Between 2012 and 2018 IPBES produced thematic assessment reports on pollination and land degradation and restoration, regional assessment reports and a methodological assessment report on scenarios and models. In many ways IPBES was modelled to be the 'IPCC of biodiversity', aiming to reproduce the IPCC's regular global assessment cycle (although as yet not part of the work programme). At the same time, IPBES has a broader mandate and several procedural differences, such as a focus on capacity building and a greater diversity in scales and forms of knowledge included (Beck et al., 2014;

[2] Although the 2005 non-governmental Millennium Ecosystem Assessment (MA, 2005) should be mentioned as an earlier global assessment of ecosystem services, the MA was not commissioned by the UN system.

Brooks et al., 2014). The UNCCD Secretariat is preparing a follow-up to GLO to be released in 2021 and has commissioned several regional reports that were published in September 2019. Finally, UNEP-IRP is also working on a follow-up to GRO to be published at UNEA-6 in 2023.

As the assessments are all linked to certain fora for international environmental diplomacy and MEAs, they differ in the way they — and especially their summaries for policymakers (SPMs) — are produced. GEO-6, IPCC1.5 and IPBES GA include government-approved SPMs. These SPMs are approved line by line in a plenary with the scientists ensuring the text of the SPM remains consistent with the underlying chapters which are accepted by the plenary. While the SPMs are not legally binding documents, their content is normally not challenged in multilateral environmental agreement conferences (Riousset et al., 2017). This does not mean that government approval of the summary is a necessary requirement for GEAs to be part of international environmental diplomacy. Both the GLO and GRO were officially presented at international fora (UNCCD COP13 and UNEA-4, respectively). In all cases governments were involved, either through the plenary (IPCC1.5, IPBES GA) or through specific bodies or working groups (GEO-6, GLO, GRO) in determining the terms of reference for the assessment and approving a draft or outline for the report.

Credibility: assessment methodologies

There are clear differences in the kinds of assessment processes used in the various assessments. The IPCC1.5, IPBES GA and GEO-6 reports are primarily the result of combining and assessing existing (mostly peer reviewed) literature, including the scenario literature. They do not include primary research but may include new model runs of previously reviewed or re-analysis of previous data sets. Besides a literature assessment the GLO and GRO also contain primary research, mostly in the form of scenario development. It was therefore less important for GLO and GRO to refer to all the relevant literature.

IPCC, IPBES and UNEP have particular procedures in place for what is considered admissible literature for their assessments. These procedures generally privilege peer reviewed scientific publications, set quality criteria for 'grey' literature, and exclude sources like newspapers, magazines, or privately held material. IPBES also aims to build on knowledge from indigenous and local sources through their presence in author teams, a special task force on indigenous and local knowledge systems, with terms of reference to guide its operations in implementing the inclusion of this knowledge.

Furthermore, to ensure the scientific validity of their findings, all the assessments employed external peer review procedures. The IPCC1.5, GEO-6 and IPBES GA reports had separate scoping reports, as well as first order and second order review rounds carried out by experts and by governments and experts, respectively. As a further part of their quality assurance procedure these three assessments had panels overseeing the scientific aspects of the assessment process[3] and review editors joining the chapter team meetings after each

3 IPCC: Bureau, GEO: Scientific Advisory Panel, IPBES: Multidisciplinary Expert Panel (MEP) and management committees comprising a sub-set of MEP and Bureau members.

external review to review the comment responses and oversee their implementation. These types of panels generally give advice on a range of matters, such as the selection of authors or decisions relating to the content of the assessment chapters and SPMs. The GRO was internally reviewed by the members of the IRP and the Steering Committee (made up of representatives from governments, UNEP and the EU), and externally by invited experts in the field. Finally, the GLO was reviewed by a panel of experts, including the Science-Policy Interface (SPI) of the UNCCD.

Legitimacy: author selection and stakeholder involvement
As mentioned in Section 2.1, assessments generally seek to obtain diversity in their authors. In the case of the IPCC1.5, GEO-6 and IPBES GA reports, author selection formally took place through nominations by member states and stakeholders. The respective panels overseeing scientific quality then made a selection from these nominations. With the IPBES GA particular emphasis was placed on diversification of the knowledge base, specifically to include indigenous and local knowledge.

For the GRO, the structure was somewhat different as it was produced under the auspices of the IRP, which has standing members. These members are nominated by member states or other IRP members and appointed by the UNEP Secretariat. The IRP Secretariat publishes calls for nominations as an open invitation to experts. A committee from IRP then reviews the applications for quality and the specific needs of the IRP in terms of the work programme. Authors for reports are then drawn from the IRP members based on their specific expertise, supplemented by external authors with expertise relevant to the report. The GLO was produced under the auspices of the UNCCD Secretariat in association with a number of knowledge institutes, with a Steering Committee guiding its development.

Several assessments have additional procedures to ensure relevant stakeholders and sources of knowledge are represented. For GEO a High-Level Intergovernmental and Stakeholder Advisory Group (HLG) of about 40 members from governments and key stakeholders provided strategic advice and guidance for the report. The GLO had a steering group in which people from the various contributing institutes were represented, as well as the SPI group from the UNCCD. For the GRO the Steering Committee fulfilled this role. In IPBES a task force on indigenous and local knowledge systems supports the efforts of the entire platform in working with these knowledge systems, while a task force on data and knowledge assists with large data sets.

2.3 Functions for policy-making

When considering how GEAs meet their objective of informing decision-making, a number of different functions can be identified. These functions can be subdivided into: (a) functions for policy-making, (b) functions supporting policy processes, and (c) functions for science (Maas et al., 2020). Functions for policy-making directly support aspects of the policy-making cycle:

1. *Demarcate the issue*. Through this function, GEAs define the terms by which a problem is understood. For instance, the IPBES conceptual framework has broadened the concept of ‘ecosystem services’ to ‘nature’s contributions to people’ (Díaz et al., 2015).
2. *Agenda shaping.* GEAs can demonstrate the environmental or societal urgency for (additional) action to be taken, thereby reducing ‘the political risk of acting’ (van Bers et al., 2007). This function is highly visible in popular and scientific coverage of assessments. For example, the media release of the IPBES Global Assessment contained the statement that one million species are threatened with extinction which was widely picked up by multiple media outlets.
3. *Contribute to potential policy goals and targets*. Assessments may offer suggestions for what kinds of targets could be set to meet a policy goal. For instance, the IPCC’s ‘reasons for concern’ diagrams serve as a tool to explore what ‘dangerous interference’ means in the context of the UNFCCC’s stated goal of avoiding ‘dangerous anthropogenic interference with the climate system’ (Mahony and Hulme, 2012).
4. *Suggest potential policy interventions and instruments.* Assess knowledge on possible policies to pursue, ranging from individual measures to combined strategies or possible pathways. While assessments rarely include ‘new’ policy instruments, they can lend credibility to existing options through an assessment of their efficacy and replicability.
5. *Monitor progress*. GEAs may contain an analysis of whether internationally agreed goals and targets are likely to be met, mostly focusing on those of MEAs. This is done in generic terms rather than as part of formal frameworks for accountability and policy evaluation. For instance, the sixth Global Environment Outlook specifically examines the environmental dimension of the SDGs as well as a number of other internationally agreed environmental goals.

Functions supporting policy processes contribute to conditions that enable more effective implementation of policies, including capacity building, social learning and standardisation. Finally, functions for science support organising science itself, as well as its funding, and contribute to shaping scientific research agendas and capacity building. Most GEAs do not strive to fulfil all these functions, and some functions are side-effects. In the following paragraphs we provide a summary of which *functions for policy* the five assessment reports cover and what that entails. Only the functions for policy are included here, as the other functions are more the outcome of the assessment process rather than the report itself.

Demarcate the issue

Of the five assessments, three include sections in which they contribute to demarcating the environmental issue at hand. The Global Land Outlook contains an extensive discussion on the various meanings of land and what drives land degradation.[4] IPBES GA (and IPBES more widely) introduced a new conceptual framework to link different interpretations of biodiversity and ecosystem services. Regarding the GRO, the issue of resource efficiency or even a ‘circular economy’ has gained traction in various fora but is equally characterised by

[4] The IPBES land degradation and restoration assessment also contributed to this issue.

many different interpretations of what it does and does not entail and how it might contribute to solving environmental issues.

Agenda shaping

GEAs may play a role in agenda-setting, meaning they can demonstrate the urgent need for additional action to be taken to combat specific environmental problems. All assessments can be seen as having this role. Since land degradation is a relatively low international priority, the UNCCD Secretariat intended that the GLO would contribute to a quantification of the problem and provide insight into interactions between land and land degradation and the SDGs. The IPCC1.5 report has been adopted by various groups attempting to raise the level of ambition for global climate policy. GEO-6, IPBES GA and the GRO all underline the need for action on their respective focal issues.

Contribute to potential policy goals and targets

Different environmental problems are addressed with different international regimes. Regardless of their specific regimes, all the assessments position their focal environmental issue relative to the SDGs. Furthermore, several assessments contribute to defining or adjusting goals and targets. For instance, the IPCC1.5 report was specifically requested to detail the difference between average global warming of 1.5 °C and 2 °C. The IPBES GA is expected to contribute to the Post-2020 Global Diversity Framework to be negotiated at the CBD in 2020. There is no internationally agreed target for resource efficiency, except for the more process-based targets of the SDGs (8.4 and 12.2). The GRO focuses on resource efficiency along with sustainable production and consumption that decouple economic growth from natural resource use and environmental degradation.

Suggest potential policy interventions and instruments

Assessments can discuss policy instruments from both a backward and a forward-looking perspective. GEO-6, for example, contains an extensive discussion on the effectiveness of current and past environmental policies, while all the assessment reports offer policy options or strategies that can help to achieve internationally agreed goals in the future. A main difference between the five assessments is the level of detail in the policy options and strategies they offer. While the GLO primarily discusses a number of examples of policy instruments,[5] the other four assessments all have dedicated chapters in which governance strategies and structures are extensively discussed, including the challenges faced in policy design and implementation. Furthermore, these four assessments discuss possible policy measures, both in terms of assessing what the policy measure entails and what evidence there is for its effectiveness, and how these measures interact (both positively and negatively) with other policy goals. They also discuss one or more 'solution pathways' in which multiple measures are combined and quantitatively assessed for their performance in terms of meeting environmental and other objectives. Section 2.4 discusses this kind of scenario analysis as included in the five assessments in more detail.

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5 Because of this deviation in its level of detail, we have not included the GLO in assessments that suggest possible policy interventions and instruments.

Box 2.1. Keeping Global Environmental Assessments fit for purpose

Four of the five assessments discussed in this report are recurring reports (or recurring reports to-be). Many other Global Environmental Assessments (GEAs) have been produced over time, each with their own environmental focus, target audience and policy niche. This raises questions about the necessity, overlap and coherence of all these assessments. Furthermore, many assessments are institutionalised to an extent that makes it difficult to adjust them to changing dynamics in science, policy and society. In a parallel study to the current one, PBL explored how global environmental assessments can remain fit for purpose (see Maas et al., 2020). Here we provide a brief summary of its key findings.

A global environmental assessment is a process, as well as a report
While GEAs are best known for the reports they produce (which are the focus of the current study), it is important also to take into account the processes that produce the report. Part of what GEAs do emerges as benefits from these processes, for example, by convening experts and policymakers allowing them to exchange perspectives on complexities and uncertainties related to the issue assessed.

Options to keep global environmental assessments fit for purpose
The study identifies a number of possible choices and options to consider when reflecting on whether the role, function and design of GEAs remain fit for purpose, while acknowledging that there is no one-size-fits-all model and that individual assessments are part of a wider assessment landscape. These options can be summarised as follows:

- **Target and involve non-state actors:** The relative importance of multilateral and national environmental governance is decreasing, with local and regional government authorities, businesses and civil society taking a more proactive role. GEAs could reflect this shift by more actively involving these actors.
- **Improve coordination between niches in the assessment landscape**: Different assessments should address individual niches. This should be matched with improved coordination between assessments to address interrelationships and make use of complementary niches.
- **Align the assessment format with its purpose:** Under the adage 'form follows function', assessments should tailor to the format in which they represent their outcomes to the niche they are supposed to fill.
- **Deal explicitly with different worldviews and values:** GEAs play a role that is both political and scientific. In order to effectively inform decision-making in a politically sensitive context, they could increase the degree to which they integrate different worldviews.
- **Back the activities that support assessment production and use:** Various activities are undertaken to stimulate effective production and use of assessments. To fully capitalise on the potential GEAs offer requires appropriate appreciation, attention and financial support for these activities.

Make use of strategic moments to align an assessment's niche and process with the needs of environmental governance
Many GEAs have recurring assessment cycles and/or multi-year work programmes. Such a long-term planning provides a window of opportunity for strategic reorientation. Before a new assessment process is started, a discussion could be held on the substance for a future report (the scope), but also its purpose, composition of the groups of authors, and the audience that it is expected to serve ('who is helped and by what?'). These discussions could also include the most suitable format for presentation of the assessment. Such a process of reconsideration takes time. This means it is important that mandating parties avoid intending to reach immediate agreement on an approach for possible follow-up but instead actively make space for strategic reorientation. The option to substantially refit or even terminate a GEA could be put on the table as reference point for the value added of a subsequent assessment cycle.

Monitor progress
Several assessments include monitoring of global progress as a key issue. IPBES GA specifically assesses progress towards meeting major international objectives related to nature and nature's contributions to people, including the 20 Aichi Targets and the 17 SDGs.[6] In the case of GEO-6, keeping the global environment under review is an explicit part of the UNEP's mandate, hence the significant attention devoted to whether internationally agreed environmental goals are being met.[7] The IPCC1.5 report was chiefly set up to explore the difference between a 1.5 °C and 2 °C increase in global mean temperature, and to assess different pathways to achieve stabilisation at 1.5 °C in the context of sustainable development, and to assess the expected contribution of Nationally Determined Contributions (NDCs) under the Paris Agreement.[8]

2.4 The use of scenarios

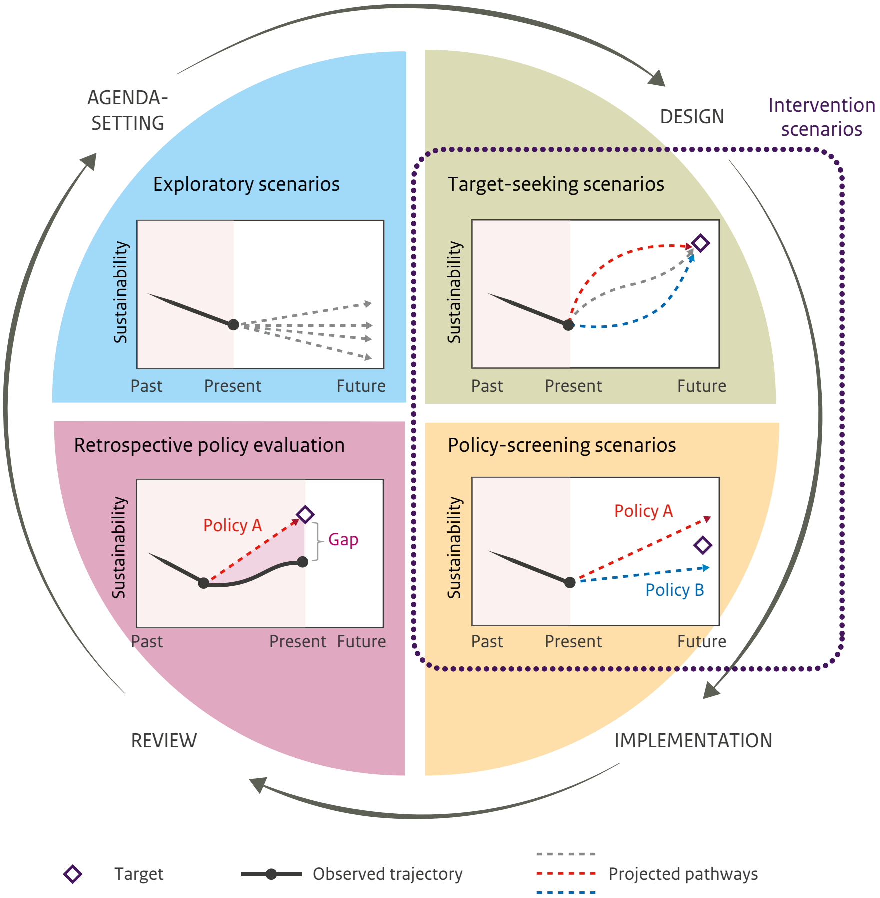
An important element of many assessments is a discussion of future trends, either to assess potential future developments on specific environmental issues or to assess progress towards internationally agreed environmental goals. Furthermore, assessments look at policies in relation to these goals, either retrospectively, to assess their effectiveness, or

6 It should be noted that the Global Biodiversity Outlook (GBO) of the CBD does a more rigorous job in assessing progress towards achieving international biodiversity targets, as it also takes national reports into account. The latest GBO provided a mid-term assessment of progress towards the implementation of the Strategic Plan for Biodiversity (CBD, 2014).

7 Measuring Progress (UNEP, 2019) is a derivative product of GEO-6 which specifically assesses progress towards the environmental dimension of the SDGs, including knowledge and information gaps.

8 Monitoring of climate change is also provided by the UNEP's annual Emission Gap report (Christensen and Olhoff 2019).

Figure 2.1
Alternative scenario types linked to major phases of the policy cycle



Source: IPBES The methodological assessment report on scenarios and models of biodiversity and ecosystem services

prospectively, to assess promising policies and their potential impact in the context of achieving specific goals. Based on different mandates, the stage in the policy cycle and the available knowledge base, assessments have adopted various strategies and tools to deal with these issues.

As policy targets are generally set for the long-term, evaluating progress and analysing measures aimed at achieving these targets could be done by exploring possible futures (Clark et al., 2006; Van Vuuren et al., 2012). GEAs generally use model-based scenarios for this purpose. Scenarios are 'plausible descriptions of how the future developments might evolve, based on a coherent and internally consistent set of assumptions (i.e. scenario logic) about the key relationships and driving forces (i.e. the technology, economy, environment interplay)' (IPBES, 2016; Nakicenovic et al., 2000). They are generally based on storylines, quantified within models. While model-based quantification can help to take account of the many relationships that occur across scales, between regions, in time and across various sectors and environmental problems, the storyline elements help to ensure consistency with other elements that are more difficult to quantify. The main purpose of this scenario methodology is to be as scientifically rigorous as possible, while providing policy-relevant information (van Vuuren et al., 2012).

Strategic orientation: exploratory scenarios and solution pathways
Scenarios have long been used in Global Environmental Assessments (IPBES, 2016; van Vuuren et al., 2012). Different types of scenarios play roles in the different phases of the policy cycle (Figure 2.1):

1) *Exploratory scenarios* examine a range of plausible futures often based on storylines to support high-level problem identification and agenda-setting. These scenarios are based on potential trajectories of indirect and direct drivers and provide a means of dealing with uncertainty, inherently associated with the future trajectory of the many drivers.
2) *Intervention scenarios* evaluate alternative policy or management options to contribute to policy design and implementation. These scenarios are either *target-seeking* (also called *normative scenarios* or *solution pathways*) or *policy-screening* (also known as 'ex-ante scenarios').
3) In *retrospective policy evaluation* (also known as 'ex-post evaluation'), the observed trajectory of a policy implemented in the past is compared against scenarios that would have achieved the intended target.

Early GEAs used *exploratory scenarios* to examine a range of plausible futures as a function of diverging drivers to investigate the future consequences of current trends and to assess whether long-term policy goals would be expected to be met. Nowadays, most GEAs also use *intervention scenarios* to assess the impact of (a set of) policy measures, or to explore solution pathways to achieve long-term policy goals. *Retrospective policy evaluation* is generally not used in GEAs.

Shared projections: from scenario families to shared scenarios
A limited number of key archetypical scenarios, or scenario families, have been identified that reappear in many GEAs published between 2000 and 2010 (van Vuuren et al., 2012). The scenarios grouped under specific scenario families share a similar storyline or logic, resulting in a similar kind of quantification. They vary mainly in the degree of dominance of markets, dominance of globalisation, and dominance of policies geared to sustainability.

More recently, the Shared Socio-economic Pathways (SSPs) were developed. These SSPs are five distinct global development pathways describing the future evolution of key aspects of society that together imply a range of challenges for mitigating and adapting to climate change (O'Neill et al., 2017; Riahi et al., 2017). The individual SSPs can also be linked to the various scenario families. As the SSPs have been formulated relatively broadly and cover a wide range of possible futures, they are also used extensively in other fields of environmental research, including land and biodiversity, and play a central role in the scenario analysis of the five assessments. Thus, where most earlier assessments developed their own scenarios with shared storylines, the five assessments discussed in this study built on the same set of scenarios, namely, the SSPs.

Exploratory scenarios analysis in the five assessments
Four of the five assessments used exploratory scenarios to assess plausible futures for natural resource use, environmental degradation, nature's contribution to people and the quality of life, while some also used them to assess progress towards internationally agreed environmental goals. All four make extensive use of the SSPs.

For the GLO, three scenarios were developed based on the SSP storylines. The assessment focused on SSP2, with SSP1 and SSP3 used to express uncertainty. The scenarios are used to examine the degree to which demand for land might evolve and how that may affect land use, the efficiency of the use of land resources and products, trade and food self-sufficiency, climate change and biodiversity, and how land degradation is projected to impact these developments.

IPBES GA looked at existing scenarios grouped in the six archetypical scenarios to assess future developments in nature, nature's contributions to people (NCP) and quality of life. Furthermore, it drew conclusions from the scenario literature with respect to achievement of the SDGs and the Aichi Targets. Finally, 14 different models were used to explore the impact of land use and climate change on terrestrial biodiversity, material NCP and regulating NCP, under three sets of scenarios based on the SSPs (SSP1, SSP3 and SSP5).

GEO-6 examined the international scenario literature, focusing on business-as-usual or trend scenarios (mostly SSP2; SSP3 was used to indicate the impact of higher population growth) to assess to what extent current and long-term trends are in line with achieving environment-related SDG targets and policy goals from a range of MEAs, and to understand and highlight potential implementation gaps.

Finally, GRO developed a business-as-usual scenario (*Historical Trends*) with assumptions aligned with the SSP2 storyline and population and GDP from OECD (2018). The scenario provides projections of natural resource use (e.g. land, water and materials), economic activity, essential services and key environmental indicators based on the assumption that observed trends and relationships over the decades leading up to 2015 would continue into future decades. Quantification of the full set of SSPs is planned for the next resources outlook (GRO-2).

Intervention scenarios in the five assessments
Of the five assessments discussed here, the GLO is the only one that does not discusses intervention scenarios. This reflects what is known about land degradation on a global

scale. The location, severity, cause and potential impact of land degradation all need to be clearer before policy options can start to be analysed. Its analysis of how to sustainably meet the demand for land-based goods is more qualitative. Solution pathways are planned to be analysed more quantitatively in the forthcoming GLO-2.

The other assessments looked at solution-oriented (target-seeking) or policy scenarios to assess pathways to achieve internationally agreed environmental goals as set out in the three Rio Conventions (i.e. UNCCD, UNFCCC and CBD) and MEAs (i.e. Strategic Plan for Biodiversity 2011-2020 and the Paris Agreement). Furthermore, they discuss solution pathways within the broader context of sustainable development as set out in the 2030 Agenda for Sustainable Development and its 17 SDGs. IPCC1.5 discusses four illustrative pathway archetypes based on the SSPs. GEO-6 conducted a broad scenario review with a focus on SSP-derived scenarios. IPBES GA conducted a broad scenario review which included target-seeking and policy-screening scenarios as well as sustainability-oriented exploratory scenarios. Finally, GRO developed its own solution pathway building on its *Historical Trend* scenario, introducing four policy packages — resource efficiency, climate policy, landscape and biodiversity policies, and food policies — broadly consistent with the narrative of SSP1.

3 Progress towards internationally agreed goals

An important role of GEAs is to assess plausible futures of human development and environmental change and what these futures imply for internationally agreed environmental goals. Policy goals on climate change, land degradation and loss of biodiversity and ecosystem services are central to the five assessments, as well as how they relate to the SDGs. In this chapter, we bring together the assessments' conclusions on the main drivers of environmental degradation and whether the world is on track to achieve policy goals on climate, land and biodiversity.

3.1 Internationally agreed environmental goals

The five assessments are all linked to or targeted towards global conventions and agreements (see Table 2.1), most notably the three Rio Conventions (UNFCCC, UNCCD and CBD) and related agreements and agendas. They also all link to the 2030 Agenda for Sustainable Development and the SDGs, discussing how environmental degradation could impact their achievement.

Climate Change: The United Nations Framework Convention on Climate Change (UNFCCC) sets out an overall framework for intergovernmental efforts to tackle the challenges posed by climate change. Its objectives are to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Paris Agreement supports the implementation of that convention by setting 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'. The Agreement additionally addresses climate adaptation and finance. Climate action is also central to SDG13.

Land degradation: Several international conventions and agreements have set targets or expressed ambitions to reduce land degradation and restore degraded land. The United Nations Convention to Combat Desertification (UNCCD) is the sole legally binding international agreement linking environment and development to sustainable land management, with a focus on drylands. Its Strategic Framework for 2018–2030 sets out desertification, land degradation and drought (DLDD) as challenges with a global dimension requiring an integrated focus on improved land productivity and the rehabilitation, conservation and sustainable management of land and water resources (UNCCD, 2017b). Aichi Target 15 addresses combating desertification[9], while SDG15.3 focuses on land degradation, aiming to achieve Land Degradation Neutrality (LDN)[10]. Moreover, the UN has announced that 2020–2030 will be the Decade for Restoration.

Loss of biodiversity and ecosystem services: The Convention on Biological Diversity (CBD) is a multilateral treaty aimed at the conservation of biological diversity worldwide, the sustainable use of its components, and the fair and equitable sharing of benefits arising from genetic resources. The CBDs Strategic Plan for Biodiversity 2011–2020 sets out a long-term vision: 'Living in Harmony with Nature', where 'By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people'. The strategic plan consists of five strategic goals and 20 targets (the Aichi Targets) for 2020. Biodiversity is also central to SDG14 (life below water) and SDG15 (life on land). A new post-2020 Global Biodiversity Framework is being negotiated and is expected to be agreed upon at COP-15 in 2021 in Kunming, China. This framework should provide new biodiversity goals and targets for the UN system, as SDG14 and SDG15 also run until 2020.

3.2 Drivers of environmental degradation

Using different approaches or frameworks for their analysis, the assessments discuss a range of drivers underlying global and regional environmental degradation. Both GEO-6 and GRO use the Drivers, Pressures, State, Impact, Response (DPSIR) framework, while GLO and IPBES GA make a distinction between indirect drivers and direct drivers. Nevertheless, there is considerable overlap between the assessments in their selection of the drivers discussed. Here, we discuss developments in environmental degradation distinguishing between indirect drivers (root causes of environmental change, and Drivers in the DPSIR framework) and direct drivers (actions that directly affect the environment, and Pressures and State in the DPSIR framework).

3.2.1 Indirect drivers

Common indirect drivers of environmental degradation in the assessments include demography (e.g. population growth, urbanisation, migration), economy (e.g. structural change, trade, finance) and technology (innovation). While most assessments implicitly discuss societal values, IPBES GA specifically includes it as an indirect driver of

[9] By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

[10] By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

environmental change. Finally, GLO and IPBES GA also discuss governance as an indirect driver. These indirect drivers are complex, interlinked and diffuse, and can originate far from the area of degradation. At the same time, they are similar across environmental challenges.

Societal values underlie lifestyle and production decisions
The values held by individuals and societies indirectly affect environmental degradation by influencing lifestyle choices and by mediating which production methods are considered acceptable (e.g. types of electricity production, agricultural practices). Values differ from person to person and between cultures, and can change over time. In recent decades, a lifestyle preference in which greater production and consumption were equated with greater well-being has become increasingly widespread. This includes more meat-intensive diets and increased material consumption.

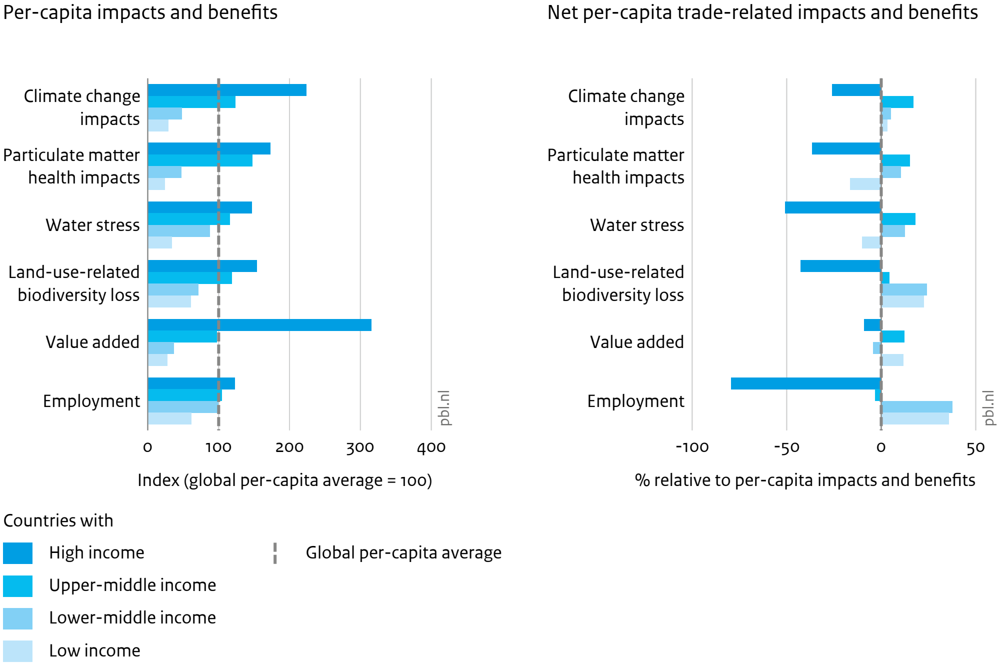
Demography, economy and technology are major determinants of aggregate consumption
Population increase, economic development (growth in per-capita income) and technological innovation are three key elements that determine both per-capita and aggregate consumption and the use of natural resources, such as materials, land and water. Since 1970 the global population has doubled and global gross domestic product has grown tenfold. Globally, both per-capita and aggregate consumption has increased with wide differences between regions due to variations in lifestyle and access to natural resources. However, due to structural shifts in regional production as well as rebound effects, global resource productivity has not improved since 2000. As a result, material resource use has multiplied more than threefold since 1970.[11] The largest growth occurred in metal ores and non-metallic materials, primarily for construction, energy and transport, industry, equipment, manufacturing and consumer goods.

International trade has disconnected the benefits and impacts of global resource use
Trade allows producers to compensate for regional differences in resource availability (e.g. materials, land, water) and supports global systems of production and consumption. While creating value in the country of origin, trade may also contribute to the unequal distribution of environmental or social impacts arising from the benefits of resource use between and within countries. Global trade has grown tenfold since 1970. While production in developed countries and rapidly growing high-income countries has become more efficient, domestic environmental degradation has also been reduced by outsourcing production and importing specific products, thereby increasing environmental impacts abroad. Cost differences and free trade have amplified this trend. Overall, the consumption-related environmental impacts of high-income countries are three to six times greater than those of low-income countries (Figure 3.1).

[11] Material resources include biomass (including crops, crop residues, grazed biomass, timber and wild catch of fish), fossil fuels (including coal, petroleum, natural gas, oil shale and tar sands), metal ores (including iron, aluminium, copper and other non-ferrous metals) and non-metallic materials (including sand, gravel and clay).

Figure 3.1

Consumption-related per-capita impacts and socio-economic benefits of global resource use, 2011



Source: IRP Global Resources Outlook 2019

Right graph: Negative values refer to the outsourcing of environmental impacts or socio-economic benefits to other regions; positive values refer to impacts and benefits accruing in the region where the extraction and processing for export takes place.

Governance efforts have not halted environmental degradation

Most countries have introduced environmental policies and established governance structures and there are now hundreds of MEAs in existence. Furthermore, innovative environmental policies are increasingly developed in developing countries, policies are revised and improved over time and policy diffusion between countries increasingly takes place. However, all these policy efforts have not consistently reduced environmental pressures. Environmental policy efforts are being hindered by a variety of factors, in particular the lack of implementation and integration in other sector policies. Furthermore, environmental policies often lack basic criteria that would ensure their effectiveness and ambition. The value of nature's contribution to people is only slowly being incorporated into policies and economic incentives while potentially harmful environmental measures have persisted. These include specific subsidies, financial transfer and the fact that environmental and social costs are not included in prices for commodities and industrial goods.

3.2.2 Direct drivers

The indirect drivers affect the direct drivers of environmental degradation. Common direct drivers discussed in the assessments include economic sectors such as energy, agriculture, and resource extraction and processing (including mining and quarrying). GEO-6 and IPBES GA specifically discuss climate change as a direct driver of loss of biodiversity and ecosystem services, while the GLO also discusses urbanisation and infrastructure development (partly driven by increasing resource demands) as direct drivers of land degradation.

Energy production and land use are the main drivers of climate change

CO_2 emissions from fossil fuels and industrial processes account for about two thirds of total greenhouse gas emissions. Furthermore, around 23% of total greenhouse gas emissions stem from agriculture, forestry and other land-use activities, including CO_2 emissions from deforestation, methane emissions from ruminants and rice cultivation, plus nitrous oxide emissions from fertiliser use (IPCC, 2019). Total CO_2 emissions exceed nature's uptake by approximately 40%. Oceans and terrestrial ecosystems absorb around 30%, causing ocean acidification, while another 30% is absorbed by terrestrial ecosystems.

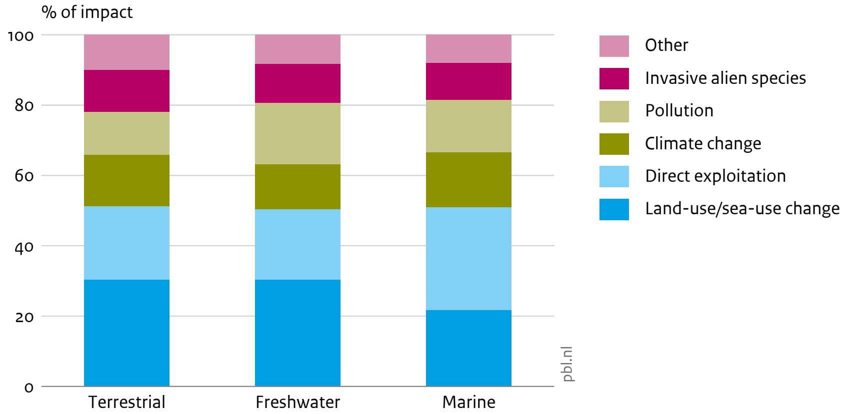
Land degradation is largely driven by agricultural dynamics

Land degradation includes the loss of productivity, soil, vegetation cover, biomass, biodiversity, ecosystem services and environmental resilience. It is generally caused by mismanagement or over-exploitation of land resources driven by agriculture and forestry, urbanisation (e.g. urban sprawl on fertile soils and farmland), infrastructure development (which encourages urban sprawl, replacing natural ecosystems and sealing soils), energy production (e.g. fuelwood and fossil fuel extraction, land demand and greenhouse gas emissions), as well as mining and quarrying (e.g. deforestation and chemical contamination). Agriculture is by far the largest human use of land occupying roughly 38% of the land surface (excluding Greenland and Antarctica). Over the last decades, around four fifths of the increase in food demand was met by agricultural intensification, and one fifth by an increase in agricultural area.

Land use change and direct exploitation has had the greatest impact on global biodiversity

Global biodiversity is impacted due to land/sea use change, direct exploitation, climate change, pollution, and invasive alien species (Figure 3.2). Historically, land-use change has had the greatest negative impact on terrestrial and freshwater ecosystems, mainly driven by agriculture, forestry, and urbanisation. Over the past two decades, total land use for agriculture, logging and mining increased by 7%. These activities are also associated with air, water and soil pollution, further impacting biodiversity. Direct exploitation, including harvesting, logging, hunting and fishing, has had the second largest impact on terrestrial and freshwater ecosystems. For marine ecosystems, direct exploitation (mostly fishing) had the largest impact, followed by land/sea use change, including coastal development and aquaculture.

Figure 3.2
Relative impact of direct drivers on the state of global biodiversity

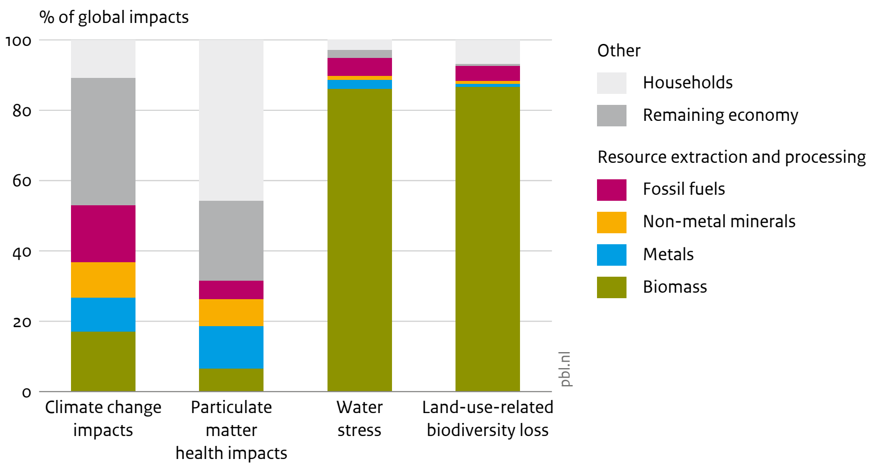


Source: IPBES The global assessment report on biodiversity and ecosystem services

Extraction and processing of natural resources are major drivers of climate change and terrestrial biodiversity loss

Resource extraction and processing includes agricultural production, mining, refining and production (e.g. steel, cement and fertiliser). This often takes place in combination with land and water use, emissions and waste. In 2011 the extraction and processing of natural resources accounted for about half of total global greenhouse gas emissions (not including emissions related to land use), around 30% of fine particulate matter emissions, and more than 90% of land use-related biodiversity loss (global species loss) and water stress (Figure 3.3). Biomass production (including food production and forestry) was the main driver of terrestrial biodiversity loss and water stress, while all types of resource extraction and processing accounted for a significant share of climate change and health impacts due to particulate matter.

Figure 3.3
Contribution of resource extraction and processing to global environmental impacts, 2011



Source: IRP Global Resources Outlook 2019

Fossil fuels include coal, petroleum, natural gas, oil shale and tar sands. Non-metallic materials include sand, gravel and clay, as well as cement and fertiliser production. Metals include iron, aluminium, copper and other non-ferrous metals, as well as steel production. Biomass includes crops, crop residues, grazed biomass, timber and wild catch of fish.

3.3 Future progress: are we achieving the goals?

The assessments use exploratory scenarios to examine a range of plausible futures and to assess whether long-term policy goals are expected to be met. They further use indicator analysis, systemic reviews and analysis of national reports to assess progress towards internationally agreed environmental goals. Here, we discuss future projections of indirect and direct drivers of environmental change and their implications for climate change, land degradation and biodiversity loss (Figure 3.4; see Appendix B for data sources), using the explorative scenarios included in the various assessments (see Section 2.4). These scenarios were all based on the same set of socio-economic assumptions (Table 3.1). Together with the other analyses from the assessments, we also discuss whether the world is expected to achieve the internationally agreed environmental goals.

Table 3.1

Main characteristics of scenarios used in the assessments

	Sustainability (SSP1)	Middle of the road (SSP2)	Regional rivalry (SSP3)	Inequality (SSP4)	Fossil fuel development (SSP5)
Population growth	Relatively low	Medium	Low in OECD and high in other countries	Low in OECD and relatively high in other countries	Relatively low
Urbanisation	High	Medium	Low	Ranging from medium to high	High
Income growth	Medium in HICs and high in LICs and MICs	Medium, uneven	Slow	Slow in LICs, medium in other countries	High
Technology development	Rapid	Medium, uneven	Slow	Rapid in high-tech economies and sectors; slow in others	Rapid
Trade	Moderate	Moderate	Strongly restrained	Moderate	High
Consumption and diet	Low growth in material consumption, low-meat diets, first in HICs	Material-intensive consumption, medium meat consumption	Material-intensive consumption	Elites: high consumption lifestyles; Rest: low consumption, low mobility	Materialism, status consumption, tourism, mobility, meat-rich diets
Policy orientation	Towards sustainable development	Weak focus on sustainability	Towards security	To the benefit of the political and business elite	Towards development, free markets, human capital
Environmental principles	Improved management of local and global issues; tighter regulation of pollutants	Concern for local pollutants but only moderate success in implementation	Low priority for environmental issues	Focus on local environment; little attention to vulnerable areas or global issues	Focus on local environment with obvious benefits to well-being, little concern with global problems
International cooperation	Effective	Relatively weak	Weak, uneven	Effective for globally connected economy, not for vulnerable populations	Effective in pursuit of development goals, more limited for environmental goals

Source: based on O'Neill et al. (2017)

The global population is projected to grow, further urbanise and become wealthier...

All the scenarios include ongoing population growth, urbanisation and income growth towards 2050 (first panel in Figure 3.4). Based on alternative future fertility, mortality, migration and educational assumptions, the global population is projected to increase from 7.2 billion people in 2015 to between 8.5 and 10 billion people in 2050. The largest uncertainty is the speed of the fertility transition, with low population projections resulting from a relatively rapid drop in fertility rates. The largest growth is projected in developing countries with small per-capita carbon footprints and high gender inequity in terms of access to education, work, and sexual and reproductive rights, such as in Sub-Saharan Africa and South Asia. Furthermore, most of this population growth is projected to take place in cities, with the global urbanisation share increasing from 54% in 2015 to between 55% and 78% in 2050. Around 90% of the population growth in cities is projected to take place in low-income countries, mainly in small and medium cities in Sub-Saharan Africa and South Asia. The critical factor for future urbanisation trends is rural-urban migration. Finally, consistent with these population projections, global average per-capita income is projected to increase by 60% to 275% between 2015 and 2050, reaching levels ranging between USD 20,000 to more than USD 50,000 per capita in 2050. These projections are largely driven by alternative assumptions about human development, technological progress and development convergence between and within regions.

…inducing significant growth in the demand for energy, agricultural products and materials…
Global demand is projected to increase faster than population growth due to changing consumption patterns (more resource-intensive lifestyles) fuelled by increasing per-capita incomes in low- and middle-income countries. Future developments in energy and material demand are sensitive to economic growth and structure, while agricultural demand is more directly affected by population growth. Primary energy demand is projected to increase by 80% to 130% between 2010 and 2050, demand for agricultural products (including wood, grass and fodder, food, feed and energy crops) by 30% to 80% between 2010 and 2050 (SSP1-3), and material consumption (including biomass, fossil fuels, metal ores and non-metallic materials) by 110% between 2015 and 2060 (second panel in Figure 3.4).[12] For material consumption, the largest growth is projected for non-metallic materials (mostly sand, gravel and clay), reflecting the additional amounts needed for buildings and infrastructure.

…and increasing global environmental pressures and related impacts
The demand for natural resources and related environmental pressures can be reduced through improved resource efficiency and changes in production, thereby decoupling economic development from environmental degradation. However, although resource efficiencies generally improve across the scenarios, they fall far short of offsetting the increases in aggregate consumption. As a result, the assessments conclude that environmental pressures will increase, including greenhouse gas emissions, land use change and nitrogen deposition (third panel in Figure 3.4). Only sustainability-oriented scenarios show a decrease in environmental pressures for land use and nitrogen deposition. Nonetheless, all the scenarios (including SSP1 for climate and biodiversity) show increasing climate change, land degradation and biodiversity loss (fourth panel in Figure 3.4).

Internationally agreed environmental goals on climate, land and biodiversity are not expected to be achieved
Overall, the assessments conclude that the main objectives of the three Rio Conventions are not expected to be met. The scenario analyses show that the indirect and direct drivers of environmental degradation continue to put pressure on the environment. As a result, many environmental indicators are moving in the wrong direction, including global mean temperature increase, loss of soil organic carbon and loss of mean species abundance

[12] Only GRO provides projections for resource extraction and processing, and in one scenario only.

(see Figure 3.4).[13] For some indicators, negative trends in biodiversity and ecosystem functions are projected to accelerate. Even in sustainability-oriented scenarios, the internationally agreed environmental goals are not being achieved.

- *Climate change*: The earth has already warmed by more than 1 °C above pre-industrial levels. In the explorative scenarios, a global mean temperature increase of 1.5 °C is projected to be surpassed around 2030 and 2 °C between 2040 and 2050. Scenarios reflecting nationally stated climate mitigation ambitions imply a global warming of about 3 °C by 2100, with warming continuing thereafter. If the scale and ambition of the climate mitigation effort is not stepped up before 2030, it is very likely that the goal of a temperature increase of well below 2 °C will be out of reach (UNEP, 2018).
- *Land degradation*: Besides land use change projections, the scenario literature on land degradation is very limited. Nevertheless, it can be concluded that the LDN target is not likely to be achieved. Except for the global sustainability scenario, land-use change is projected to continue at the expense of forest and other natural land, while under the business-as-usual projection in the GLO, land productivity and soil organic carbon continue to decrease.
- *Loss of biodiversity and ecosystem services*: Although the implementation of policy responses and measures to conserve nature and manage it more sustainably have progressed, that progress has been insufficient to stem the direct and indirect drivers of nature deterioration and most of the Aichi Biodiversity Targets for 2020 will be missed. Overall, the state of nature continues to decline. Scenario studies show that the combined impacts of climate and land-use change on biodiversity include major declines in local species richness, increases in regional to global scale species extinction and declines in biodiversity intactness, while also negatively impacting several important regulating ecosystem services, such as coastal protection, soil erosion protection and crop pollination.

Climate change, land degradation and loss of biodiversity and ecosystem services are strongly interrelated and mutually reinforcing

The three environmental challenges central to the assessments are interconnected in many ways. Land degradation both contributes to climate change and is affected by it. Land use change and loss of soil organic carbon contribute to increasing greenhouse gas emissions, while land degradation can also adversely affect important ecosystem services. In addition, climate change-induced temperature rises, changing rainfall patterns and increasing water scarcity are likely to decrease agricultural yields and the availability of suitable agricultural land, further contributing to land degradation. Climate change, land-use change and land degradation act synergistically to the loss of biodiversity and ecosystem services. Climate change induces an increased risk of species extinction, decreased species richness and the decline of biodiversity intactness. Over the next few decades, climate change is likely to become as important, or even more important, than land use change in driving biodiversity loss. Overall, addressing climate change, land degradation and loss of biodiversity and ecosystem service separately will become increasingly challenging.

[13] GEO-6 draws similar conclusions for climate change, land degradation and biodiversity loss, while also projecting increasing trends in water scarcity, excess nutrient run-off and ocean acidification.

Environmental change can undermine progress in meeting the SDGs
Over the last 15 years, good progress has been made in terms of putting in place policy, financial and institutional processes in support of achieving the environmental dimension of development (UNEP, 2019b). Mixed progress has been made in improving access to natural resources and reducing the impacts of environmental degradation on human health and food security, while material footprints and domestic material consumption continue to rise globally. Economic development has lifted millions of people out of poverty and enhanced their access to health and education. However, around 600 million people worldwide still live in extreme poverty with more than 800 million chronically undernourished, while 2.3 billion people lack access to safe sanitation and more than 2.6 billion people do not have access to clean cooking fuels. Modifiable environmental risks are responsible for almost a quarter of the global disease burden and related mortality, with a greater proportion occurring in populations in vulnerable situations and in developing countries. Trend scenarios project clear improvements over time in reducing hunger, increasing access to safe drinking water and adequate sanitation, and increasing access to modern energy services, but not fast enough to meet the associated SDG targets by 2030. Increasing environmental degradation could put further pressure on achieving the SDGs. For example, increased extreme weather events, soil erosion, loss of crop pollinators and declining fish stocks all negatively impact food security, while climate change impacts human health through, for example, increasing vector and water-borne diseases, heat stress and extreme weather events. These impacts disproportionately affect disadvantaged and vulnerable populations and exacerbate inequalities within and between countries. Negative trends in biodiversity and ecosystems are estimated to undermine the progress made towards achieving 35 out of 44 of the SDG targets assessed in IPBES GA, including the targets relating to poverty, hunger, health, water and cities.

Acting now is often cheaper than cleaning up later
Overall, the assessments conclude that current patterns of consumption and production could turn out to be more expensive in the long run in terms of impacts and required adaptation, as well as mitigation. The timeframe to achieve internationally agreed environmental goals and avoid the negative impacts of global environmental change is shrinking and, with it, flexibility in response strategies. For example, the lower global greenhouse gas emission levels will be by 2030, the greater the chances of achieving the Paris Agreement goal of keeping global mean temperature increase at well below 2 °C. The challenges arising from delayed climate mitigation action include rising mitigation costs, the lock-in of carbon-emitting infrastructure, stranded assets and diminished flexibility in future options for reducing emissions. Projected negative trends in the various dimensions of biodiversity will negatively impact important regulating ecosystem services, such as wild pollinators and coastal mangroves for flood protection. Once lost, some ecosystem services are irreplaceable, while for others replacement through built infrastructure can be extremely expensive.

Figure 3.4
Globally agreed goals not expected to be achieved

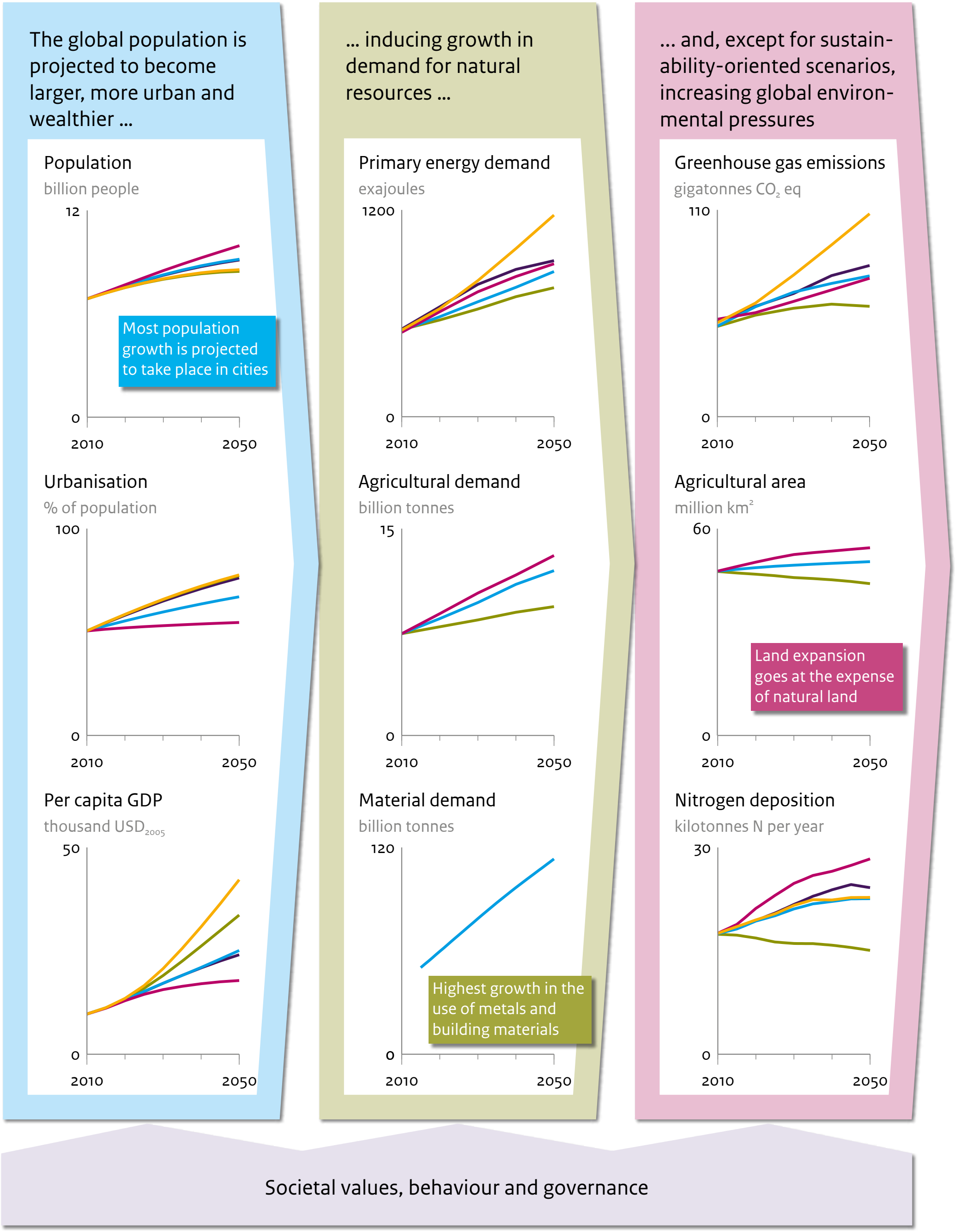
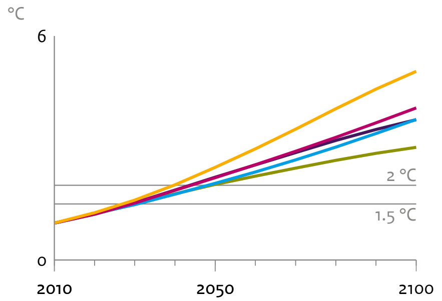


Figure 3.4 continued

Globally agreed goals not expected to be achieved

As a result, climate change, land degradation and biodiversity loss are projected to worsen, and related goals are not expected to be achieved

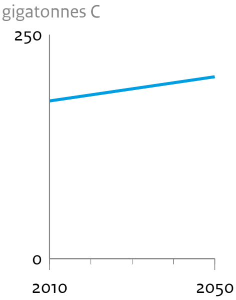
Temperature increase



Climate change

Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temparature increase to 1.5 °C above pre-industrial levels (Paris Agreement)

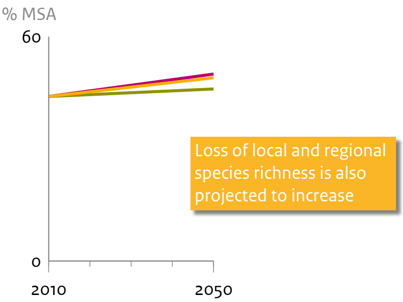
Loss of soil organic carbon



Land degradation

By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world (SDG15.3)

Loss of Mean Species Abundance



Biodiversity loss

By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people (Vision of the Strategic Plan 2011 – 2020)

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- Sustainability (SSP1 scenario)
- Middle of the road (SSP2 scenario)
- Regional rivalry (SSP3 scenario)
- Inequality (SSP4 scenario)
- Fossil fuel development (SSP5 scenario)

Source: IPCC, IPBES, UNEP, UNEP-IRP and UNCCD

4 Transformation to sustainability

A key message in all five assessments is that it is still possible to achieve many of the internationally agreed environmental goals but that this requires fundamental changes in the technological, economic, social and political factors underlying the drivers of unsustainable development. These changes are considered to be unprecedented, far-reaching, systemic and structural, and they need to happen urgently. Collectively, the assessments refer to these fundamental changes as 'transformation', 'transformative change' or 'transitions'. In this they echo Agenda 2030 which also calls for a transformation.

As discussed in Chapter 3, central to achieving the goals on climate change, land degradation and loss of biodiversity and ecosystem services are the energy system, the food and agricultural system, and, more broadly, the extraction and processing of natural resources. While not taking a systems approach *per se*, the assessments all discuss transformations in the context of these and also sometimes other systems. In this chapter we discuss the strategies put forward by the assessments for achieving the internationally agreed goals. Section 4.1 discusses measures and insights for the energy system, the food and agricultural system, and resource use, separately. Recognising that these systems are largely interconnected, Section 4.2 discusses synergies and trade-offs between the measures across the systems and goals. Finally, Section 4.3 discusses governance strategies.

4.1 Transformation pathways

The assessments generally refer to transformation pathways as model-based scenarios that describe system transitions towards achieving one or more policy goals. The pathways discussed in the different assessments are aimed at achieving internationally agreed environmental goals in the context of sustainable development and poverty eradication. GLO does not include any such pathway but does discuss measures and policy strategies for more sustainable land management. IPCC1.5, GLO and IPBES GA focus on a specific goal, namely those related to climate change, land and land degradation, and loss of biodiversity and ecosystem services, respectively, while GEO-6 specifically focuses on pathways that aim to achieve multiple environmental goals simultaneously. All five assessments further place their analysis in the context of the SDGs, thereby also looking at the links to achieving other environmental goals, as well as human development goals.

The pathways discussed in the assessments consist of combinations of behavioural, technological and management measures. Broadly they can be divided into: 1) changing consumption patterns to reduce demand for natural resources and environmental pressures; 2) development and deployment of more resource-efficient and sustainable production methods and technologies; and 3) improving environmental management, and protecting and restoring land and biodiversity. The five assessments covered by this study put much more emphasis on changing consumption patterns than previous generations of assessments did (see PBL, 2008).

4.1.1 The energy system

With respect to the energy system, the assessments discuss pathways to achieve policy goals on climate change in the context of sustainable development, including access to modern energy services, and air pollution control (most notably the well below 2.0 °C objective of the Paris Agreement, SDG7 and SDG13). The pathways all include a transition away from fossil fuel consumption and the use of traditional biomass, while concluding that achieving the Paris climate objective also requires major changes in the food and agriculture system (see Section 4.1.2).

Staying well below 2 °C global mean temperature increase requires rapid and far-reaching system transitions

Limiting global warming requires limiting global cumulative CO_2 emissions, i.e. staying within a global carbon budget. Pathways consistent with the climate objective of the Paris Agreement are characterised by a rapid phasing out of CO_2 emissions, together with deep emission reductions in other greenhouse gases and climate forcers, including methane, nitrous oxide and a series of fluorinated gases. This requires a broad transformation of the energy system, as well as transformations in agriculture, forestry and land use. Pathways that limit global warming to 1.5 °C with no or limited overshoot are characterised by a reduction in global net anthropogenic CO_2 emissions of about 45% by 2030 compared with 2010 levels and net zero CO_2 emissions by around 2050. Pathways that limit global warming to 2 °C, are characterised by a reduction in CO_2 emissions of about 25% by 2030, compared with 2010 levels, and net zero CO_2 emissions by around 2070. Non-CO_2 emission reductions are similar for both the 1.5 °C and 2 °C pathways. As agricultural greenhouse gas emissions are particularly difficult to abate, they do not reach zero globally.

The necessary system changes are unprecedented. Such rates have been seen in the past in certain sectors, technologies, and spatial contexts, but not on the scale required. Historically, the carbon intensity of the global economy (ratio of CO_2 over GDP) has improved by 1% to 2% per year, while in order to stay well below a 2 °C temperature increase, the reduction in global carbon intensity needs to increase to around 4% to 6% per year between now and 2050. Where in 2010 emission reductions of 2% per year were estimated up to 2030 to be able to meet the emission levels for 2.0 °C, recent estimates indicate 3% per year (and even more than 7% per year for 1.5 °C) will now be required, given that emissions have increased over the past decade (Höhne et al., 2020).

Box 4.1: Differences in climate change impacts and mitigation between 1.5 °C and 2 °C global mean temperature increase

Overall, climate change impacts and related adaptation needs will be smaller for a 1.5 °C global mean temperature increase than for an increase of 2 °C. Examples include:

- Lower climate-related risks, such as lower temperature extremes on land, reduced risk of droughts and lower precipitation deficits.
- Around 0.1 metre lower global mean sea level rise, with up to 10 million fewer people exposed.
- Lower impacts on terrestrial biodiversity and ecosystems, including species loss and extinction. Around 50% smaller area at risk of undergoing a transformation of ecosystems from one system to another.
- Reduced increases in ocean temperature and ocean acidity and reduced decreases in ocean oxygen levels. A decline in coral reefs of 70% to 90% at 1.5 °C increase, compared to >99% at 2 °C increase.
- Reduced climate-related risks to health, livelihoods, food security, water supply, human security and economic growth.

Compared to 2 °C mitigation pathways, 1.5 °C pathways are associated with lower energy use (including through enhanced energy efficiency and faster electrification of energy end use), a higher share of low-emission energy sources (especially before 2050) and greater emission reductions in industry, transport and buildings.

A broad portfolio of measures is available and necessary

Transformation pathways for the energy system include lowering energy demand, thereby reducing the energy intensity of the economy, and decarbonisation of the energy system by increasing the share of low-carbon technologies. Achieving the Paris climate goal of well below 2 °C also requires reducing non-CO_2 greenhouse gas emissions and changes in land use and in the agricultural sector (see Section 4.1.2). Energy demand reductions can be achieved, for example, through behavioural changes, energy efficiency improvements and sector specific measures, including a modal shift in transport (away from aircraft and private vehicles to high-speed trains and local electric public transport), improved appliance efficiency, improved building design and refurbishment of existing buildings, and substitution and circularity in industry. Decarbonisation of the energy supply can be achieved by increasing the share of low-carbon technologies (including bioenergy and biofuels, non-biomass renewables, electricity and nuclear energy), further electrification of end use and the use of hydrogen, and with carbon capture and storage (CCS) applied to fossil and biomass carbon.

As overall emissions are limited by a global carbon budget, choices in one sector or measure will affect the efforts required in other sectors or measures. Besides this, different portfolios face different implementation challenges and will have different potential synergies and trade-offs with sustainable development (see Section 4.2). In all portfolios, adaptation will be required to reduce the negative impact of climate change. Nevertheless, climate change impacts and related adaptation needs will be less for a 1.5 °C global mean temperature increase than a 2 °C temperature increase (see Box 4.1), especially if synergies between mitigation and adaptation measures are maximised and trade-offs minimised.

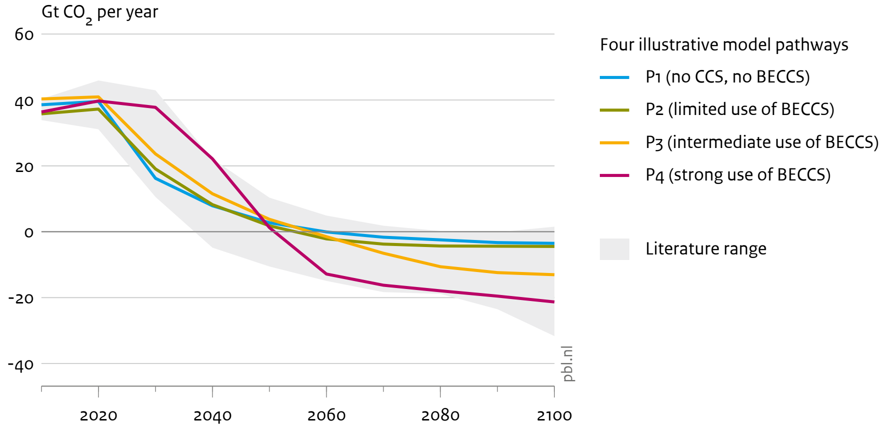
Immediate, rapid emission reductions can avoid dependence on large-scale carbon dioxide removal (CDR) technologies in the long term

An important determinant in climate change mitigation is the timing of emission reductions, affecting both short and long-term technology choices, most notably the deployment of CDR technologies (also see Dagnachew et al., 2019). To remain within the carbon budget pathways with more lenient emission reductions in the short term will require very rapid reductions later in the century, followed by large-scale removal of carbon dioxide from the atmosphere to compensate for excess emissions earlier in the century (Figure 4.1). CDR can also compensate for emissions from sectors that are difficult to decarbonise (e.g. agriculture). Pathways that do not depend on CDR deployment are characterised by significant near-term emission reductions, reduced energy demand and food wastage, a shift away from meat and dairy consumption, and improved land and ecosystem management (see also Section 4.1.2).

The CDR technologies discussed in the assessments include bioenergy in combination with carbon capture and storage (BECCS), afforestation and reforestation, soil carbon sequestration and other land conservation, restoration and management options, enhanced weathering of minerals, direct air carbon capture and storage (DACCS), and ocean fertilisation. Most CDR technologies are associated with multiple feasibility constraints and can have significant impacts on land, energy, water or nutrients when deployed on a large scale. For example, BECCS and afforestation and reforestation compete with other land uses and may negatively impact food and agricultural systems, biodiversity and other ecosystem services. DACCS require large amounts of energy while enhanced weathering runs the risk of water pollution. For BECCS, the assessments indicate uncertainty about timely upscaling, weak economic incentives and limited public acceptance for both bioenergy and CCS. Furthermore, there is uncertainty about the permanence of carbon storage, especially in terrestrial systems and oceans. Other CDR options, such as the restoration of natural ecosystems and soil carbon sequestration, do not require land use change and can have co-benefits, such as improved biodiversity, soil quality and local food security.

Avoiding reliance on large-scale CDR deployment in the future can only be achieved by significant near-term emission reductions (with global CO_2 emissions starting to decline well before 2030), reduced energy demand and food wastage, a shift away from meat and dairy consumption, and improved land and ecosystem management (see also Section 4.1.2). A mix of CDR options can reduce negative impacts and increase the likelihood of limiting warming to 1.5 °C. Effective governance is needed to limit trade-offs and ensure the permanence of carbon removal in terrestrial, geological and ocean reservoirs.

Figure 4.1
Net anthropogenic CO_2 emissions in pathways limiting global warming to 1.5 °C



Source: IPCC Global Warming of 1.5 °C

4.1.2 The food and agricultural system

In the context of food and agriculture, the assessments discuss pathways to achieve policy goals on food, land and biodiversity (most notably SDG2 and SDG15, and the Aichi Targets). The pathways are thus broader than just food and agriculture and also include other land uses, such as biodiversity and ecosystem services. The overall challenge for these pathways can be summarised as meeting the needs of an increasing global population (most notably food), while at the same time conserving and, where possible, restoring land quality and biodiversity.

Achieving policy goals on food, land and biodiversity requires sustainable management of production and consumption and land use planning

Addressing global hunger and feeding a growing and more prosperous global population will require an increase in global food production, alongside improvements in distribution, local availability and nutritional value. At the same time, land is finite and is also required for non-food products (e.g. bioenergy and timber), human settlement and infrastructure, as well as to safeguard biodiversity and essential ecosystem services. Finally, the loss of soil organic carbon and other forms of soil degradation can significantly impact crop yields and the nutritional value of the food produced. Central to the pathways for food, land and agriculture are more sustainable agricultural production and intensification, reducing demand for agricultural products (a shift away from meat and dairy consumption and reduced food loss and waste), together with improved land and ecosystem protection, management and restoration. All types of measures are required, while the focus on sustainable intensification versus consumption change may differ.

Food and agriculture and, more broadly, land use also play an important role in climate change mitigation
Agriculture, forestry and other land-use activities account for almost a quarter of global greenhouse gas emissions. At the same time, climate change negatively impacts agriculture and food systems, such as the stability of the food supply and crop and livestock productivity in drylands. Climate mitigation measures include reduced deforestation and reductions of methane and nitrous oxide emissions from agriculture (e.g. sustainable intensification, livestock management, reducing food wastage and a shift away from meat and dairy consumption). The assessments also discuss a range of land-based climate mitigation measures that potentially increase competition for land, most notably bioenergy and afforestation and reforestation (see Section 4.2). Together food, agriculture and land-based climate mitigation could contribute up to about 30% of the global mitigation needed by 2050 to limit the global temperature increase to 1.5 °C (Roe et al., 2019). Adaptation measures include mixed crop-livestock production systems, improving irrigation efficiency, and the use of crops that are more temperature, drought, heat stress, salinity, and pest tolerant.

Expanding and enhancing sustainable intensification in agriculture is key to increasing production while decreasing environmental pressure
The assessments stress the need for significant yield increases to increase food availably while decreasing land expansion, accompanied by more sustainable agricultural practices. In the absence of significant demand reductions (e.g. a shift away from meat and dairy consumption, reduced food loss and waste and limited bioenergy use) GEO-6 concludes that to feed an increasing global population while limiting cropland expansion, growth in global average yields would need to increase from a projected 1.0% per year in the period 2015-2050, assuming no additional policies, to around 1.4% per year. At the same time, the assessments raise the question of whether such high yield gains are possible. On the one hand, there is a large yield gap between the most and the least productive regions. On the other hand, easy yield gains could already have been achieved, the most productive land is already in use, and climate change is likely to decrease yields and the availability of suitable agricultural land in those regions most in need of production increases (e.g. Sub-Saharan Africa and South Asia). In addition, if not done sustainably, yield increases could coincide with increases in environmental pressure, including loss of biodiversity in agricultural landscapes, soil degradation from nutrient depletion, soil compaction and other degradation processes, with increased fertiliser and water use adding to the eutrophication of freshwater and coastal areas, as well as local and regional water scarcity. The assessments call for more attention to be devoted to closing yield gaps adapted to a changing climate and without excessive environmental pressure, the adoption of more sustainable agricultural practices, more efficient use of land, water, nutrients and pesticides, and reducing greenhouse gas emissions, as well as the conservation of genetic diversity and safeguarding native species, varieties, breeds and habitats.

Reduced agricultural demand decreases pressure on land, biodiversity and food systems
All five assessments stress the importance of limiting future increases in the demand for agricultural products, where appropriate, through a dietary shift away from meat and dairy

consumption (especially in richer countries) and reduced food loss and waste. The assessments also discuss limiting the use of bioenergy (see Section 4.2). Dietary shifts away from meat and dairy consumption reduce crop use for animal feed, while reduced food loss and waste reduces overall crop requirements. Both changes in agricultural demand reduce the demand for land (both cropland and pasture), water, nutrients and pesticides, and thereby the pressures on land, water and biodiversity, and can have a positive impact on global food security. Reduced agricultural demand is also discussed extensively in the context of climate change mitigation as an important measure for reducing CO_2 emissions from land use change and agricultural greenhouse gas emissions (see Section 4.1.1).

A mixture of protection, management and restoration are necessary to address competing claims for land
The pressures on land have never been greater and there is increasing competition for land, driven by, among other factors, the demand for food, water and energy, along with the need to safeguard ecosystem functions that regulate and support life, and land-based climate change mitigation, including bioenergy and reforestation measures (see Section 4.1.1). The assessments stress the need to expand and effectively manage the current network of protected areas and create connections, while at the same time integrating biodiversity into multi-use landscapes. What is optimum may greatly differ regionally based on socio-economic, cultural and ecological characteristics and conservation priorities, as well as the region's role in the global food system. Integrated landscape approaches, based on participation, negotiation and cooperation, aim to allocate and manage land to achieve social, cultural, economic and environmental objectives in landscapes where multiple land uses coexist. These include the integration of conservation, land and water management; multifunctional approaches to land use, land management and planning; soil organic carbon management; and improved and sustainable forest management. Integrated landscape planning also includes ecological restoration when land and ecosystems are unable to self-repair.

4.1.3 Resource use
Only GRO specifically discusses resource use other than land, focusing on material resources, i.e. biomass, fossil fuels, metals and non-metal materials. The report discusses decoupling environmental impacts and resource use (e.g. land, water, materials) from economic activities and human well-being (central themes in SDG8 and SDG12, respectively). The other assessments discuss resource efficiency in the context of the energy system (e.g. energy efficiency) and the food and agricultural systems (e.g. yield improvements, water- and nutrient-use efficiency). Resource use is thus strongly linked to the other two transformations discussed in this chapter. The circular economy is not a central topic in the assessments but often mentioned as a means to transform the way natural resources are extracted, processed, used and disposed of, to reduce resource demand and related environmental impacts, and increase resource security.

Achieving policy goals on climate, land and biodiversity requires significant improvements in resource use efficiency
GRO concludes that it is possible to decouple resource use and environmental impacts from economic activity and human well-being and that this can deliver substantial social and

environmental benefits. As already discussed in Sections 4.1.1 and 4.1.2, major improvements in energy efficiency and agricultural yield are needed to stay well below a 2 °C global mean temperature increase and to achieve policy goals for land and biodiversity. This includes more than a doubling of the rate of carbon intensity improvement compared to historic levels, a 40% increase in agricultural yields compared to business-as-usual projections, and major improvements in resource efficiency for metal ores and non-metallic materials, especially for climate change mitigation. To achieve these levels the assessments specifically point to policies that enable technological innovation, emphasising public and private research and development, and providing incentives for technological diffusion.

Resource efficiency alone is not enough and needs to be complemented with sustainable consumption and production measures, and environmental management

Resource efficiency in production and consumption can significantly reduce resource use, but the levels analysed in the various assessments do not result in achieving the environmental goals. GRO discusses a move from linear to circular flows through a combination of extended product life cycles, intelligent product design, standardisation and re-use, recycling and remanufacturing. It further stresses the need to coordinate resource decoupling with climate change mitigation and measures for food, agriculture and land use. The extent of such efficiency requirements strongly depends on the extent to which other measures are taken. In that context, GRO discusses shifting taxation away from income and consumption towards resource extraction, along with the importance of changes in consumption patterns and the benefits of a uniform world carbon price.

4.2 Interlinkages between pathways

The assessments conclude that there are strong links between strategies for addressing climate change, land degradation and loss of biodiversity and ecosystem services and thus also between the three transformation pathways for energy, food and agriculture, and resource use. Specific measures put forward to further individual goals can aid (creating synergies) or hamper or conflict (creating trade-offs) with other environmental goals and more broadly the SDGs (see Table 4.1). While the assessments conclude that there are more synergies than trade-offs, the overall effect of different pathways depends on the scale of deployment of the individual measures, the make-up of the portfolio and the management of the transformation. Portfolios of measures that consider interlinkages (both synergies and trade-offs) between environmental issues, as well as with sustainable development, and that include strong demand-side changes, are found to be more effective. How interlinkages manifest themselves in practice depends to a large degree on aspects specific to the context of implementation, including the extent to which issues are mainstreamed to provide cross-cutting options and possible win-wins. The assessments generally do not specify these aspects in great detail but mostly provide overall considerations.

Table 4.1

Measures or technologies with potentially strong synergies or trade-offs across SDGs

Synergies	Trade-offs
• Consumption change • Reduced food loss and waste • Resource efficiency • Non-biomass renewables • Reduced air pollution • Land and ecosystem restoration • Soil carbon sequestration • Female education	• Large-scale biofuel use (incl. BECCS) • Afforestation and reforestation • Agricultural intensification • Nuclear energy • Fossil CCS

Poverty alleviation and achieving environmental goals

The assessments conclude that there are both synergies and trade-offs between poverty alleviation and achieving environmental objectives. Higher incomes, improved food security and better access to water and energy are expected to push up demand for food, water and energy, thereby increasing the related environmental pressures. Furthermore, achieving universal access to clean fuels and technologies is generally accompanied by an increase in the use of fossil fuel-based products (e.g. liquefied petroleum gas, natural gas, fossil-based electricity). At the same time, the impact on increased greenhouse gas emissions is estimated to be limited. Similarly, the additional demand for food resulting from the eradication of hunger is estimated to be relatively small, especially when compared to current production levels and the projected increase needed to keep pace with a growing and more wealthy global population. Moreover, a transition to modern energy services at household level could lead to economic gains, as the investment in modern stoves may well be countered by reduced spending on fuel due to greater efficiency gains and significant health improvements, especially for women and children under the age of five, due to reduced household air pollution. Challenges from environmental policies related to ecosystem protection and land-based climate mitigation (such as biofuel production, afforestation and reforestation), for example, could compete with local livelihoods and food production and thus raise food security concerns. Pricing carbon could also slow down the transition to modern cooking fuels. Overall, the assessments argue for well-being and equity considerations to be included in climate change adaptation and mitigation strategies, along with redistribution policies and policies aimed at shielding poor and vulnerable groups to avoid exacerbating poverty and inequality.

Technology versus consumption change

The scale and urgency of the transformations required to achieve the internationally agreed environmental goals means that both technology (new and existing) and consumption change (a shift away from resource-intensive lifestyles) are required. Portfolios of measures may differ in their relative emphasis on the two, reflecting underlying assumptions and preferences about what contributes to human well-being, as well as in how to address intra and inter-generational equity. Portfolios with a strong emphasis on technology require a relatively modest change in consumption patterns, especially by people in high-income countries, and thereby in the current well-being paradigm. However, such portfolios include technologies that face multiple feasibility constraints, including economic, technological and social acceptability (e.g. CCS, onshore wind and bio-industry). Furthermore, several technologies are associated with trade-offs with other sustainability objectives when deployed on a large scale (e.g. large-scale CDR deployment). Conversely, portfolios with a strong emphasis on changing consumption patterns are less reliant on technologies with significant feasibility constraints and trade-offs with achieving other sustainability objectives, and provide synergies across sustainability objectives. However, they require relatively large changes in current well-being paradigms. Specifically, they imply that current generations with a large environmental footprint must change their consumption significantly to reduce environmental pressures and create space for future generations and for people in middle- and low-income countries to develop further.

The assessments conclude that there is considerable potential for more sustainable production with many practices and technologies already available. However, they also discuss certain technologies that, if poorly managed, come with significant trade-offs across sustainability goals including transboundary effects, especially when applied on a large scale. In this context the assessments specifically discuss land-based climate mitigation measures (including specific CDR technologies) with potential challenges in areas such as food security, biodiversity protection and water scarcity (Section 4.1.1) and yield improvements with challenges around freshwater and coastal eutrophication, and water stress (Section 4.1.2). Several technologies are further associated with various feasibility constraints, including timely upscaling, weak economic incentives, limited public acceptance and uncertainty about the permanence of carbon storage.

Demand-side measures discussed in the assessments include a shift away from resource-intensive lifestyles, especially in high-income countries and among the global middle class (e.g. reduced meat and dairy consumption, reduced energy demand and low material consumption), reduced food loss and waste, and improved resource efficiency in production. Reduced demand for natural resources has clear synergies with many environmental and human development objectives. For example, the assessments conclude that reduced meat and dairy consumption could reduce demand for land (both cropland and pasture), water and fertiliser, with positive implications for climate, air, land, biodiversity, freshwater and oceans, as well as global food security; while reduced red meat consumption also has positive implications for human health (e.g. reduced risk of cardiovascular disease and certain forms of cancer). Furthermore, besides synergies with environmental and human development objectives, a shift away from resource-intensive lifestyles reduces dependence on technological innovation and deployment, most notably the deployment of large-scale CDR technologies and agricultural intensification.
While behaviour- and lifestyle-related measures have led to emission reductions around the world, successful policies that modified dietary choices remain limited and globally demand for meat is still increasing.

Increasing global competition for land continues
Global competition for land was a new theme assessment, a decade ago (see PBL, 2008). The assessments discussed here conclude that since then global pressures on land have only increased, with causes and consequences spilling over national borders. Future pressures on land are primarily driven by the ever-growing demand for food, wood, minerals and other land-based products, exacerbated by land degradation and climate change. Furthermore, several solutions put forward in the assessments to address global environmental changes require land, including for land-based climate mitigation (e.g. bioenergy or BECCS, afforestation and reforestation), for the conservation of land, biodiversity and ecosystem services, and for nature-based solutions. Sustainable intensification, agro-ecological approaches and limiting or changing agricultural demand (reduced meat and dairy consumption and reducing food losses and waste) are put forward as broad strategies to reduce pressure on land, while all of these face significant implementation challenges when applied on a large scale. To address the multiple claims on land the assessments specifically discuss integrated landscape and spatial planning approaches for the protection, management and restoration of land. Restoration of agricultural and natural areas contributes to multiple societal objectives, such as ensuring local food and water security, climate mitigation and adaptation, as well as resilience and improved livelihoods. Overall, the continued pressure on land requires that more attention be devoted to land governance at local, national and international levels, especially in regions where this is currently underdeveloped. The attention devoted to land in assessments is not reflected in global governance, in the same way as it is for climate change and biodiversity loss (see also Willemen et al., 2020).

4.3 Enabling transformation

The preceding sections show that achieving the goals requires a clear break in current trends, including the large-scale development and deployment of more efficient and sustainable production methods and technologies, changing consumption patterns to low resource-intensive lifestyles, and improved environmental management, restoration and protection. These changes are considered unprecedented, far-reaching, systemic and structural, yet need to happen rapidly.

The assessments conclude that more can be achieved through improved and enhanced implementation and enforcement of existing policy instruments and regulations (see also EEA, 2019). This includes enhancing institutional capacity for monitoring and evaluation, as well as for policy design and implementation. However, enabling the systemic changes in the longer term also requires strategic interventions that address the root causes of environmental degradation. Such interventions go beyond traditional environmental policy and span issues and domains encompassing consumption patterns, population growth, inequality, international trade, technological innovation and financial systems. To achieve their full potential, the interventions should specifically consider equity and inclusiveness, be facilitated through long-term planning, and actively pursue policy coherence and integration across sectors, scales and actors.

Address the root causes of environmental degradation
The assessments point out that the decisions made by governments, consumers and corporations are underpinned by societal values. In this way, values influence the degradation caused by consumption, international trade, technological innovation and financial systems. In this context the assessments highlight the importance of a shift in well-being paradigms from the current dominance of material consumption and economic growth, to reflect the much wider set of aspects that matters to human well-being. In practice this could be spurred by wider definitions of progress (i.e. beyond GDP) and integrating these into decision-making processes to strengthen the balancing act of achieving social, environmental, and economic objectives.

In addition, the assessments discuss changing or creating new financial and non-financial incentives to stimulate more sustainable choices in production and consumption, along the whole supply chain. This includes reforming or removing environmentally harmful subsidies; for example, because they stimulate overproduction or overconsumption, as well as phasing out unsustainable practices, such as single use plastics or coal-fired power plants. Policies discussed to enable or strengthen lifestyle and behavioural change include awareness raising and information campaigns (e.g. labelling and health campaigns), certification schemes, nudging, financial incentives and regulatory measures, as well as aligning these activities with existing norms. The financial sector has substantial leverage over the actions of other actors and can steer investment through the types of reporting financiers require from the corporations they finance. New incentives will be most effective when made part of policy mixes in which unintended distributional effects are compensated for through other measures. For example, carbon pricing could be accompanied by transfers to compensate for unintended distributional effects and by non-financial incentives (like emphasising the benefits of action) to avoid reducing the intrinsic motivation to act. Other examples of incentives to encourage sustainable choices include securing land tenure and paying for ecosystem services. Generally, incentives supporting positive action tend to have fewer perverse consequences than incentives countering damaging activity and can ‘draw in’ desirable motivations.

Explicit consideration of equity and inclusiveness
Since transformation inevitably involves winners and losers, all five assessments underline the importance taking into account the social dimension of environmental policies. Mechanisms need to be incorporated that take social concerns and equity considerations into account and empower stakeholder participation in decision-making to ensure that such decisions reflect a broad range of interests. Empowerment and recognition of equity increases the legitimacy of decisions. Empowerment is particularly important to specific groups that are commonly excluded, especially indigenous people and local communities (IPLCs), women and youth. Distributional effects can be addressed through social safety nets and other mechanisms that specifically support vulnerable groups during the

transition. Aside from legitimacy concerns, participation contributes to mobilising actors by increasing the acceptance of change and producing ownership of decisions taken. Inclusion of IPLCs can help balance land use and natural and material resource extraction for local and global needs, while female education is associated with lower birth rates and reduced population growth. Furthermore, various participation methods foster public dialogue. This increases the actors' understanding of the perspectives of other actors which, in turn, facilitates consideration of all voices and interests in decision-making.

Plan for the long-term
The assessments note that having a long-term vision helps making it clear to multiple actors what overarching objectives are desirable. A vision does not say *how* to reach a certain objective but aids in formulating more concrete goals and targets to pursue. A vision that is based on long-term robustness and resilience increases the ability of policies to deal with uncertainty and non-linear effects, and create flexibility to adjust policies in response to ongoing learning processes. This complements a precautionary approach, in which risk is addressed before definitive proof of impact is established, so that systems are less susceptible to irreversible changes. Including adaptivity by design is a way in which visions can institutionalise learning, as well as create space for possible conflicts between different objectives to become visible and be taken into account. Adaptivity also makes it possible to tap into the potential of policy innovation and experimentation. Local scale experiments with an emphasis on social learning and adaptive management are seen as a promising form of policy innovation and a way to avoid policy mistakes. To realise their full potential, such experiments depend on sharing their lessons in wider contexts which requires an enabling environment that can multiply and scale up local successes.

Integrate across sectors, scales and actors
As the environmental challenges are strongly interlinked, the assessments specifically discuss policy coherence and integration, including integration across themes, aligning policies across levels of government and mobilising all types of actors.

Policy coherence across different themes reaps synergies while avoiding or mitigating unintended harmful side-effects. Corresponding approaches offer opportunities to reconcile multiple interests, values and forms of resource use. In this context, the assessments specifically refer to integrated landscape approaches to navigate multiple claims on land. Policy coherence further includes mainstreaming environmental considerations throughout other policy domains. The assessments specifically point to negative spill over effects and telecouplings (including shifting environmental footprints abroad) suggesting that trade agreements could be redesigned to create a level playing field and avoid externalising negative impacts to other countries.

Policy coherence also entails cooperation within and between the different tiers of government (local, national and international). International cooperation is often necessary to deal with systemic global problems and transboundary issues (such as trade), while aligning plans and visions at different levels of government helps to effectively deal with links between the challenges. Rules on accountability and transparency as well as participation and coordination across and within these levels are required to facilitate such alignment. Consistent indicators and targets (e.g. of resource use) may have to be developed. Global governance platforms may also be a way to exchange experience, methods used and technologies. Local governments are often well placed to take steps while taking the full complexity of the local context into account and thus could play a larger role in international governance through their collaborative organisations — such as ICLEI, C40 or the Covenant of Mayors.

Finally, transformative change requires a wide variety of actors to change their behaviour and decisions. In many ways then, transformative change first requires mobilising all types of actors. Mechanisms by which many different actors can be engaged and which take into account the coherence of their actions include public–private partnerships, as well as cross-stakeholder interactions without state involvement.

5 Lessons for the Netherlands

The five assessments convey a clear and unanimous message about the urgency of addressing global environmental challenges. In the Netherlands too, environmental problems are systemic and persistent. Despite policy efforts undertaken and progress made, many environmental indicators are not on track to achieve related national and international policy objectives. This message has been consistently put forward in PBL's *Assessments of the human environment* since 2001 (PBL, 2016; 2018). Greenhouse gas emission levels are still high, livestock farming is reaching its ecological and social limits, biodiversity is under great pressures, and the use of raw materials is leading to significant environmental pressure.

The recent Monitor of Well-being & the Sustainable Development Goals of Statistics Netherlands concludes that Dutch material well-being is high, but that the Netherlands is vulnerable in terms of its natural capital and, in many respects, it ranks bottom compared with other EU Member States (CBS, 2020). The Netherlands' nitrogen surplus is among the highest in the EU, the capacity and share of renewable energy are among the lowest, and most biodiversity indicators show a negative trend. Compared to the other EU Member States, the Netherlands scores the lowest on certain environment-related SDGs, i.e. affordable and clean energy (SDG 7), climate action (SDG 13), life below water (SDG 14) and life on land (SDG 15) (SDSN and IEEP, 2019). Dutch consumers further have a relatively high and, for some indicators, increasing, environmental footprint, with large environmental impacts abroad, including outside the EU (Lucas and Wilting, 2018; SDSN and IEEP, 2019).

The assessments conclude that a clear break with current trends is required and that the coming 10 years are crucial for initiating the transition — the Decade of Action called for by the United Nations. Not only because the SDGs have to be achieved by 2030, but also to meet the long-term ambitions of the CBD Strategic Plan for Biodiversity and the UNFCCC Paris Agreement. The Dutch nitrogen crisis has shown the urgency of improving the sustainability of the food and agriculture system, while the COVID-19 pandemic and the related green recovery discussion shows that a systemic approach to environmental challenges is warranted.

Since 2015, the government's approach to systemic challenges has changed, with three policy agendas addressing sustainability transitions now clearly initiated. These include the national climate agreement (EZK, 2019), the government vision on agriculture, nature and food (LNV, 2018), and the government-wide programme for a circular economy (IenM and

EZ, 2016). Recent policy initiatives include the interdepartmental programme for strengthening biodiversity (BZ and LNV, 2020; LNV, 2019).

This chapter discusses policy lessons from the five assessments for Dutch sustainable development policies, building on conclusions from recent PBL publications.
More specifically, it discusses to what extent key insights from the five assessments are already part of the three Dutch policy agendas addressing sustainability transitions, and offer lessons to assist Dutch policymakers in their efforts to further develop and implement these agendas and contribute to achieving internationally agreed environmental goals and targets.

Make clear policy choices on long-term and transboundary effects
The joint message in the assessments of urgency in addressing global environmental change is reflected by the three Dutch policy agendas dealing explicitly with sustainability transitions. However, the three agendas differ greatly in how their visions are articulated — for example, formulated as time-bound quantitative targets or as broad ambitions — and in their ability to drive the individual transitions. Furthermore, their visions also contain implicit assumptions about inter- and intra-generational equity that need to be made explicit to be able to address their ethical implications and transboundary effects. These include environmental burden shifting, 'environmental space' for development in middle- and low-income countries, and dependence on technological innovation.

The Dutch Climate Act aims for a 95% reduction in greenhouse gas emissions by 2050, compared to 1990, with an interim target of 49% by 2030. These reduction targets are roughly in line with earlier calculations for the Netherlands for achieving the 2 °C target with a likely (>66%) probability (Van Vuuren et al., 2017). The same study showed that achieving the 1.5 °C target (with a probability of around 50%) would require a reduction of more than 100% by 2050. A 95% reduction in total greenhouse gas emissions by 2050 already implies that long-term CDR deployment will be needed to compensate for excess emissions and emissions that are difficult to abate (e.g. from agriculture). As most CDR technologies are associated with multiple feasibility constraints, as well as trade-offs with other sustainability objectives (e.g. with biodiversity and food security), a discussion is required, both within the EU and internationally, concerning if and how much CDR is desired. If CDR is to be applied extensively, criteria could be defined under which CDR technologies would be considered acceptable and, where relevant, what measures should be taken to mitigate potentially negative side-effects. This further requires timely development and deployment of technologies, as many are not yet ready to be scaled-up extensively. If large-scale CDR deployment is to be limited, while still aiming for a global mean temperature increase of well below 2 °C, the 2030 reduction target has to be tightened, while consumption changes (e.g. reduced energy demand, reduced food loss and waste, and reduced meat and dairy consumption), will become more important in the short term.

The government’s vision on agriculture, nature and food is to become the leader in sustainable use of raw materials and circular agriculture. However, so far, there is no scientific or societal consensus on what qualifies as circular agriculture, or on what it aims to achieve. Multiple targets are currently being advocated and pursued — by government, other actors in the agricultural and food system and by nature conservationists — with conflicts and sometimes inconsistencies between them. The dilemmas include techno-optimisation versus animal welfare, and more efficient production to create space for nature versus extensive but more nature-inclusive agricultural production. Progress towards more sustainable agriculture requires a vision that takes these multiple perspectives into account and makes more specific political choices about what values agriculture should serve (PBL, 2019a) and what nature is desired (see also van Zeijts et al., 2017). Recent ambitions to fully achieve the EU Birds and Habitats Directives and halve the Netherlands’ ecological footprint, both by 2050 (LNV, 2019), offer further guidance. However, it is not yet clear how circular agriculture will contribute to halving the footprint and what it implies for Dutch agriculture as an export-oriented sector.

Finally, the government-wide programme for a circular economy aims to develop a 100% circular economy in the Netherlands by 2050, with an interim target of halving the use of primary abiotic resources by 2030. Similar to the vision for circular agriculture, the 2050 goal also requires further elaboration, while the interim target needs to be more clearly defined and made measurable (Kishna et al., 2020). The latter includes deciding whether it also applies to fossil fuels, applying a footprint approach to provide insight into total resource use in the whole value chain (including environmental pressures abroad), and taking a production and a consumption perspective, as both provide relevant entry points for policy. The focus on material input to the economy will not necessarily reduce environmental impact and supply security risks, which is the underlying rationale of the government-wide programme. Working towards operational, broadly accepted sets of targets, differentiated by transition agenda and product group, enables better linkage with these overall ambitions of the circular economy programme.

Increase policy coherence across the three agendas

Although the three policy agendas make reference to one another in various ways, the relationships between them remain largely unaddressed. As a result, synergies may remain unused (e.g. between climate change mitigation, air pollution control and reductions in nitrogen deposition), systems run the risk of being optimised for one specific objective (e.g. techno-optimisation in agriculture to mitigate greenhouse gas emissions, leaving behind animal welfare and extending product lifetime for the circular economy, thereby reducing overall energy efficiency improvements) with trade-offs between agendas remaining unaddressed (e.g. increased material demand for the energy transition conflicting with reduced material use in a circular economy, competing demands for biomass for food, bioenergy, medicine and the biobased economy).

An integrated policy approach, as called for by the assessments, entails explicit consideration of the synergies and trade-offs of possible strategies for various issues and stakeholders. This does not have to mean that there should be one integrated decision-making process cutting across all agendas, but at least requires explicit awareness of the downsides of a siloed policy approach and dedicated processes where significant interrelationships may be expected. A 'win-win' across policy agendas is not always possible. An integrated policy approach is thus also about ensuring that policy choices on trade-offs are made deliberately and that synergistic implementation is promoted.

Operationalising, such a process of consideration, requires clarity on the roles of the different ministries in each of the three transitions, as well as on who is responsible for their coherence. In addition, an accessible knowledge base on potential interrelationships can facilitate this process. Ways to further policy coherence include using the concept of 'policy coherence for sustainable development' (PCSD) as called for by SDG17.14 (OECD, 2019) and using a broad set of sustainability indicators throughout all phases of policy-making (e.g. the Dutch concept of '*brede welvaart*' (i.e. overall well-being) and the SDGs). The indirect drivers of environmental change provide a good starting point for policy coherence across the three agendas, including for lifestyle and behaviour, international trade and finance. Finally, coherence can be sought through shared challenges, such as around biomass and land use.

Here, we further elaborate on land use, which is linked to both environmental challenges and solutions, and is especially relevant in the context of biomass and spatial planning. Competition for land is a central theme in the five assessments. Globally, demand for land is already high (e.g. for food, energy, forestry, cities) and, if it remains unchecked, is set to increase further. Individual policy agendas can further increase global land demand. For both the energy transition and the circular economy, demand for biomass is increasing, such as for biofuels, bioplastics, wood in construction and biobased chemicals, most of which are imported. In addition, certain climate mitigation measures increase land demand, both domestically, such as for solar farms and wind parks, and internationally, such as for afforestation and reforestation measures. Finally, internationally and within the EU, new targets are under discussion to increase the area of protected land, in the post-2020 global biodiversity framework and the EU biodiversity strategy, respectively, which will further increase the demand for land.

Shared sustainability criteria for all types of biomass could strengthen coherence across the agendas. While perspectives on what qualifies as sustainable vary, recommendations for an extended set of Dutch and/or European criteria for sustainable biomass include specific attention for biodiversity loss, ensuring that land quality is safeguarded and land-use change is avoided, the inclusion of air quality and human health objectives, as well as improving the monitoring and traceability of biomass production (Strengers and Elzenga, 2020). A shift away from meat and dairy consumption is extensively discussed in the assessments as an effective means of reducing pressure on land. For the Netherlands, reduced meat and dairy consumption mostly reduces land use abroad, as most animal feed is imported. Finally, integrated landscape approaches can help to negotiate competing claims for land at local or regional levels. Such approaches could emphasise ways of connecting the transitions and foster plural land use in which priority is given to mixed and coupled land use rather than a strict separation of functions (Meijer et al., 2020; PBL, 2019b). The National Strategy on Spatial Planning and the Environment (NOVI) is the Dutch policy framework within which the Netherlands' spatial planning will be realised. Furthermore, the forthcoming revision of the EU Common Agricultural Policy, which is likely to give more leeway to individual member states, could create opportunities to tailor implementation more to local priorities. At the same time, evaluation at higher spatial scales, including at national, EU and global levels, is required on how to combine climate, food security and biodiversity strategies.

Integrate external environmental footprints in the agendas
Integrating the external footprint into national policy agendas is an important way by which environmental pressures abroad can be reduced and burden shifting can be avoided. The Netherlands, as a densely populated global trading nation with large imports and exports, has a relatively large external environmental footprint (SDSN and IEEP, 2019). As concluded in the assessments, international trade has led to increased geographical disparity between the impacts of global resource use and its benefits. While domestic production has become more efficient, environmental degradation has also been reduced by outsourcing production, thereby increasing environmental impacts abroad. A large share of the consumption footprint lies outside of the Netherlands or even outside the EU and between 1995 and 2010 this share has grown (Lucas and Wilting, 2018). In 2015 about 40% of the Dutch carbon footprint was outside the Netherlands, with three quarters outside the EU. For land use (mostly for food, wood and paper), in 2017 around 80% of the footprint was abroad, with a large share within the EU.[14]

External footprints are generally not part of international agreements. Although footprint indicators, including the ecological footprint, are part of the indicator set intended to track progress towards achieving the Aichi Targets. The Dutch climate agreement and the government's vision on agriculture, nature and food also focus mostly on domestic environmental pressures. This is at odds with the circular economy that focuses on reducing environmental pressure along the whole supply chain. Investments in a circular economy often lead to a reduction in greenhouse gas emissions abroad which are not rewarded under current energy and climate policy. Recently, a new ambition has been formulated to halve the ecological footprint of Dutch consumption by 2050. This is still a general ambition which needs to be made more concrete before coherent polices can be formulated and implemented. Policy choices that have to be made include the consumption categories (energy, food, materials), location (internal or external) and footprint types (carbon, water, land, biodiversity) that the target will apply to.

Addressing external environmental footprints requires integrating responsibility for environmental and social issues in sourcing areas outside the Netherlands into Dutch environmental policies. Addressing the sustainability of trade requires many types of actors

[14] See: https://www.clo.nl/indicatoren/nl0075-voetafdruk-landgebruik.

to change their behaviour and decisions. Sustainable and responsible trade has already been part of official government policies for some time now (Aid and Trade Agenda, Ministry of Foreign Affairs). An important emphasis in existing efforts towards creating responsible supply chains is the market uptake of certification for wood and agro-commodities like soy, palm oil, cacao and coffee, i.e. conformance to a set of international production standards that aim to improve the production conditions of resources and products. This could make the Dutch footprint more sustainable and reduce local impacts. However, to halve the carbon and land footprint of food consumption, for example, besides production measures, changes in consumption patterns will also be required (Westhoek, 2019).

Although certification can contribute to both the social and environmental domains of sustainability, its effectiveness is much debated (Strengers and Elzenga, 2020) and the transaction costs of assurance mechanisms tend to create a market disadvantage for more sustainably produced goods (SCSKASC, 2012; van Oorschot et al., 2014). Promising new approaches seek to operate at higher levels of spatial integration, such as landscape approaches, verified sourcing areas, or jurisdictional approaches (IDH, 2018). Instead of certifying individual producers at farm level, these approaches aim for sustainable production regionally, thereby balancing claims on land from different stakeholders in the region and contributing to a sustainably managed production landscape. This may be a way to avoid shifting environmental effects from certified farms trading internationally to those producing for the local market. A broadening of the approach can already be observed in which supply-chain sustainability by certification is combined with local approaches supported by large international companies, for instance, in the Dutch coffee sector (Kuepper and Kusumaningtyas, 2020). The two approaches should be seen as complementary and building on each other's resources and efforts.

Voluntary initiatives alone are unlikely to expand the market further (van Oorschot et al., 2014). This is partly due to the large share of some products that is destined for re-export and thus the limited share that is intended for Dutch consumers (e.g. soy and palm oil). Requiring companies to provide greater transparency in supply chains and setting EU-wide minimum standards on 'due diligence' requirements can further strengthen policies on international corporate social responsibility (Smith et al., 2020). By applying due diligence principles, companies have to identify risks in their supply chains and take appropriate measures to mitigate these risks. Certification of resources imported from high-risk areas could be part of such an approach, which is already required for the legal status of wood imported into the EU market.

Place more emphasis on consumption change

The assessments underline that a shift away from resource-intensive lifestyles is an important element in portfolios of measures to reduce environmental pressures. Such consumption changes are highly synergistic with achieving environmental and human development objectives and help to reduce dependence on technologies that are associated with significant feasibility constraints and trade-offs with achieving other sustainability objectives. Nonetheless, the three policy agendas largely focus on technology-based solutions. Addressing consumption change, including waste reduction, requires behavioural changes as well as overcoming the 'throw-away culture'. This is challenging as it requires people to change their values and notions of good quality of life, including their habits, heuristics and biases. The assessments discuss a range of policy options, albeit with varying degrees of evidence on the conditions to make them successful.

The assessments particularly stress the importance of a dietary shift away from meat and dairy consumption. For the Netherlands it is estimated that reduced food waste, more sustainable consumption patterns and more efficient and sustainable production could yield a combined reduction of 30% to 40% in the greenhouse gas footprint of food consumption and 25% to 40% in the land-use footprint (also indicating biodiversity benefits), with the largest contribution coming from changes in consumption (Westhoek, 2019). The climate agreement includes objectives to alter the ratio of animal versus plant-based proteins in the national diet and to reduce overall protein intake. Overall, intensification and technological solutions are dominant in Dutch food policy (de Krom and Muilwijk, 2019). Given the urgency, the feasibility constraints and trade-offs associated with specific technologies, and the strong synergies across policy agendas, more pronounced policies to target dietary changes are warranted.

Food consumption patterns are largely determined by social routines that come about through a combination of the availability and price of food, the social and cultural meaning of food, and consumers' food skills (PBL, 2019a). Policies to address routines include education, promoting changes in the availability of food, reflecting the negative effects of food production in food prices, and supporting innovative products and supply chains. As also stressed in the assessments, these policies are most effective when deployed jointly and in conjunction with the various actors that influence consumption routines, actors such as companies, civil society organisations and government authorities. As changes in routines do not happen overnight, policies addressing consumption change should start sooner rather than later.

Specifically address equity and inclusiveness

Recognising that transitions involve shifts in the structures and conditions that have generated environmental harm, such as social, economic and political inequality (i.e. 'structural transformation'), they can only be successful if sufficient attention is devoted to equity and inclusiveness. This includes recognising 'winners' and 'losers', and the fair distribution of costs and benefits (both within and between countries), as well as creating support in society. Societal support is required not only to effectively implement many of the transitional measures, but also because the transitions and the goals they contribute to are themselves to support the well-being of current and future generations. Because people hold different views regarding transitions, it is important to ensure meaningful inclusion of different perspectives in decision-making.

The social ramifications associated with the three agendas have only recently gained attention in public and policy debates. Although Dutch citizens support policies that promote transition, they are less sure that these are sufficiently inclusive (Vringer and Carabain, 2020). As parliamentary discussions on well-being have also highlighted, more attention and clearer insight into who are the winners and losers of transitions is needed. At the same time, the Netherlands has a longstanding tradition of making the effects of intended policies on different income groups visible and attempting to spread these fairly across society. Making more explicit use of this tradition in the environmental domain could help to limit the adverse distributional effects of transitions.

As social ramifications are broader than merely direct income effects, transitions also affect cultural values. For instance, part of the reason for Dutch farmers' protests in 2019 was dissatisfaction with society's appreciation of their position and role in society. While employment is often about more than merely providing a source of income, transitions also have implications for future employment and labour markets. Efforts to take the non-financial aspects of equity and inclusiveness into account could focus on ensuring that there is a positive perspective, including through schooling and retraining, for those who are most likely to lose out, or who feel like they could lose out.

Internationally, the equity discussion centres around 'common but differentiated responsibilities and respective capabilities' (CBDR-RC) and the need for low-income countries to develop with related demand for natural resources. CBDR-RC is mentioned in the climate convention and the 2030 Agenda for Sustainable Development. However, there is no global agreement on what may be considered an equitable or fair distribution of responsibility and environmental resources, while environmental agreements have moved from a top-down approach to more bottom-up, pledge-based contributions. Nevertheless, differences between countries' national circumstances and capacities (e.g. stage of development, relative contribution to the problem, ability to act) are relevant when translating global goals into national policy ambitions. The Netherlands can take considerations of 'fair' shares into account when defining national policy goals regarding natural resource use (e.g. land, biodiversity, materials). This is already more common with respect to climate change, but is not yet well-established for other environmental issues. Defining national fair shares requires making normative political decisions regarding global limits, distributive fairness and national responsibility (Lucas and Wilting, 2018).

Combine international cooperation with national action

The assessments stress that international cooperation is a necessary condition to be able to deal with the global systemic problems they address. No single country can achieve the goals and targets in isolation. Successful cooperation contributes to effectiveness, equity, efficiency and ensuring a level playing field, as well as uniting smaller countries' market power. Policies created through international cooperation can be highly effective because of the large number of actors they influence. For example, efforts to create standardised international indicators for a circular economy could provide coherence between countries for internationally operating companies (Koch, 2020). Many non-state actors are themselves increasingly operating transnationally, not just in their internal organisation modes but also in the supply chains in which they operate and are thereby shaping global environmental governance. As the focus of the assessments is predominantly on multilateral governance, the trend towards transnational governance has so far only been addressed to a limited extent.

By virtue of its large and relatively wealthy market, the European Union has significant influence on global standards for products and production processes. A linked European energy market can create the necessary conditions for large cost-efficiency gains in reaching national emission targets. The financial sector and international trade, highlighted by the assessments as two important indirect drivers of environmental degradation, are both important to the Dutch economy. The Netherlands could therefore take a proactive role in strengthening policies in these domains in the European context.

At the same time, the process of achieving successful international or even European cooperation can be lengthy and comes with no guarantees. Such cooperation requires the alignment of many different interests at a time when the world is becoming increasingly multipolar and in which the multilateral systems of past decades are under pressure. Furthermore, a leading role in advocating for ambitious international cooperation can only be credibly claimed when combined with serious national action. This could be aided by structural transparency about the considerations concerning the relative importance of unilateral, European and international levels in intended policy interventions. This reduces the degree to which making deliberate choices can be unnecessarily externalised to viscous multilateral processes, while at the same time making use of and strengthening multilateral fora that have retained potency. As part of development cooperation, considering national policies in conjunction with transitions in developing countries could improve policy coherence.

Make more use of the concept of overall well-being and the SDGs
The assessments underline the importance of employing wider definitions of progress than the general focus on economic growth and material consumption to strengthen policy efforts. At the request of the Dutch House of Representatives, Statistics Netherlands reports annually on the status and trends in national overall well-being of Dutch citizens (‘*brede welvaart*’) (CBS, 2020). The concept is about well-being ‘here and now’, as well as to what extent current well-being comes at the expense of the well-being of future generations and people in other countries. The report provides a much broader set of indicators for measuring development than the traditional focus on GDP growth, also including indicators related to environmental issues, health, education, trust and inequality. The report further covers where the Netherlands stands in terms of the SDGs.

Yet, both overall well-being (‘*brede welvaart*’) and the SDGs offer the potential to be much more than a monitoring tool and could actively facilitate policy debates on policy coherence as well as on medium and long-term policy goals. The concept of overall well-being is gaining currency in terms of its use by the government in policy processes and budgeting.

At the same time, ensuring there is a link to the SDGs is important because of their international recognition and active use by the private sector and civil society. The SDGs are incorporated in the government's 'integrated assessment framework for policy and legislation' which requires that new policy proposals are assessed in light of their effect on the SDGs and developing countries. Still, the actual application is challenging, and, besides actively assessing potential trade-offs, seizing on synergies is also important when pursuing policy coherence.

Both overall well-being ('*brede welvaart*') and Agenda 2030 provide frameworks that integrate social, economic and environmental aspects of sustainable development. Furthermore, the SDGs are internationally agreed goals on '*brede welvaart*'. Bringing the two concepts to the fore of the policy process can help to improve coherence across the three policy agendas, with other sustainability objectives, and with international policy efforts. It can help ministries to recognise their challenges and roles in relation to other ministries' challenges, where conflicts arise, and where coherence can be sought. Furthermore, achieving the SDGs by 2030 could provide an important step towards achieving the 2050 ambitions on energy and climate, food, agriculture and nature, and the circular economy.

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Appendix A Main conclusions from the five assessments

What is the current state of the environment worldwide and what are the most important drivers of change? Are we on track to achieve internationally agreed environmental goals, such as those outlined in the 2030 Agenda for Sustainable Development, the Paris Agreement and the Strategic Plan for Biodiversity 2011-2020? What kind of measures are available to get on track, and what are the interrelations (synergies and trade-offs) between broad measures and internationally agreed environmental goals? What policy strategies are required to make the necessary changes? The most important conclusions of the individual assessments related to these questions are summarised below. For more detailed conclusions see the summaries in the individual assessments.

Conclusions about land use and land degradation from the UNCCD Global Land Outlook

- Pressures on land resources have never been greater and there is increasing competition for them driven by the demand for food, water and energy and the need to safeguard ecosystem functions that regulate and support life. Some 20% of the Earth's vegetated land productivity is declining, including on around 20% of cropland areas. Land degradation contributes to climate change and increases people's vulnerability to environmental stresses. Furthermore, climate change-induced rising temperatures, changing rainfall patterns and increasing water scarcity are changing the suitability of vast regions for food production and human habitation. Small-scale farmers, in particular, have few alternatives to be able to sustain their livelihoods.
- Scenario projections show increasing tension between the need to increase food and energy production, and continuing declines in biodiversity and ecosystem services. Sub-Saharan Africa, South Asia, the Middle East and North Africa are projected to face the greatest challenges due to a mix of factors, including high population growth, low per-capita GDP, limited options for agricultural expansion, increased water stress and high biodiversity losses.
- To have sufficient land available to meet both the demand and the need for a wide range of goods and services requires changes in consumer and corporate behaviour, along with sustainable land management policies and practices, including planning. This includes shifts away from resource-intensive production, carbon-intensive processing and transport, land-intensive diets (primarily from the increased demand for animal products and processed foods) and the current high levels of food waste, including post-harvest

losses. Integration of conservation, land and water management, a multifunctional approach to land use, land management, planning and restoration, are critical to achieving the target on Land Degradation Neutrality and an important accelerator for achieving most of the SDGs.

- Response pathways that producers and consumers, governments and corporations can follow to stabilise and reduce pressure on land resources include a multifunctional landscape approach, resilience building, farming for multiple benefits, managing the urban-rural interface, no net loss, and creating an enabling environment.

Conclusions about climate change from the IPCC Global Warming of 1.5 °C

- Human activities have already caused approximately 1.0 °C of global warming above pre-industrial levels and impacts on natural and human systems from global warming have been observed.
- Current Nationally Determined Contributions (NDCs) under the Paris Agreement would not limit global warming to 1.5 °C, even if supplemented by very challenging increases in the scale and ambition of emission reductions after 2030. The challenges associated with delayed action to reduce greenhouse gas emissions include the risk of cost escalation, the lock-in of carbon-emitting infrastructure, stranded assets, and diminished flexibility in future response options in the medium to long term. Avoiding overshoot and reliance on future large-scale deployment of carbon dioxide removal (CDR) can only be achieved if global CO_2 emissions start to decline well before 2030.
- Pathways limiting global warming to 1.5 °C with no or limited overshoot reach net zero global emissions around 2050 (and around 2070 for 2 °C). These pathways would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems. The rates of system change required have occurred in the past within specific sectors, technologies and spatial contexts, but there is no documented historic precedent for their scale or spread. All pathways that limit global warming to 1.5 °C with no or limited overshoot rely on the use of CDR15 to compensate for residual emissions and, in most modelled pathways, achieve net negative emissions to return global warming to 1.5 °C following a peak. Afforestation and bioenergy may compete with other land uses and may have significant impacts on agricultural and food systems, biodiversity, and other ecosystem functions and services. Some agriculture-, forestry- and land-use- (AFOLU-)related CDR measures, such as the restoration of natural ecosystems and soil carbon sequestration, could provide co-benefits such as improved biodiversity, soil quality, and local food security. These impacts affect the feasibility of CDR options, plus there are uncertainties and a lack of knowledge concerning, in particular, the socio-cultural and institutional dimensions of feasibility. A mix of CDR options could reduce negative impacts and increase the likelihood of limiting warming to 1.5 °C.

[15] Existing and potential CDR measures include afforestation and reforestation, land restoration and soil carbon sequestration, bioenergy with carbon capture and storage (BECCS), direct air carbon capture and storage (DACCS), enhanced weathering and ocean alkalinisation.

- Mitigation options are associated with multiple synergies and trade-offs with achieving the Sustainable Development Goals (SDGs). While the total number of possible synergies exceeds the number of trade-offs, their net effect will depend on the pace and magnitude of change, the nature of the mitigation portfolio and the management of the transition. Pathways that include low energy demand, low material consumption, and low greenhouse gas-intensive food consumption have the most pronounced synergies and the lowest number of trade-offs in terms of sustainable development and the SDGs.
- Six crucial enabling conditions for systems transitions are identified: multi-level governance, behaviour change, institutional capacity, technological innovation, policy instrumentation and finance.

Conclusions about environmental change from the UNEP Global Environment Outlook 6

- A healthy environment is both a pre-requisite and a foundation for economic prosperity, human health and well-being. However, the overall condition of the global environment has continued to deteriorate despite environmental policy efforts by all countries and regions. Furthermore, poor environmental conditions cause approximately 25% of global disease and mortality, in particular, due to outdoor and household air pollution, and contaminated water.
- Environmental policy efforts are being hindered by a variety of factors, in particular the lack of implementation and integration in other sector policies, such as production and consumption. Most countries have introduced environmental policies and established governance structures, and there are now hundreds of multilateral environmental agreements in existence. Furthermore, innovative environmental policies are increasingly developed in developing countries, and policy diffusion between countries is also increasingly taking place. However, environmental policies often lack basic criteria to ensure their effectiveness and ambitions.
- The world is not on track to achieve internationally agreed environmental goals, such as those outlined in the SDGs and the Paris Agreement. Indicators related to human development, including hunger and access to clean water, are likely to improve but not sufficiently to meet related targets. Trends in environmental degradation, including climate change, biodiversity loss, water scarcity, excess nutrient run-off, land degradation and ocean acidification, are expected to continue to worsen at a rapid rate.
- Various pathways could be taken for achieving internationally agreed environmental goals. They all require wide-ranging innovation in production and consumption that go beyond what has been achieved in the past and which cannot be achieved by environmental policies alone. There are already many transformative projects and innovative solutions available at local level that could be appropriately scaled up.
- There are many synergies as well as conflicts between achieving the various goals. For example, synergies can be found for measures related to education, promoting sustainable consumption (including low-meat diets) and reducing air pollution. Improving agricultural yields is important to address biodiversity loss and land-based climate mitigation (including bioenergy and afforestation) and to tackle climate change but could also have significant detrimental effects on other environmental targets if not carefully managed.

- An integrated policy approach is key for policies to be effective. This includes integrating environmental concerns into the various policy-making sectors at all levels, including the equity and gender dimensions. Transformative pathways to sustainable development require: (i) visions to guide systemic innovation towards sustainability; (ii) social and policy innovation; (iii) the phasing out of unsustainable practices; (iv) policy experimentation; and (v) engaging and enabling actors and stakeholders.

Conclusions about resource use from the UNEP-IRP Global Resources Outlook

- The use of natural resources has more than tripled since 1970 and continues to grow, resulting in increasingly negative impacts on the environment and human health. Resource use has grown per capita and, therefore, is attributable not only to population growth. Further, global resource productivity has not improved since 2000, indicating that technological advances do not automatically improve resource efficiency on a global scale. This is due to structural shifts in regional production as well as rebound effects.
- Resource extraction and the processing of materials, fuels and food make up about half the total global greenhouse gas emissions (disregarding climate impacts related to land use), as well as more than 90% of land-use-related biodiversity loss (global species loss) and water stress. Agriculture, especially food production, is the main driver of global biodiversity loss and water stress. For climate change and particulate matter all types of resources are responsible for a significant share of the overall impacts.
- The use of natural resources and their related benefits and environmental impacts are unevenly distributed between countries and regions. Global trade in materials allows producers to compensate for regional differences in natural resource availability and supports global systems of production and consumption. While creating value in the country of origin, the movement of resources may also contribute to the unequal distribution of environmental or social impacts arising from the benefits of resource use between and within countries.
- In the absence of urgent and concerted action, rapid growth and inefficient use of natural resources will continue to create unsustainable pressures on the environment.
- Natural resource use and environmental impacts can be decoupled from economic activity and human well-being and also deliver substantial social and environmental benefits, including the repair of past environmental damage, while at the same time supporting economic growth and human well-being. Policy interventions, environmentally sound technologies, sustainable financing schemes, capacity building, and public–private partnerships can all contribute to this. Resource efficiency alone, however, will not be enough. What is needed is a shift away from linear towards circular flows through a combination of extended product life cycles, intelligent product design, standardisation and re-use, recycling and remanufacturing. Climate mitigation, protecting biodiversity, as well as changing consumer and societal behaviour are other important components.
- An approach to policy-making which provides multiple benefits includes: a) indicators and targets; b) national plans; c) policy mixes; d) sustainable financing; e) unlocking the resistance to change; f) policies for the circular economy; and g) leapfrogging. International exchange and cooperation can help to ensure fair competition in international trade.

Conclusions about biodiversity and ecosystem services from the IPBES Global Assessment Report

- Nature and its vital contributions to people — which together embody biodiversity and ecosystem functions and services — are deteriorating worldwide. Nature is essential for human existence and a good quality of life and offers a large untapped potential for many of the challenges humanity is facing. While more food, energy and materials than ever before are now being supplied to people in most places, this is increasingly at the expense of nature's ability to provide such contributions in the future and frequently undermines nature's many other contributions in the form of its regulating functions (e.g. regulating climate, air and water pollution, pests and diseases, pollination and floods) and non-material contributions (e.g. learning and inspiration, supporting identities). The biosphere - which is fundamental to the existence and richness of human life on Earth — is being altered to an unparalleled degree across all spatial scales.
- The direct drivers of change in nature with the largest global impact have been changes in land and sea use, the direct exploitation of organisms, climate change, pollution and invasive alien species. Mediated by societal values and behaviours, the indirect drivers include production and consumption patterns, human population dynamics and trends, economic growth, trade, technological innovation and local to global governance. Global trade has shifted the environmental burden of consumption and production across regions. Exclusion, scarcities and the unequal distribution of nature's contributions to people (NCP) can fuel social instability and conflict in many parts of the world.
- Most short-term goals for conserving nature and achieving sustainability, such as those embodied in the Aichi Biodiversity Targets, the 2030 Agenda for Sustainable Development and the Paris Agreement, cannot be met by current trajectories. Negative trends in NCP are projected to continue to 2050 and beyond due to the projected impact of increasing land use change, exploitation of organisms and climate change. Goals for 2030 and beyond may only be achieved through rapid and significant transformative changes in economic, social, political and technological factors.
- Nature can to some extent be conserved, restored and used sustainably while simultaneously meeting other global goals through urgent and concerted efforts that foster transformative change. This includes international cooperation and linked locally relevant measures, inclusive governance systems (which include indigenous peoples and local communities) and the evolution of global financial and economic systems to build a sustainable global economy: one which steers away from the current, limited paradigm of economic growth.
- Five main interventions (or levers) can be used to generate transformative change by tackling the underlying indirect drivers of nature's deterioration: (1) incentives and capacity building, (2) cross-sectoral cooperation, (3) pre-emptive action, (4) decision-making in the context of resilience and uncertainty, (5) environmental law and implementation. These levers will be most effective when directed towards the following key leverage points: (1) visions of a good life, (2) total consumption and waste, (3) values and action, (4) inequalities, (5) justice and inclusion in conservation, (6) externalities and telecouplings, (7) technology, innovation and investment, and (8) education and knowledge generation and sharing.

Appendix B Data sources

Table B.1

Data sources for Figure 3.4

Figure element	Indicator	Source
Indirect drivers (First panel)	Population	IPBES Figure 4.12, GLO Figure 6.1, IPCC1.5 Figure 2.4, GEO6 Figure 21.2, KC and Lutz (2017) and SSP database[1]
	Urbanisation	GEO6 Figure 21.2, Dellink et al. (2017) and SSP database[1]
	Per-capita GDP	GLO Figure 6.1, IPCC1.5 Figure 2.4, GEO6 Figure 21.3, Jiang and O'Neill (2017) and SSP database[1]
Demand (Second panel)	Primary energy demand	GEO6 Figure 21.7 and SSP database[1]
	Agricultural demand	GLO Figure 3.6
	Material demand	GRO Figure 4.5
Environmental pressures (Third panel)	Greenhouse gas emissions	GEO6 Figure 21.8 and SSP database[1]
	Agricultural area	GLO Figure 3.2
	Nitrogen deposition	GEO6 and Mogollón et al. (2018)
Environmental impacts (Fourth panel)	Temperature increase	GEO6 Figure 21.9 and SSP database[1]
	Loss of soil organic carbon	GLO Figure 4.5
	Loss of Mean Species Abundance	IPBES Figure 4.2.14 (biodiversity intactness), based on Schipper et al. (2020)

[1] SSP database: https://tntcat.iiasa.ac.at/SspDb/.

PBL Netherlands Environmental Assessment Agency

Mailing address:
PO Box 30314
2500 GH The Hague
The Netherlands

www.pbl.nl/en
@leefomgeving

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