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79

HOW SECTORS CAN CONTRIBUTE TO SUSTAINABLE USE AND CONSERVATION OF BIODIVERSITY

PBL Netherlands Environmental
Assessment Agency

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THE UNIVERSITY OF BRITISH COLUMBIA

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Contents

Foreword

Biodiversity is an important element of our natural capital. Ongoing loss of biodiversity as a result of a short-term focus has to be halted in view of long-term responsibilities and benefits. A focus on the sustainable use and conservation of biodiversity in primary sectors will help to realise this halt.

In 2010, PBL Netherlands Environmental Assessment Agency published its study 'Rethinking Global Biodiversity Strategies' in which we concluded that significant and lasting improvements in the downward biodiversity trend have to come from changes in human activities including agriculture, forestry, fishing and energy use. While traditional biodiversity policies that focus on conservation and protection measures would continue to be important, they need to be complemented with additional policies to address drivers and pressures of biodiversity loss. This study showed that ambitious, cross-sectoral strategies would half the rate of biodiversity loss by 2050, compared to what was projected without any new policies.

The importance of addressing underlying causes and reducing pressures is now reflected in the goals and targets in the Strategic Plan for Biodiversity 2011-2020, adopted in Nagoya, Japan in 2010. However, now that we are half way through the implementation of the Strategic Plan, it has become clear that addressing the underlying causes and pressures of biodiversity remains a key concern to keep the Strategic Plan on course.

To support the further implementation of the Strategic Plan this report shows first of all what key sectors can do to address the underlying drivers and pressures of biodiversity loss and contribute to its sustainable use. Secondly, this report presents actions and strategies for countries, the private sector, civil society and international organisations to support sectors to mainstream the sustainable use and conservation of biodiversity in their daily operations.

This study shows the potential that natural capital, biodiversity-friendly strategies and nature-based solutions offer for agriculture, forestry, fisheries and water management. It furthermore builds on the recognition that a numerous actors in sectors worldwide are starting to take action in favour of biodiversity. National governments will have to play an active role to ensure that these actions gain the necessary momentum to halt further biodiversity loss. Further implementation of this agenda will require new engagements between the biodiversity community and production sectors, as well as experimentation, sharing and learning about best practices in various regions of the world.

This study was conducted following a request of the Executive Secretary of the Convention on Biological Diversity, Mr Braulio Ferreira De Souza Dias, to the Dutch government, as a contribution to the fourth Global Biodiversity Outlook (GBO-4).

Professor Maarten Hajer

Director, PBL Netherlands Environmental Assessment Agency

How sectors can contribute to the sustainable use and conservation of biodiversity

Key messages

Underlying causes of biodiversity loss need to be addressed…

The Strategic Plan for Biodiversity 2010–2020 provides an overarching framework on biodiversity for the entire United Nations system and all other partners engaged in biodiversity management and policy development. The parties have agreed to translate the Strategic Plan that includes the Aichi Biodiversity Targets for the 2010–2020 period into revised and updated national biodiversity strategies and action plans.

The mid-term evaluation of progress towards implementing the Strategic Plan shows that, if current trends continue, pressures on biodiversity will increase in the coming decade. Consequently, global biodiversity will decline further, despite the increase in responses by national governments and many public and private initiatives worldwide. Addressing the underlying causes of biodiversity loss is a key concern to keep the Strategic Plan on course.

… this requires a focus on primary sectors

Developments in sectors such as agriculture, mining, wood production, water management and fisheries largely shape the world's current and future biodiversity, as they exert direct pressures on biodiversity. These sectors depend on biodiversity and ecosystems in various ways to provide food, fibre, wood, bio-energy, fish and clean water for the world's growing human population.

If current trends continue, demand for food, wood, water and energy is projected to increase 1.5–2 fold to match the rise in global population and increasing wealth, with negative consequences for biodiversity. Addressing these pressures therefore requires integrating biodiversity in the way in which food systems operate worldwide, how energy is produced, wood is extracted and produced, and fresh waters and oceans are managed.

Large potential for more biodiversity-friendly production methods and nature-based solutions exists in these sectors

Loss of ecosystems and their functions harms primary production in different ways, incurring costs and necessitating changes to sector operations. These sectors are therefore increasingly assessing their vulnerability to changes in their natural resource base and looking for ways to limit their impact and exposure.

There is a large potential for more biodiversity-friendly production methods and nature-based solutions in these sectors. These considerations should become mainstream in the operations of the agriculture, energy, wood production, fisheries and water sectors. This requires these sectors to become more aware of the values of biodiversity and well-functioning ecosystems, as well as the immediate risks that a loss of the natural resource base constitutes to the supply chain, and for these considerations to be embedded in decisions in production chains, either by companies, through consumer demand or through government intervention.

Realisation of this potential also contributes to broad set of sustainability goals

Scenario analysis shows the potential of future pathways to halt global terrestrial biodiversity loss by 2050 and to at least halve the rate of loss of all natural habitats, including forests, by

2020 (Aichi Target 5) and to expand protected areas to 17% of the terrestrial area (Aichi Target 11). At the same time, these pathways eradicate poverty and hunger, provide access to safe drinking water and modern sources of energy and limit the global mean temperature increase to two degrees Celsius in 2100 compared with pre-industrial levels. Achieving these targets simultaneously requires major and transformative change, but the analysis also shows that the 2050 Strategic Plan Vision is still within reach.

The pathways show that changes in the agro-food system can significantly contribute to halting biodiversity loss in 2050, through a combination of new agricultural practices that increase productivity as well as improvements in the sustainability of production, reduced food losses and waste and changing dietary patterns. Measures to improve forest management, combined with reduced wood consumption, will lower the increase in negative impacts of wood production. This combination of measures relating to both production and consumption is necessary to reduce or even eliminate dependency on wood that is derived from converting forests to other land use. Better land-use practices, including a more efficient use of agrochemicals, will improve the state of freshwater biodiversity and reduce pollution and its negative impacts on biodiversity, while better integrated land and water management can help restore watersheds and wetlands. In addition, considerably reducing the fisheries effort, eliminating illegal, unregulated and unreported fishing, unsustainable practices and destructive fishing gear and reducing by-catch will restore fish stocks and safeguard future yields.

Mainstreaming biodiversity succeeds when aligned with the core values of actors in the production chain

Embedding biodiversity concerns within sectors (mainstreaming) is more likely to succeed if biodiversity is aligned with the core values and – economic – interests of primary producers and other actors in the value chain. This requires that sectors recognise the opportunities that biodiversity provides, such as improved availability of fish and wood, improved soils for agricultural production systems and cost-effective nature-based solutions in water management. This is what mainstreaming policies need to achieve.

A broad perspective on production sectors that includes subsistence and commercial activities, local, regional and international supply chains, as well as consumers, helps to identify the most promising opportunities to move primary producers in a biodiversity-friendly direction. These opportunities are usually best found when sectors are further regionally specified. In addition, efforts to integrate biodiversity can benefit from the many sustainability initiatives already being taken within sectors, although more attention to biodiversity is necessary in many of these initiatives. A focus on actors in supply chains such as processing companies and retailers – who hold key positions to influence both production and consumption – will make these efforts more effective.

Key strategies to improve, speed-up and scale-up the integration of biodiversity within sectors are…

To effectively improve, speed-up and scale-up the integration of biodiversity within sectors, the following four strategies are suggested:

1. Apply integrated land, water and seascape approaches to reap benefits of ecosystem services across landscapes, inland water and marine environments, dealing with cross-sectoral issues, protecting interests of smallholders and improving current conservation efforts.

2. Strengthen biodiversity within emerging voluntary sustainability initiatives such as standard-setting and certification within international supply chains. To scale-up, it will be necessary to increase the awareness that biodiversity loss constitutes a risk to the supply chain, to increase the number of supply chains that apply biodiversity criteria, the market shares of certified products and the production areas certified in all world regions.

3. Strengthen the buyer's and consumer's perspective on biodiversity by raising awareness of the impacts of different products as well as the importance of biodiversity for food security and healthy diets. Increased adoption of less meat-intensive diets has health benefits and reduced food losses and waste has cost benefits; both would also reduce pressure on biodiversity.

4. Mobilise finance by improving the business case for biodiversity and green investments. This requires anchoring natural capital in companies' non-financial reporting to influence the decisions made by executives and investors and shift sectoral investment flows in a more biodiversity-friendly direction.

Governmental policies important for the effective mainstreaming of biodiversity in sectors…

While these strategies require joint efforts from public and private actors, public policies will be essential to enable their implementation. The following policies will be important for the effective mainstreaming of biodiversity in sectors:

- Raise awareness of the potential and opportunities biodiversity provides. Experimentation and joint learning in diverse contexts will be important to improve understanding of the role biodiversity and natural capital play in sectors and businesses.
- Work towards improved valuation, accounting and reporting of biodiversity and ecosystem-related impacts, risks and performances of primary producers, companies and investment projects.
- Realise the full potential of the many emerging sustainability standards and certification systems by ensuring proper inclusion of biodiversity, making sure that these initiatives go beyond first movers and are applied in all world regions.
- Take an integrated approach to land-use planning that includes sectoral interests, smallholders and local communities, improve land tenure security for smallholders, and realise the bundling of payments for ecosystem services.
- Employ policies that align sector incentives with biodiversity conservation and sustainable use, such as regulation and green taxation to internalise the public good aspects of biodiversity and ecosystems, reform environmentally-harmful subsidies and support innovation and technology diffusion to make production systems more efficient with lower impacts.
- Leverage the power of consumer choice. Health and cost arguments may trump biodiversity arguments in areas such as reduced waste of food products and less meat-intensive diets, but biodiversity will also benefit.
- Provide a level playing field, including setting and reinforcing legal standards. Successful biodiversity policies furthermore require the involvement of ministries of economic development and finance and sectoral ministries.

To conclude…

The CBD can play a leading role in mainstreaming biodiversity in sectors at the international level, by mainstreaming the spirit and substance of the Aichi targets into public and private governance of sectors; by ensuring the inclusion of biodiversity concerns in newly-emerging public and private partnerships on sustainability; and by working with sectoral bodies and other conventions to include biodiversity goals and actions in their activities.

The successful mainstreaming of biodiversity in production sectors will inherently become a diverse, dispersed and long-term process, requiring new engagements between the biodiversity community and production sectors, finding new ways to bring nature and economy together. As the practicalities of a shift towards more biodiversity-friendly production are not yet well-understood in sectors, much more experimentation, showcasing and sharing of experiences between diverse sector contexts around the world is required. The challenge will be to step-up, scale-up and speed-up action and to ensure a balance between public and private benefits.

Main findings

Pressures on and underlying causes of biodiversity loss need to be addressed

The mid-term evaluation of progress (SCBD, 2014) towards meeting the Strategic Plan for Biodiversity 2010–2020 shows that, with current socio-economic trends, pressures on biodiversity will continue to increase, and consequently biodiversity will continue to decline. This is despite the fact that society's responses to biodiversity loss are rapidly increasing. While there has been some progress, this will not be sufficient to achieve the Aichi Biodiversity Goals set for 2020. Improvement in and scaling-up of efforts is therefore required to keep the Strategic Plan to halt further biodiversity loss on course. In addition to improved nature conservation and species protection, the integration of biodiversity concerns across society (mainstreaming) needs to happen to be able to address the pressures on and the underlying causes of biodiversity loss and to promote sustainable use, as also suggested by the Aichi Biodiversity Targets.

This requires a focus on primary sectors

Developments in sectors such as agriculture, energy production, mining, wood production, water management and fisheries largely shape the world's current and future biodiversity. These sectors depend on biodiversity and healthy ecosystems in various ways to provide food, fibre, wood, bio-energy, fish and clean water for the world's growing human population. If current trends continue, demand for food, wood, water and energy is projected to increase 1.5–2 fold to match the rise in global population and increasing wealth, with consequences for biodiversity. The main pressures driving global terrestrial biodiversity loss under current trends are shown in Figure MF 1, and further elaborated for food and wood production.

Food production is the economic sector with the largest negative impact on biodiversity, contributing 60–70% to date of total biodiversity loss in terms of the 'Mean Species Abundance' indicator (MSA)[1] in terrestrial ecosystems and about 50% of MSA in freshwater systems. The extraction of wood products is a main driver of degradation of biodiversity in forests, accounting for about 5–10% global MSA loss, while agricultural expansion is the main driver for deforestation. Mono-functional, technical (or 'grey') solutions, traditionally chosen in water management, have not only led to extensive alteration of water bodies and biodiversity loss of about 20% MSA in rivers and 15% in floodplain wetlands, but have also hampered multifunctional use. Fishing also directly impacts biodiversity and has widely altered marine ecosystems through persistent overfishing and the use of destructive fishing practices that directly damage or modify habitat structure with resulting impacts on both target and non-target species. Furthermore, effective climate policies will be necessary to halt biodiversity loss, while from a biodiversity perspective possible synergies and trade-offs between climate change adaptation and mitigation policies and biodiversity policies need to be taken into account.

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[1] MSA is an indicator for intactness of ecosystems and is defined as the mean species abundance of originally occurring species relative to their abundance in undisturbed ecosystems.

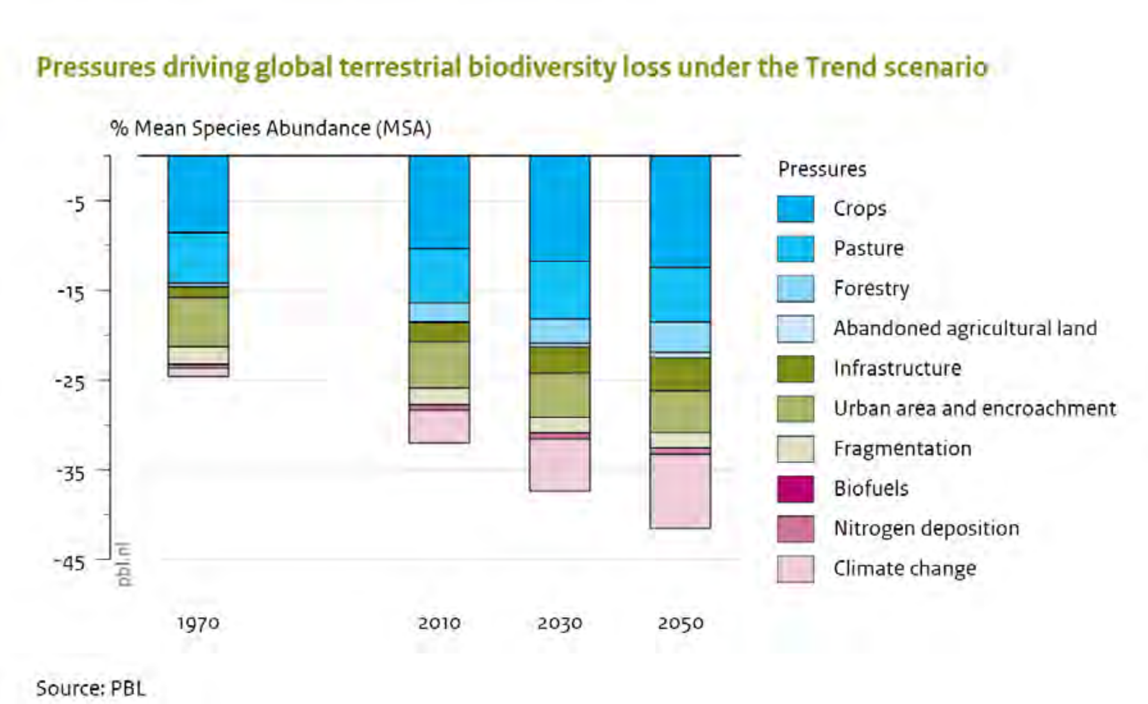


Figure MF 1. Pressures driving global terrestrial biodiversity loss.

Biodiversity provides opportunities to help realise a broad set of sustainability goals

A large potential exists within sectors for 'biodiversity-friendly production' and 'nature-based solutions' that, while resulting in the conservation and sustainable use of biodiversity, also contributes to food security, improved health and improved access to clean water and sustainable energy for all. Realising this potential requires that the opportunities that biodiversity provides are recognised within sectors. This is what mainstreaming policies need to achieve.

Mainstreaming biodiversity (also referred to as integration of biodiversity) is defined in this study as the process of embedding biodiversity considerations into policies, strategies and practices of key public and private actors that impact on biodiversity, so that biodiversity is conserved and the services that biodiversity provides are sustainably used, both locally and globally. Mainstreaming biodiversity into sector-relevant decision-making processes can create a powerful and necessary complement to nature conservation and species protection including – for example – the proper management of forest reserves, natural world heritage sites, national parks, wetlands, including RAMSAR sites, and marine parks. If drivers of and pressures on biodiversity loss fail to be addressed, the state of biodiversity will decline further and current conservation efforts will become less effective and more costly.

Both public and private (business, civil society) actors are important for mainstreaming biodiversity in sectors, each with separate but interrelated roles and responsibilities. Mainstreaming biodiversity within sectors is more likely to succeed if biodiversity is aligned with the core values and – economic – interests of primary producers, other actors throughout supply chains, and consumers. Identifying these opportunities also requires regional specific analysis. The specific sub-sectors addressed and technological and behavioural options analysed in this report are summarised in Table MF 1. These are elaborated in the next sections, together with the potential that biodiversity provides and some indication of what sectors are already doing in favour of biodiversity. The barriers and levers that can be identified from these experiences are summarised in Table MF 2, after which the analysis turns to potential pathways to realise long-term goals.

Table MF 1. Main technical and behavioural options to contribute to the halt of biodiversity loss in each (sub)sector.

Food production	Wood production	Water management	Fisheries
Crop production Livestock	Woodworking (e.g. construction) Paper and pulp production Local fuel wood, charcoal and wood pellets	Cities and drinking water Water for food Hydropower Flood protection	Marine fisheries Aquaculture
Increase crop and grassland yield and feed efficiency Reduce nutrient and pesticide losses and greenhouse gas emissions Stimulate local farmland biodiversity Stimulate improved land and water management Reduce food losses and waste Lower consumption of meat, dairy and fish	Responsible management incl. reduced impact logging Plantations in suitable areas while managing High Conservation Values Reduce wood consumption by increasing wood processing efficiency, re-use and recycling Technological innovation in use of residual and 'low quality' (soft) woods Fuel-efficient cookstoves and alternative energy sources for cooking	Apply ecosystem-based integrated water resources management Improve treatment, recycling and reuse of waste water Implement restoration Reduce water demand in sectors through design Implement sustainable dam management Preserve wetlands for water retention and filtration	Implement ecosystem-based fisheries management (EBFM) & co-management arrangements Implement gear restrictions Set up Marine Protected Areas (MPAs) Put restrictions on discards Adopt mitigating measures at farm level Integrated Multi-Trophic Aquaculture (IMTA)

Table MF 2. Barriers to mainstreaming and levers for change based on the sector analyses in this report.

Barriers to mainstreaming	Levers for change
Lack of awareness of the problems and lack of sense of urgency amongst actors. 'Mainstreaming overload': the large number of issues that compete for attention. Lack of operationalisation of the concepts of biodiversity and ecosystem services. Lack of knowledge of and capacities for opportunities and solutions. Short-term interests dominate, lack of economic incentives and lack of financial resources to invest. Lack of knowledge on the actual on-ground impact of tools/initiatives. Lack of integrated approaches at all levels of private and public decision-making.	Normative agreement (united vision) on importance of biodiversity for economic sectors slowly emerging. Increasing attention for resource availability, sustainable sourcing, nature-based solutions and license to produce amongst producers. New partnerships between NGOs and businesses throughout supply chains. Emerging business and biodiversity initiatives in the supply chain to learn from; pioneers may give a push to the market. Sustainability reporting is increasing. Increasing awareness among consumers of environmental problems. Emergence of innovative market-based instruments.

Food production and biodiversity

Agriculture faces the challenge of producing 30–70% more food by 2050 while at the same time improving food security. The actual figure depends on the degree to which food losses and waste can be reduced, as well as on future diets. The sector has an extensive impact on ecosystems and their biodiversity, but is also dependent on ecosystems in providing essential goods and services.

Food production can be regarded as a provisioning ecosystem service that crucially depends on a number of supporting and regulating services. Biodiversity plays an essential role in pest control, pollination and soil fertility, although in current agricultural systems some of these services are, partly, replaced by external inputs such as pesticides or fertilizers. Furthermore, the diversity of crop, livestock and fish varieties (agro-biodiversity) and their wild relatives is of long-term interest for maintaining viable and resilient crop varieties and livestock breeds. Regarding food security and healthy diets, biodiversity also provides nutritional benefits such as essential vitamins and micro-nutrients.

At the same time, the agriculture sector is one of the main factors contributing to biodiversity loss globally. The main impact of the sector on terrestrial biodiversity is through land use, through the conversion of natural lands into agricultural lands. Other impacts of the sector are through encroachment, the introduction of exotic species and the contribution to climate change due to greenhouse gas emissions from livestock. Furthermore, nutrient losses and nitrogen and pesticide emissions cause major stresses to the functioning of ecosystems and biodiversity. The agriculture sector also has major impacts on aquatic biodiversity through nutrient and pesticide leaching, soil erosion and consequent sedimentation and the introduction of exotic species.

There are a number of options for the agriculture sector to reduce its impact on biodiversity. Firstly options that reduce the demand of food by reducing food losses and waste and shifting diets towards a moderate level of meat consumption. Secondly by a sustainable increase in crop yields (especially in low-income countries) that could significantly contribute to reducing the expansion of agricultural land. Thirdly in regions with high yields in monocultures, where local farmland biodiversity is typically low, an option is the introduction and restoration of semi-natural landscape elements. If sensibly done, this will increase biodiversity while only marginally affecting crop yields. Simultaneously increasing grassland livestock productivity and improving the sustainable use of these grasslands are important for the sustainable development of the livestock sector.

There are many ongoing initiatives by various actors in the food sector that take biodiversity into consideration. Some focus more on the local impacts of agriculture on biodiversity, while others aim more to reduce the global pressure on the food system (e.g. reducing food waste and increasing crop yields). Examples are farmers certifying their production and companies participating in pre-competitive initiatives to assist farmers around the globe to implement good management practices to raise yields (or maintain current high yield levels in richer countries) while reducing the pressure on biodiversity. Some important pressures can be addressed by regulation (e.g. reduced nutrient losses and pesticide emissions) while others (such as the maintenance or reintroduction of landscape elements) typically require positive incentives. Changing consumer practices to reduce food waste and promote sustainable dietary patterns can be addressed by a combination of governments, NGOs and private actors such as retailing companies and restaurants.

Wood production and biodiversity

The wood production sector is, similarly to the agricultural sector, both dependent on ecosystems and their goods and services and a major contributor to forest biodiversity loss. The demand for wood-based products such as timber, wood fuel, pulp and paper will increase in the future. There will also be an increase in demand for wood-based bio-energy, driven by greenhouse gas emission reduction targets. The main ecosystems for the required resources are forests. The wood production sector is therefore highly dependent on forests and their production capacity. The gradual depletion of virgin forests from which wood can be 'mined', combined with the dependence of the wood production sector on forests, has increased awareness about sustainable production methods. A diversity of tree species is essential to provide a variety of different forest products for different end-uses – from timber to paper and fuel. Sustainable production methods keep the harvest intensity within the forest regrowth potential. Sustainably managed forest ecosystems also provide services for agriculture and water management and other sectors.

While the direct impact of the wood production sector on deforestation and the conversion of natural forests is relatively limited, compared to agriculture, the sector's major direct impacts on forest biodiversity degradation arise from the selective extraction of trees, wood fuel collection, and from establishing wood plantations. On the other hand, the sector has a very significant but indirect impact on land use change as a precursor to other human activities in previously inaccessible areas, leading to the eventual conversion of forests to cropland and pastures, leading to biodiversity loss. CO_2 emissions from deforestation and forest degradation (and energy use during harvest and processing) also contribute to biodiversity loss, as well as the use of pesticides, water pollution and the fragmentation of forests by infrastructure.

Options to reduce biodiversity loss while maintaining wood production are: to concentrate production in high-yield plantations established preferably in degraded and low-biodiversity areas while managing high conservation values, to implement sustainable forest management in natural and semi-natural forests, and to increase processing efficiency (by re-using and recycling wood products). High biodiversity values are contained in forests (globally more than half of all terrestrial species) and both primary and well-managed forests are important for conserving this biodiversity. Therefore, any option that reduces incentives to convert forests rather than manage them for timber and other products and services is beneficial for biodiversity conservation. Which option has the most potential is different per region, and depends on the present biodiversity status, the applied production methods, and the availability of land and finances for plantation establishment.

Globally, numerous initiatives have been taken up by different actors to reduce the impact of the sector on biodiversity. Examples of these are the growing uptake of certification schemes for sustainable production standards like FSC, Rain Forest Alliance and PEFC by primary producers, governments combating illegal logging and trade through the establishment of policies such as the EU Forest Law Enforcement, Governance and Trade (FLEGT) action plan, the US Lacey Act, Australia's Illegal Logging Prohibition Act, and NGOs stimulating the demand for certified and legal wood products, such as WWF's Global Forest Trade Network. More attention is also required for the supply of wood fuel, especially where it is collected and harvested informally, supplying local populations with energy sources.

Water management and biodiversity

Many production sectors depend on good quality water (e.g. for drinking water), as well as an adequate water supply (agriculture, industry) and regulation (hydropower generation, flood protection, navigation). The increasing demands of most sectors challenge the water management sector in many parts of the world as it is increasingly difficult to meet all water quantity and quality requirements simultaneously. In addition, climate change is expected to further aggravate most of these water quantity and quality issues.

In water management, biodiversity and well-functioning ecosystems are essential for the provision of clean water. Natural elements and upstream forests in catchment areas and natural river, lake and wetland systems regulate and purify water flows, allow adequate water provision for the different users and decrease the vulnerability to climate change. On the other hand, the water management sector has major impacts on freshwater biodiversity through the loss of aquatic habitats caused by conversions and water works, flow modification and loss of connectivity, as well as pollution.

In many cases, water management goals can be achieved by naturally functioning ecosystems and nature-based solutions, thereby creating synergy with biodiversity protection. For this reason, ecosystem-based Integrated Water Resources Management (IWRM), including the regulation of water demand and pollution, is the preferred approach if biodiversity goals are to be achieved. Biodiversity-friendly and nature-based solutions are possible in the fields of land-use management (such as forest and wetland conservation and sustainable agricultural practices in source areas of drinking water, resulting in a reduced outflow of nutrients), the improved treatment, recycling and reuse of wastewater, integrated river basin management and flood protection (preservation of wetlands for water retention and filtration, balance of various demands, restoration of fish migration, floodplain extension as natural flood protection), lake management (restoration of connectivity between lakes and wetlands, natural shorelines), stream restoration (re-meandering, creation of riparian zones), reduced water demand in agriculture, cities and industry, and hydropower generation (adapted design, sustainable dam management).

The water sector has already taken steps in the direction of reducing its impact on biodiversity. Examples are the implementation of PES (Payments for Ecosystem Services) to protect upstream watersheds and the adoption of water allocation policies for water-scarce areas by governments, usually as part of IWRM.

Fisheries, aquaculture and biodiversity

The fisheries sector faces the challenge of an increasing global demand for seafood, which is projected to grow from around 150 million tons in 2010 to over 210 million tons in 2050. Oceans, and the biodiversity they support, provide important goods and services for humans. Marine fisheries and aquaculture provide important provisioning services, namely seafood, that support the food security and welfare of millions of people worldwide, while fish populations provide regulating services through their role in regulating food web dynamics and nutrient balances. Fishing can also be considered a cultural service, as it plays an integral role in coastal cultures and traditions.

Fishing directly impacts biodiversity through the removal of fish and damage or modification to marine habitats, which in some cases has driven populations to such low levels that it has resulted in the local extinction of marine species. Aquaculture production, on the other hand, has an impact on biodiversity through its use of and impact on forage fish species, the introduction of invasive alien species, pollution and land use.

There are various options for the fisheries sector to reduce its impact on biodiversity. These include the implementation of ecosystem-based fisheries management (EBFM), eliminating or diverting subsidies that contribute to overcapacity and overfishing, reducing Illegal Unregulated and Unreported (IUU) fishing, gear restrictions, creating marine protected areas, the use of economic incentives, co-management arrangements involving fishers and governments and/or NGOs, and sustainability certification and labelling. Options for aquaculture are the implementation of mitigating measures with regard to environmental impacts at the farm level, the development of monitoring and assessment programmes, the implementation of Integrated Multi-Trophic Aquaculture (IMTA) and voluntary certification.

There are currently a number of ongoing initiatives in the fisheries and aquaculture sectors that aim to reduce the impact of the sector on biodiversity. These vary from the implementation of certification schemes by primary producers to the adoption of EBFM through policies such as the EU Common Fisheries Policy, and the establishment of multi-lateral fisheries management conventions by governments, such as the UN Law of the Sea Convention. Paired with the increase in demand for fish and fish produce is also an expansion in incentives to producers to produce in a more sustainable and low-impact way. These incentives come from the market, with an increased demand for sustainably-produced seafood carrying a food safety and sustainability label. They also come from society at large, which demands that the producers obtain a societal ‘license to produce’. It is also increasingly embedded in the marine management systems that pair ecosystem and biodiversity concerns with management measures and a governance system that allows producers to actively take part in the management of the resource.

Pathways towards halting biodiversity loss and realising 2050 Vision

To contribute to the realisation of the Biodiversity 2050 Vision of the Strategic Plan and the Aichi 2020 Biodiversity Targets, a broad set of options is available in sectors (see Table MF 1). A number of those options are already being taken up around the globe, as is indicated above and will be shown in more detail in the sectoral chapters. Current efforts are however not sufficient to realise the 2050 Vision and available options need to be adopted much more widely.

To identify the potential and required efforts for realising the Biodiversity 2050 Vision, three different pathways (combinations of bio-physical and behavioural options) to step-up and scale-up sector efforts towards biodiversity-friendly production methods were analysed. This was done by applying a model-based back-casting approach (see Chapter 2 and Annex 1 for details).

The suggested pathways emphasize different solutions and strategies, either ‘global technology’, ‘decentralised solutions’ or ‘consumption change’. The Global Technology pathway elaborates large-scale technologically-optimal solutions, such as intensified production on relatively smaller areas, a reliance on market-based approaches and assumes a high level of international coordination. The Decentralised Solutions pathway focuses on regional solutions such as more sustainable and biodiversity friendly use of land over more extended areas and agriculture that is interwoven with natural corridors. The Consumption Change pathway prioritises changes in human consumption patterns, most notably by limiting meat intake per capita, by ambitious efforts to reduce waste in the food production and consumption chain and by increased recycling and re-use of wood and paper. These pathways should not be interpreted as blueprints. Rather they are used here to identify potentials of different technical and behavioural options, trade-offs and synergies to halt biodiversity loss, using a model-based analysis. The analysis only focusses the on food and wood production.

The analysis is designed to show what is needed to achieve a halt to global terrestrial biodiversity loss by 2050, while at least halving the rate of loss of all natural habitats by 2020 (Aichi Target 5) and expanding protected areas to 17% of the terrestrial area (Aichi Target 11). At the same time, these pathways realise a much broader set of sustainability objectives including eradication of poverty, feeding the world, supplying clean water and energy and limiting the global temperature increase to two degrees Celsius in 2100. These pathways result in preventing more than half of the loss of biodiversity that is projected to take place in the coming 35 years, i.e. a MSA of 64% by 2050. The pathways towards 2050 are depicted in Figure MF 2, while the reductions in loss of nature areas and protected areas in the pathways are presented in Figure MF 3.

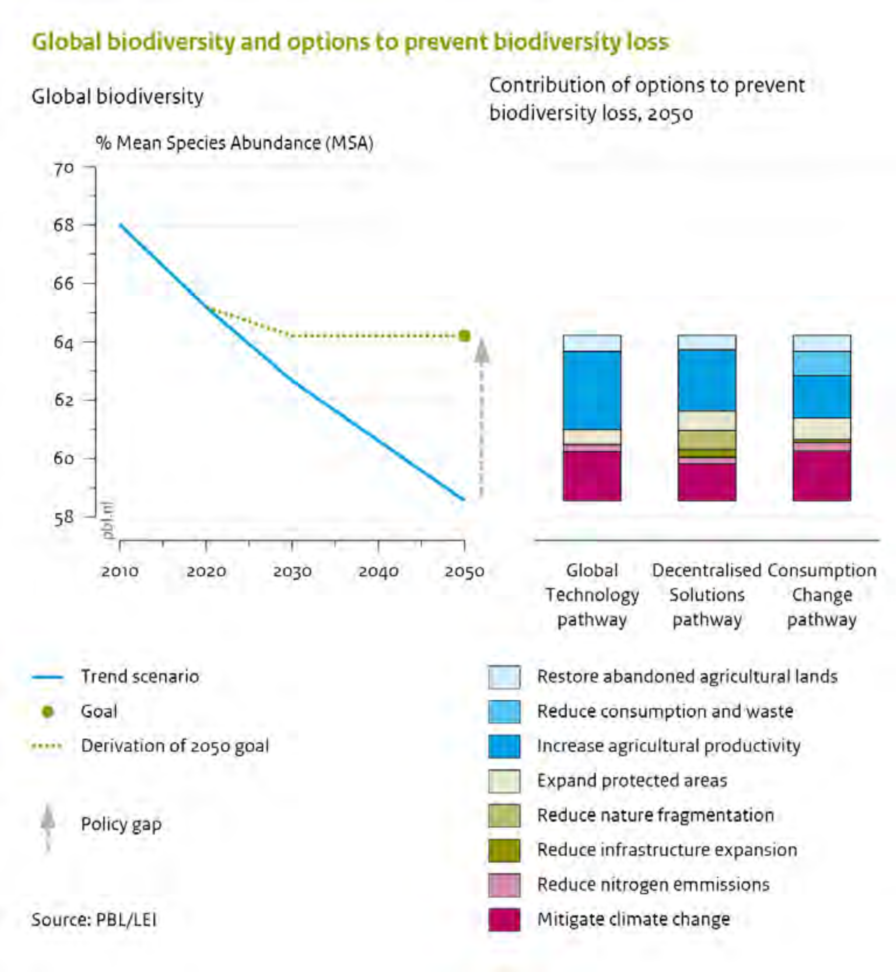


Figure MF 2. Options to prevent global terrestrial biodiversity loss in three pathways (Updated from PBL, 2012 for this report).

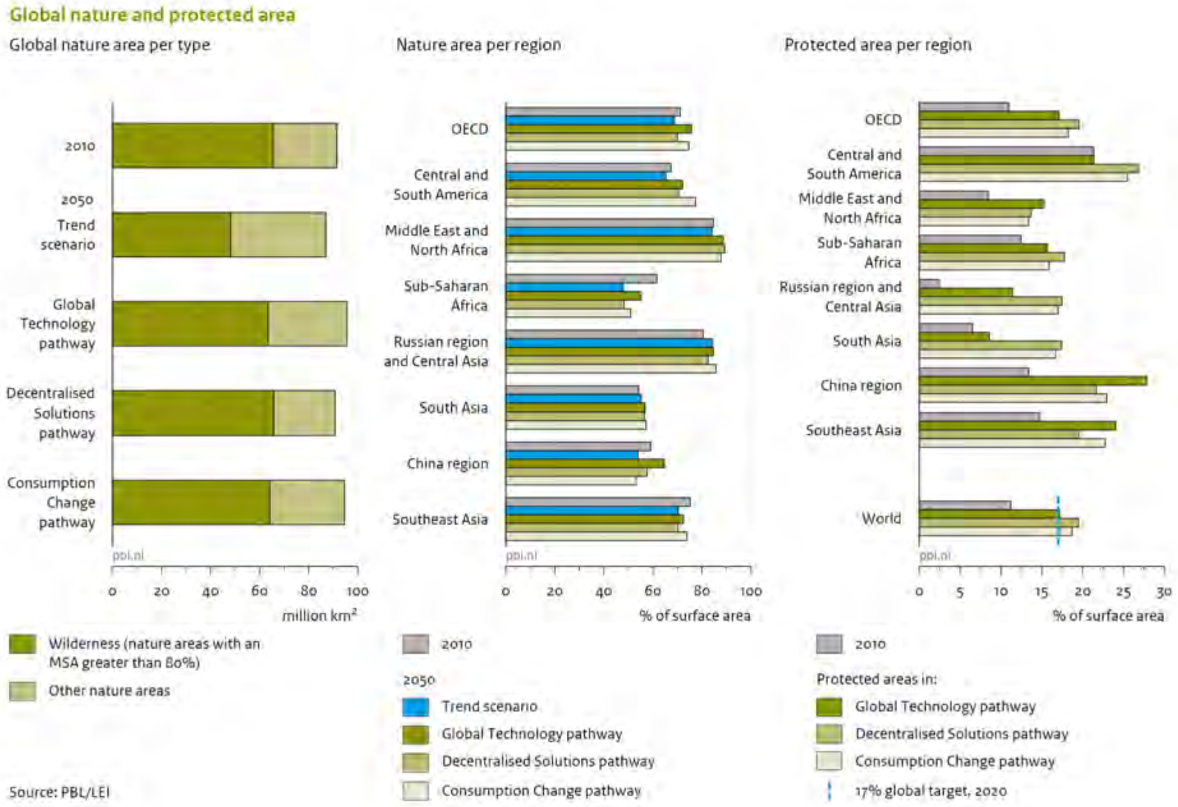


Figure MF 3. Global nature area and protected areas under Trend scenario and pathways. The pathways will considerably reduce the loss of nature areas, and of wilderness in particular. The different allocations of protected areas in the pathways causes differences in the efforts that would have to be undertaken in regions to achieve the Aichi Target on the expansion of protected areas to 17% of terrestrial and inland biomes in ecologically-representative systems (Updated from PBL, 2012 for this report).

Pathway analysis for food and wood production

For *agriculture,* the scenario analyses show sufficient potential to contribute to halting further biodiversity loss in 2050 in all three pathways (see Figure MF4, left panel). However, substantial efforts will be needed to fulfil the conditions underlying these pathways. In the developed regions of the world, where population growth is limited, the options within the food production sector is by far the most important to reduce biodiversity loss in all three pathways both on the land and in freshwater systems. In these regions, agricultural productivity is already high, and realising the necessary improvement under the *Global Technology* pathway of annual yield increases of the same magnitude as reached in the past 20 years (1.3%) will be challenging, especially if compared to the FAO projection of an annual 0.67% increase for the 2006–2050 period. The opportunities for developing countries to reach the productivity assumptions in the pathways are much better, but innovative solutions will be needed to reach this productivity growth if there are to be no negative effects on biodiversity and the environment (this is referred to as sustainable intensification). In *Decentralised Solutions*, productivity increase will come from ecological solutions. In the currently intensively-managed landscapes of the United States and Europe, remnants of biodiversity are relatively scarce, putting ecological solutions at risk. This pathway therefore requires a profound change in these intensive farming systems, so that time and investments will be needed to improve degraded ecosystem services (this is referred to as ecologisation). In Figure MF 5 trajectories of agricultural intensification and ecologisation are depicted.

Moreover, the current globalized system challenges the resilience of agro-ecosystems by spreading invasive pests and diseases. Evidence for compatibility between an agricultural production goal and reduced pest problems by conservation of biological enemy density is still scarce. Improved knowledge is needed for the design of new agricultural systems that combine ecological resilience with efficient technologies. This is important because most of the currently-known ecological solutions are labour-intensive, which people increasingly want to avoid. Diminishing the impacts on biodiversity by changing consumption is especially promising in the affluent world. Consumption towards a reduced intake of animal products is not only helpful for biodiversity protection, by the reduced demand for land, but will also contribute to human health.


Pathway options for reducing biodiversity loss in selected sectors

Food production

Wood production

Source: PBL

Figure MF 4. Improvement in biodiversity in the pathways for the sectors food (left panel) and wood production (right panel) in comparison to trend (in MSA percent points).

For *wood production*, global wood demand will be lower in all pathways compared with the Trend scenario due to a lower demand for wood fuel, substitution from other sources, increased re-use and recycling and the use of residual wood for generating bio-energy. Wood is produced more efficiently in all pathways using highly-productive wood plantations, that reduce the land use. Further degradation in semi-natural forests, where wood is harvested by selective logging is reduced by applying less damaging harvesting techniques, usually referred to as reduced impact logging. In itself, these solutions offer a large potential to reduce biodiversity loss. Nevertheless, the potential result of these options in the Pathways are blurred by interactions with other sectors An important difference between scenarios is the area of land deforested for agricultural use. As agricultural expansion comes to a halt in Global Technology and Consumption Change pathways (and not in Decentralised Solutions), deforestation does no longer provide a source of wood products. A larger area for permanent forestry is therefore required to satisfy global wood demand in these pathways. More sustainable wood production in semi-natural forests may lead to lower yields and will required a larger area. As a result, the forest area under management for wood production in the Global Technology pathway will be 30% higher compared with the Trend scenario by 2050. In the Decentralised Solutions pathway, deforestation still occurs as increases in agricultural productivity are lower than in the other pathways. This interaction puts more emphasis on balancing the remaining forest land to different uses, either plantation establishment, biodiversity protection, and sustainable forestry, and combinations.

In two of the three pathways, however, a net loss of biodiversity is still projected as a result of these interacting effects (see Figure MF 4, right panel). The effects of changes that are due to shifts in the relative shares of the different forest management systems (each with their specific biodiversity value) are comparatively small, and do not present a major influence on the mean global biodiversity value of production forests.

Establishing plantations leads to additional loss of forest biodiversity in all pathways, as these low biodiversity value systems usually replace areas with higher biodiversity values. If plantations can be established on degraded or abandoned agricultural lands and if high conservation value forest remnants within plantation landscapes are set aside and managed for biodiversity, part of this loss can be mitigated.

These scenario analyses show that there are crucial interactions between the agriculture and forestry sectors that must be taken into account when designing robust and integrated sustainable future pathways that meet the biodiversity targets in different ways. There are also effects of reduced climate change. Part of the positive biodiversity effects of global greenhouse gas mitigation can be attributed to the wood production sector, through carbon sequestration in forest and by reducing the use of wood fuels. This positive effect on biodiversity loss concerns all the worldwide affected biomes (grasslands and shrubs), and not only the forested ones that are in use for wood production.

Trajectories of agricultural intensification

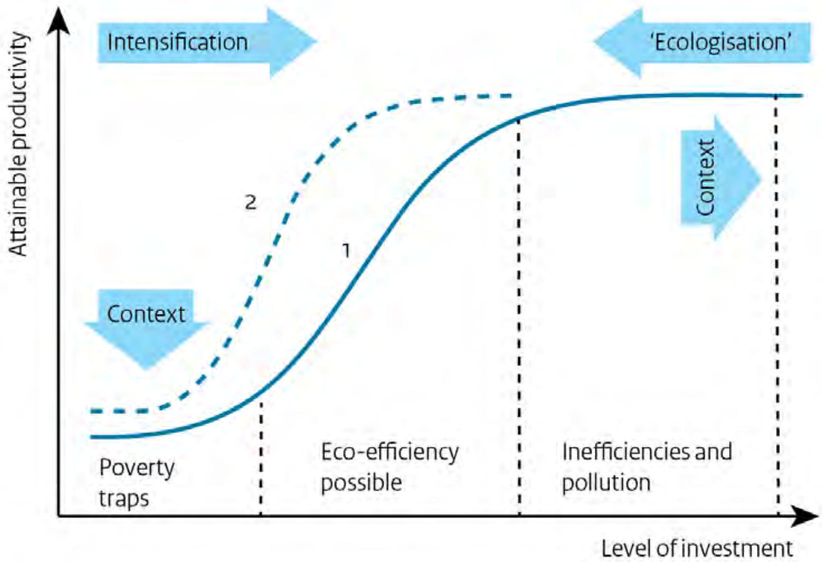


Figure MF 5. Attainable agricultural productivity per hectare of land or person as a function of the level of resource investment (capital, labour) (after Tittonell, 2013). Investments in research would allow a move from trajectory 1 to trajectory 2. The demographic and socio-political context in low-income countries makes it difficult for smallholders to escape from the poverty trap. In high income countries, farmers continue to invest in inputs in order to reduce production costs, pushing them further in the direction of inefficiency and pollution.

Need for cross-sectoral approaches

As there are clear linkages between the sectors presented here, this also implies that the long-term solutions need to be looked at in coherence to consciously deal with trade-offs and to capture possible synergies. Agriculture is an important factor contributing to biodiversity loss in forests, water bodies (e.g. through outflow of nutrients and high water demands) and coastal ecosystems. As explained above halting deforestation is associated with a reduced supply of unsustainable wood that must be compensated elsewhere. Projected climate change will have major impacts on biodiversity in the coming decades, showing the importance of effective climate policies for the protection of biodiversity. Mitigating climate change through the increased use of bio-energy or hydropower may result in an expansion in agricultural lands and larger numbers of hydropower dams, further fragmenting rivers. Both have negative impacts on biodiversity. The use of bio-energy is therefore relatively limited in the pathways, as they are designed to meet both climate change and biodiversity objectives. While not covered in the model analysis, international trade and the scale of supply chains will expand, implying transportation of goods over longer distances, contributing to accelerated invasion of alien species, pests and pathogens over larger scales. In transport and trade activities in all sectors, the application of appropriate measures to prevent the spread of invasive alien species, pests and diseases is therefore necessary.

Priority actions per sector

Based on the scenario analysis, and taking the barriers and levers for change to mainstream biodiversity into account, priority actions per sector for the four sectors covered in this report are suggested in Table MF 3. These options will contribute to biodiversity conservation and a more sustainable use of natural resources and are identified with keeping long-term sustainability objectives in mind. Strategies for implementation and necessary government policies are addressed later in this chapter.

Actors who hold key positions in supply chains have influence to realise major changes

Various actors in different parts of the supply chain (such as processors, traders, retailers, investors and banks) are in key positions to create demand for more sustainably-produced, biodiversity-friendly consumption goods (where supply chains become narrow, see Figure MF 6). A relatively small number of actors provide a lever for change and may be able to realise major changes throughout the supply chain. In several sub-sectors, a concentration of actors offers levers for mainstreaming. It is more difficult to reach parts of sectors with a high level of actor fragmentation, including more informal and subsistence activities (as is the case in wood for local and domestic consumption). Decisions taken by primary producers are influenced by key actors throughout supply chains, including consumers and other end-users. Building partnerships between public and private actors to explore the potential for mainstreaming biodiversity much improves the perspective on levers of change. Within food supply chains, retailers, restaurants and catering businesses could play a major role in this shift towards more biodiversity-friendly agriculture.

Table MF 3. Priority actions for sectors to contribute to biodiversity protection and more sustainable use of natural resources.

Sector	Priority actions
Food production	Sustainable intensification of agriculture in regions with low crop yields (higher crop yields, higher feed efficiency for livestock): - develop appropriate knowledge and techniques; - create clear and fair market conditions; - seed companies should diversify their breeding programmes; - adopt sustainability initiatives (certification schemes, PES, etc.); - design innovative financial arrangements directed towards the 'missing middle'. 'Ecologise' intensively-farmed areas: - reduce emissions from farmed land and livestock, such as nutrient losses, greenhouse gas emissions and pesticides; - preserve agro-biodiversity; - reduce water use; - system change from monoculture towards alternative cropping rotations or cropping systems; - implement innovative techniques and precision farming; - align agricultural and biodiversity policies; - apply taxes and remove harmful subsidies; - implement and enforce existing regulations and stimulate transparency and good practices. Reduce food waste and change diets: - reduce portion size, improve packaging; - influencing consumer choice by retailers(choice editing); - reformulate products and develop alternatives to meat; - promote dietary shifts; - raise awareness; - public procurement; - promote healthy and sustainable diets in education.
Wood production	Implement sustainable forest management: - stimulate certification of sustainably forest management, especially in the tropics; - avoid wood production activities in primary and old growth forests; - limit and, if needed, carefully plan and manage expansion of road networks into previously inaccessible forest areas. Strengthen business case for responsible wood production: - create local, national and international demand for sustainable wood products; - halt illegal logging; - increase value of standing forest to forest managers by creating markets for environmental services provided by forests. Sustainable expansion and intensification of plantations: - steer plantation establishment towards degraded and abandoned lands; - manage High Conservation Values as part of larger-scale plantation landscapes. Reduce impact of processing industries: - Reduce wood resource use - improve re-use and recycling efficiency; - responsible siting of high impact industries like paper and pulp factories.

	Include informal and small-scale producers: - provide positive regulatory and fiscal incentives that improve practices of informal and small-scale producers, especially access to resources; - Provide alternatives for wood based energy sources - Expand the working of Voluntary Partnership Agreements by including and integrating domestic markets; - integrate trees for local use of timber and wood fuel into agricultural systems.
Water management	Strengthen and expand the potential for ecological approaches in IWRM, including environmental flows. Improve water management in cities and villages: - protect biodiversity-rich watersheds and wetlands upstream; - improve treatment and recycling of urban and industrial wastewater, reduce pollution. Reduce impact of agriculture: - reduce water use in agriculture; - reduce pollution from agriculture; - shift away from animal production, which requires a lot of water. Make hydropower more sustainable: - implement sustainable dam management; - implement initiatives such as Payments for Ecosystem Services; - implement hi-tech infrastructure and regulatory installations at large dams. Improve flood protection: - restore natural streams; - use green infrastructure; - implement ecologically-based water management solutions.
Fisheries and aquaculture	Fisheries: - develop and implement modified or alternative fishing gear; - reduce by-catch; - establish communication systems to report observations of by-catch hotspots; - eliminate destructive fishing gear; - establish Marine Protected Areas; - establish management systems based on ‘credit system’, which could incentivise fishing operations with lowest biodiversity loss; - promote adoption of certification schemes; - provide incentives for fishing communities to engage in fisheries and marine conservation; - improve regional cooperation in fisheries management; - eliminate Illegal Unregulated and Unreported (IUU) fishing; - make international standards, such as the FAO Code of Conduct for Responsible Fisheries, mandatory. Aquaculture: - reduce pressures on wild fisheries; - produce and consume low food chain products such as molluscs, seaweed and omnivorous/herbivorous fish preferentially over species that use more fish meal/oil in their production; - move away from use of wild juveniles in cases where wild populations are impacted; - reduce dependence on alien species; - particularly for shellfish culture, shellfish restoration could be beneficial for both biodiversity and aquaculture.

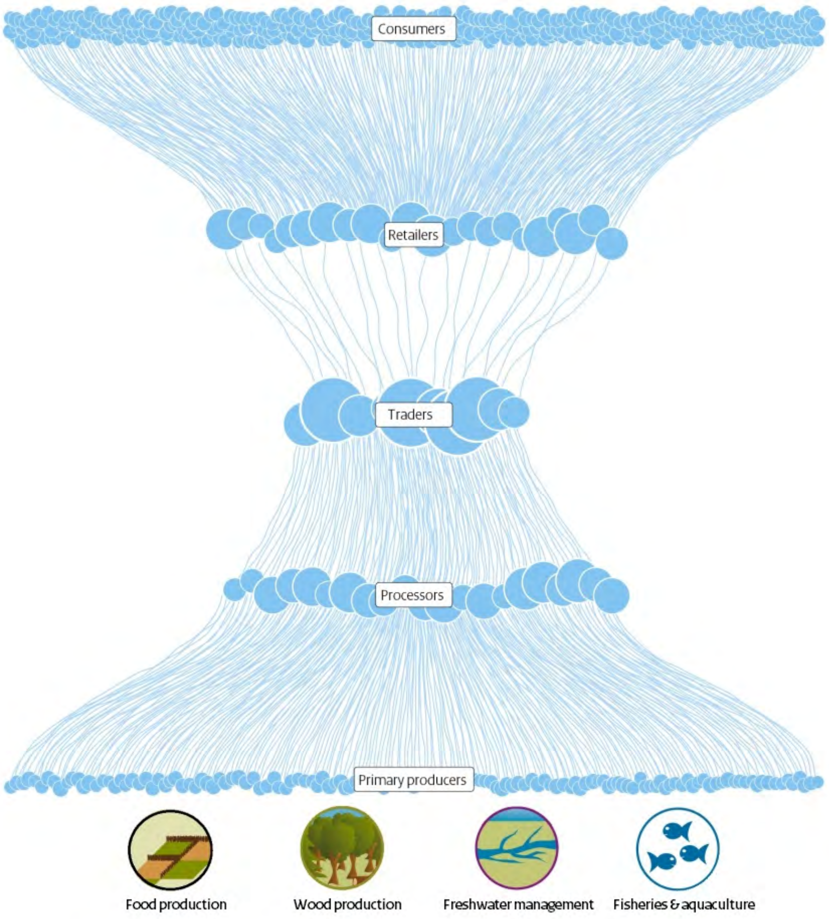


Figure MF 6. Supply chain perspective on sectors.

Strategies to step-up, scale-up and speed-up efforts to mainstream biodiversity

If biodiversity considerations are to be sufficiently embedded into sectoral policies, strategies and practices, an intensified collective effort is needed by governments, the private sector and civil society. Table MF 3 summarises the priority actions suggested in this report, which provide a rich portfolio of possible actions to take. Their relative relevance will depend on local circumstances. To be able to effectively and efficiently implement relevant actions, an integrated perspective can be helpful to effectively step-up (improve, scale-up and speed-up) efforts to mainstream biodiversity and help move sectors in a more biodiversity-friendly direction. Four building blocks for such an integrated perspective are suggested below; the specific role of governments in them is summarised in Table MF 4.

1) Apply integrated land, water and seascape development approaches. Integrated planning approaches can help balance sustainable production within sectors with the interests of smallholders and other stakeholders, and are better able to deal with cross-sectoral issues and anchor conservation efforts in the area. The land-sparing (intensification, mono-functional land use) versus land-sharing (multi-functional land use) debate can be taken up in land-use planning, illustrated in the Global Technology and Decentralized Solutions pathways. Figure MF 7 shows the effects of mono-functional and multi-functional landscapes on biodiversity and the regional differentiation of these pathways, and hence the need to find regionally optimal solutions, in which only in the green areas in Figure MF7 a choice between sharing and sparing strategies is possible to realise positive biodiversity effects. This can be made explicit in integrated landscape approaches, but requires improved spatial planning (land-use planning, land tenure, integrated water resource management, integration of local actors in decision-making) within countries. Creating level playing fields for all stakeholders – ranging from multinational corporations to indigenous populations – in a landscape remains an important role for governments. To increase the effectiveness of programmes like PES and REDD on a landscape level, the bundling of these financial incentives should be considered. The landscape level seems to be the most appropriate level for tackling the drivers of continuing degradation of natural resources and setting up viable long-term restoration projects in public-private partnerships.

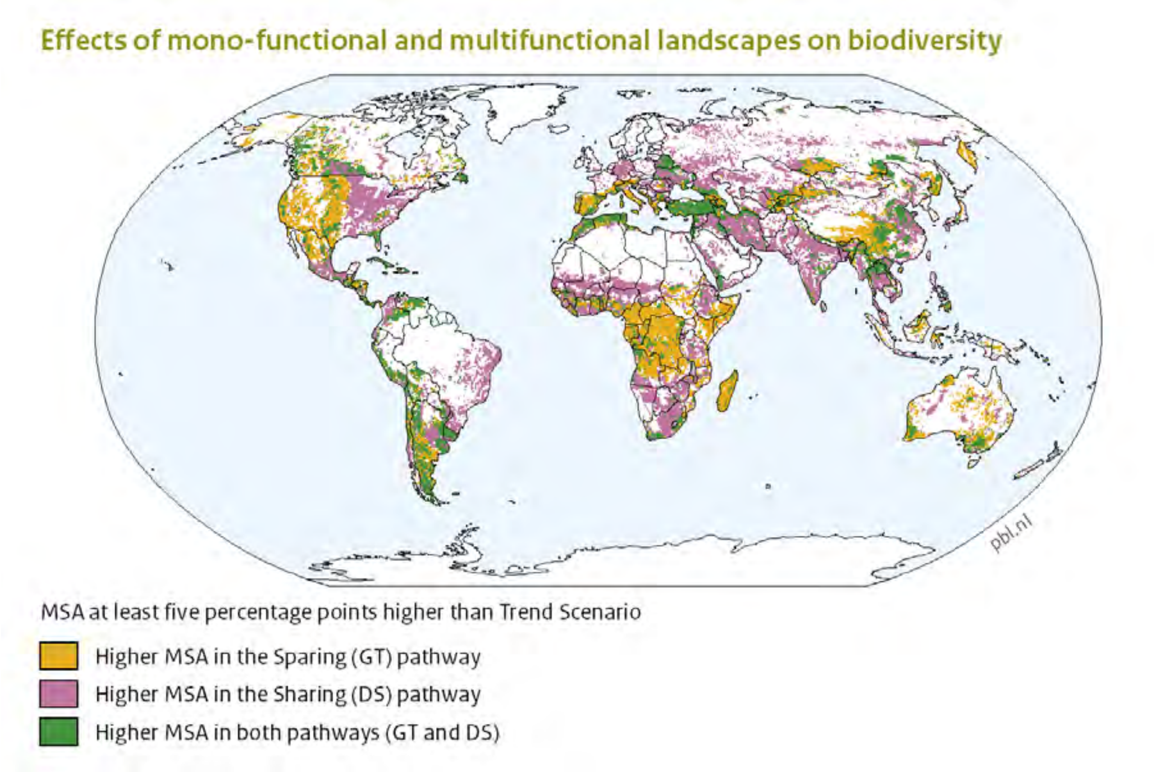
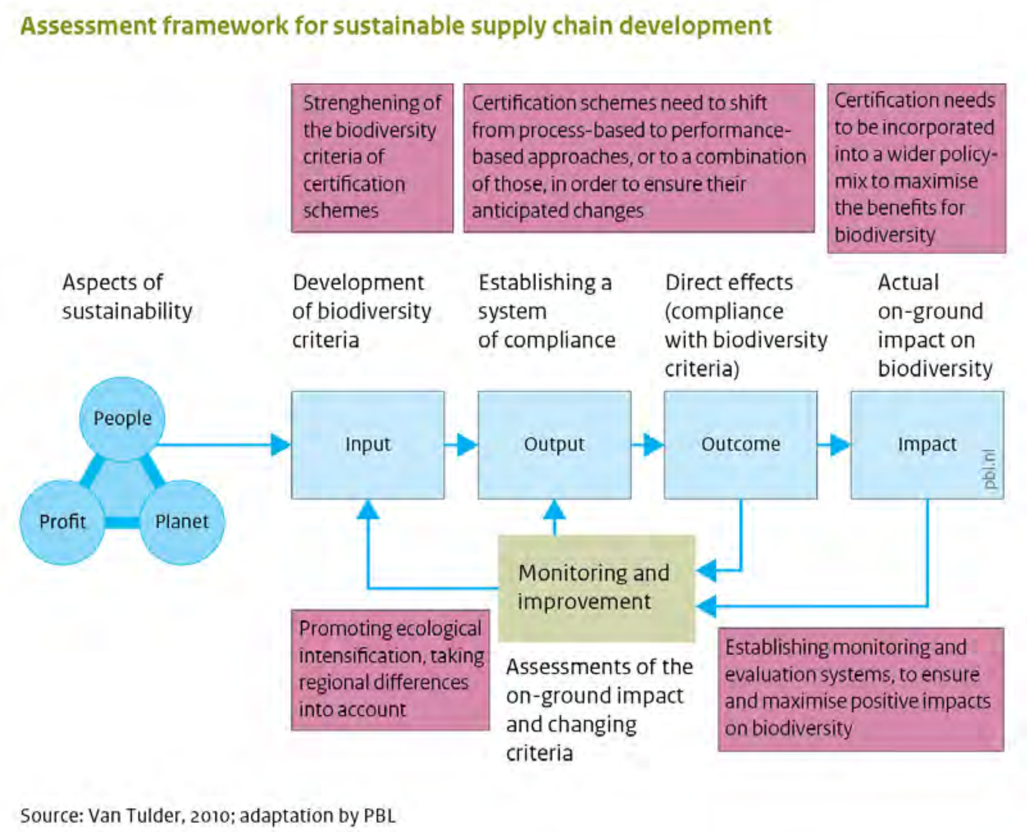


Figure MF 7. Effects of mono-functional and multifunctional landscapes on biodiversity, represented as Mean Species Abundance (MSA) of the original species.

2) Better integration of biodiversity in voluntary sustainability initiatives along supply chains to benefit from their increasing momentum worldwide. These initiatives include standards and certification, corporate social responsibility, and public and private procurement policies to support primary producers to move in a more sustainable direction. An important issue for biodiversity policy is if and how the biodiversity benefits of these initiatives could be improved. As most (visible) progress is taking place in the certification of supply chains, possible improvements are suggested in Figure MF 8. This is done using the ‘I-O-O-I evaluation framework’, which connects stepwise the biodiversity criteria of certification schemes (input), through selling/buying certified products (output) and changed behaviour by farmers (outcome), to the actual long-term impacts on biodiversity (impact). To scale-up, it will be necessary to increase the number of supply chains that apply biodiversity criteria, the market shares of certified products and the production areas certified in all world regions.


Assessment framework for sustainable supply chain development

Source: Van Tulder, 2010; adaptation by PBL

Figure MF 8. Entry points for maximising the positive impact of certification schemes (general framework based on van Tulder (2010; adapted by PBL, 2014). These recommendations are also helpful to identify entry points for improvements in other types of voluntary initiatives.

3) Further develop a consumption perspective on biodiversity by raising awareness of the potential of biodiversity for food security and healthy, sustainable diets, as well as of detrimental effects of consumption patterns on natural resources and biodiversity. Through reducing food losses and waste and shifting diets towards a moderate level of meat consumption, impacts of the food system on biodiversity can be significantly reduced. Consumer demand for certified products also needs to play a role here. The focus should not only be on consumers, but on all actors in the food system that influence food choices, such as the media, retailers, catering training institutions, hotels and restaurants, public procurement, and on showing how production conditions and consumer choices are linked.

4) Shift current and future investment flows into key sectors towards more biodiversity-friendly alternatives. Annual investment flows into biodiversity-related sectors are large relative to dedicated biodiversity financing. Much of the financing of these sectors is of public or private domestic origin, with a smaller part from foreign direct investment and development assistance. These flows will increase in the future, especially in developing countries. Biodiversity needs to be mainstreamed into these public and private, foreign and domestic investment flows. Governments can move indirectly by increasing the information base through national-level natural capital accounting and company-level non-financial reporting. Governments can also move directly by using financial mechanisms that tip the balance of decision-makers in companies and local governments towards greener investment choices. The integrated nature of such solutions makes the government capacity to monitor and evaluate these policies crucial.

Table MF 4. Government policies for four strategies.

Landscape	Supply chain	Consumption	Finance
Improve spatial planning to include all stakeholders. Create institutional capacity and co-management schemes. Ensure land tenure for smallholders and local communities. Combine different incentive schemes for ecosystem services. Monitor impacts. Integrate farm-level initiatives with further upscaling.	Capacity-building. Prioritise national/international supply chains, commodities and regions where largest impacts are and where actions are required. Create (local) markets for sustainable produce, including the use of public procurement. Stimulate certification and labelling Focus on laggards. Improve extension services. Monitor impacts.	Raise awareness through information and education campaigns. Health policies. Public procurement. Develop instruments to push back food waste.	Increase non-financial reporting on biodiversity by companies. Engage with financial sector initiatives. Redirect investment flows in biodiversity-related sectors. Assess and use the relative strengths of domestic and foreign public and private investment flows.

Government policies at the international level

The strategies identified above require the joint effort of private and public actors, but governments will have to provide an enabling and regulatory environment through adequate public policies to get these strategies realised. Specific domestic policies in relation to the four strategies are summarised in Table MF 4. In addition, governments can act in the international arena to further develop a sectoral mainstreaming agenda:

- help realise shared visions and a sense of urgency for biodiversity-inclusive solutions to make biodiversity-friendly production a part of the ‘new normalcy’ of sustainable production and consumption in all relevant sectors;
- ensure coherent global norms to monitor and preserve the global public good aspects of biodiversity. This can be done through related Multilateral Environmental Agreements and the proposed Sustainable Development Goals and ensuring that biodiversity is taken into account in with other policy domains like trade, finance, development cooperation and climate adaptation and mitigation;
- further develop partnerships with business and include biodiversity in already existing UN partnerships with business such as the Global Compact, the Global Reporting Initiative and the UN Forum on Sustainability Standards;
- support programmes for the uptake of Natural Capital Accounting systems in national governments (like the System of Environmental-Economic Accounts adopted by the UN Statistics Commission and the World Bank’s WAVES partnership) and in the business world;
- support the inclusion of biodiversity in the further development of private norms, reporting and review mechanisms (e.g. ISEAL or ISO for certification).

The CBD can play a leading role in mainstreaming biodiversity at the international level:

- mainstreaming the spirit and substance of the Aichi targets into public and private governance of sectors;
- ensuring the inclusion of biodiversity concerns in newly-emerging public and private partnerships on sustainability;
- working with sectoral bodies and other conventions to include biodiversity goals and actions in their activities;

- creating ownership and leadership amongst key players in public and private governance for biodiversity. Natural Capital Accounting in Central Statistics Offices and companies could play an important role in this.

To conclude…

The successful mainstreaming of biodiversity in production sectors will inherently become a diverse, dispersed and long-term process, requiring new engagements between the biodiversity community and production sectors, finding new ways to bring nature and economy together. As the practicalities of a shift towards more biodiversity-friendly production are not yet well-understood in sectors, much more experimentation, showcasing and sharing of experiences between diverse sector contexts around the world is required. Furthermore, the mainstreaming of biodiversity into sectors needs to be seen as part of a broad policy agenda of biodiversity conservation and the promotion of the sustainable use of biodiversity and natural resources. Governments need to play an enabling and regulatory role to involve the relevant private and societal actors. The challenge will be to step-up, scale-up and speed-up action and to ensure a balance between public and private benefits.

Chapter 1. Introduction

1.1 Context and rationale

The mid-term evaluation of progress towards the attainment of the Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets shows that, if the world stays on its current development path, pressures on biodiversity will continue to increase in the coming years, and the state of biodiversity will decline further (sCBD, 2014). While there has been some, mainly regional, progress in the societal response to biodiversity loss, in most cases this will not be sufficient to achieve the Aichi Biodiversity Targets set for 2020 (sCBD, 2014). Not achieving these targets will make it more difficult to realise the long-term vision of a world '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.' Additional action is therefore required to keep the Strategic Plan on course.

To provide better insight into how the pressures on and underlying causes of biodiversity loss can be addressed, this report focuses on the possible contribution of key economic sectors to halt biodiversity loss and enhance the sustainable use of natural resources. The further integration of biodiversity policies across society was put forward in the Strategic Plan for Biodiversity, 'to address the underlying causes of biodiversity loss, to reduce the direct pressures on biodiversity and promote sustainable use, and to enhance the benefits to all from biodiversity and ecosystem services'. The choice for a sectoral perspective is motivated by the fact that the future of the world's biodiversity is largely shaped by the way in which worldwide food, energy and water systems are operate (Sala et al., 2000; PBL, 2010). How we organise agriculture and fishery, produce energy and wood and manage the world's freshwaters and oceans determines biodiversity levels to a large extent. This report therefore specifically looks at food production, wood production, water management and fisheries and marine aquaculture: sectors that are highly dependent on the natural resource base and healthy ecosystems (MEA, 2005).

The report does this in two ways. Firstly, it identifies options for production sectors to contribute to a world 'Living in harmony with nature' in the coming decades in sectors that are highly dependent on nature. The potential for 'biodiversity-friendly production', and 'nature-based solutions' (IUCN, 2012) in these sectors is identified, as are the strategic choices to be faced, including the synergies and trade-offs between sector priorities on the one hand and biodiversity conservation and sustainable use on the other. Secondly, the report looks at the governance challenge of getting biodiversity concerns embedded (mainstreamed) into the sectors under study. This report identifies promising strategies to mainstream biodiversity in primary production sectors and actions for public and private actors to support sectors to move in a more biodiversity-friendly direction. Focusing on sectors also requires showing the business case for biodiversity in sectors. To identify levers of change, this analysis will not be restricted to the production side, but will also look into the supply chains the sectors are part of. The demand and consumption side of the supply chain may have a decisive influence on the way in which agro-commodities are produced and natural resources are managed.

1.2 Aim and research questions

This report is a contribution to the fourth Global Biodiversity Outlook (GBO-4), which provides a mid-term assessment of progress towards the Aichi Biodiversity Targets (sCBD, 2014). Parties to the CBD requested GBO-4 to, amongst other things, address possible policy responses that could be effective in contributing to the achievement of the Aichi Biodiversity Targets. The aim of this technical report for the CBD is to provide insights that can support countries, non-state actors such as private sector and civil society, and international organisations to mainstream biodiversity and its sustainable use in production sectors.

The main question addressed in this report is, 'What can sectors do to contribute to halting the loss of biodiversity and improve its sustainable use; and how to support sectors to mainstream biodiversity?'

The report addresses the benefits of and dependencies on biodiversity and ecosystem services for food and wood production, water management and fisheries and aquaculture, and the impacts on and the risks of further biodiversity loss for these sectors. Activities and initiatives in the sector to reduce their impact on biodiversity and improve its sustainable use are explored, taking into account the different economic stakes that sectors have. Based on this barriers and levers for change are identified. In addition, the long-term options for different actors in the sector to reduce their impact on biodiversity are presented. Based on these analyses, strategic directions for policymaking for countries, private and societal actors and international organisations are formulated to support sectors in contributing to the conservation of biodiversity and its sustainable use.

1.3 Definitions of some crucial concepts

Biodiversity in a sectoral context

Biodiversity, and especially the services derived from ecosystems, is essential for the secure production and supply of food, fibres, biofuels and freshwater and for resilient production systems (Cardinale et al., 2012). From a production or sector perspective, this is often referred to as the natural resource base or natural capital. In this report, we apply the term 'biodiversity'. Biodiversity is a multifaceted concept and includes diversity within species, in wild and domesticated species, among species and between ecosystems (CBD/A, 1992; Mace et al., 2012). These facets of biodiversity have different roles in delivering the various ecosystem services. We look at terrestrial, aquatic and marine biodiversity and the services provided by nature that are relevant for the sectors under study (see Figure 1.1 for an illustration). However, not all facets of biodiversity will be addressed equally in the report. When describing 'biodiversity loss', we mainly focus on the biodiversity of natural ecosystems and wild species (SCBD, 2014; PBL, 2010). When describing the benefits of biodiversity we mainly focus on the genetic diversity of domesticated species and their wild relatives (agro-biodiversity), and on biodiversity at the ecosystem level that provide essential services to sectors. Sectors can safeguard and conserve these facets of biodiversity and improve its sustainable use.

The genetic diversity of species used in the different sectors, for example crop and livestock species in agriculture, tree species for wood production and fish species for fisheries, is an important asset for these sectors. The genetic diversity includes wild relatives of domesticated species. In production systems, the genetic diversity of these species is intentionally manipulated to increase yields or expand geographical extent. This mainly happens in agriculture, aquaculture and wood plantations and planted forests. In low input systems, a large diversity exists on farms, whereas in technologically developed systems this diversity tends to be low (IAASTD, 2009). To improve or renew varieties and breeds, access to genes is necessary. These genes are derived from wild relatives, 'old' varieties maintained in gene banks or in situ. The tendency towards single crop and single variety systems as a means for improving yields and intensification requires genetic sources, or agro-biodiversity, to be protected in gene banks, in situ and in the wild.

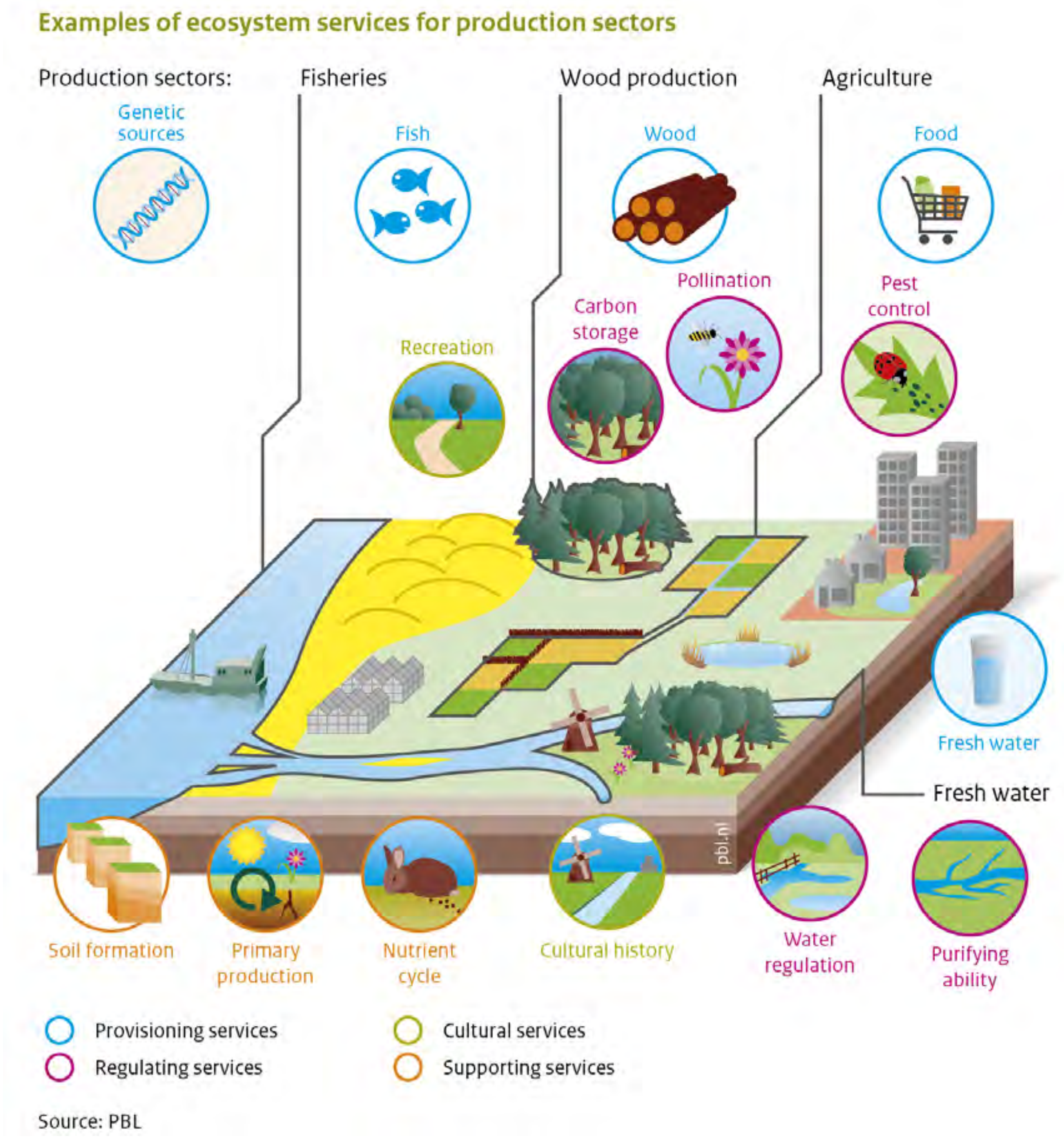
Biodiversity indicators

Biodiversity policies apply a broad set of indicators. The main aspects that are included in these indicators are the number of species, or species richness in a clearly-defined area (such as a country or a continent); the uniqueness of these species; the distribution and abundance of species; the status of protected areas; and the status of species as endangered or threatened (IUCN Red Lists). The indicators for changes in richness are extinction risks of species. At the global level, extinction rates are expected to increase due to continuing increasing pressures (Pereira et al., 2010). Endemic species or species with a very limited distribution range are a major concern in conservation policy. Another set of indicators is based on the average abundances of individual species. These indicators show broad tendencies in the overall population changes of a large set of species. Examples are the 'Living Planet Index' (LPI) and the 'mean species abundance' (MSA) (Collen et al., 2009; Loh et al., 2000; Alkemade et al., 2009). Changes in abundance and distribution are also included in Red Lists indices. This report mainly uses the MSA indicator, which is an index of the naturalness of an ecosystem. The patterns of change indicated by the MSA are largely similar to those indicated by LPI or red list indices (SCBD, 2014). For more detail on the MSA in relation to other indicators, see Annex B.

Ecosystem services

Benefits of ecosystems and biodiversity are generally referred to as ecosystem services (MEA, 2005). Some services are substitutable with man-made capital; others are not (Fitter, 2013). Some benefits have a market value, while many other do not (Costanza et al., 1997; de Groot et al., 2012). The production of food, wood, fibre and the provision of drinking water are considered provisioning services. Provisioning services depend on several regulating ecosystem processes, such as the maintenance of soil fertility, pest control, pollination, soil formation and stabilisation, water retention by soil and vegetation and carbon storage. Another category of ecosystem services is cultural services, such as spiritual and aesthetic services, especially for indigenous and local communities, and providing space for recreation. These services all depend on well-functioning ecosystems and their species composition. The capacity of provisioning services from, mainly, agro-ecosystems is often maintained and enhanced by technical means, such as the application of fertilizers, pesticides and soil and water management. These technologies however have often replaced the capacity of ecosystems to provide services.

The relationship between biodiversity and ecosystem services is not straightforward. Whether more biodiversity would imply more ecosystem services depends largely on the type of ecosystem service and the specific biodiversity facet. Biodiversity can play a crucial role in the provision of regulating services; examples include the role of pollinators and a large variety of predator species reducing outbreaks of pests in agricultural fields. In addition, biodiversity is essential as a genetic reservoir for crop and livestock improvement. In this report, we analyse the prospects of a number of ecosystem services at the global level in view of the benefits for sectors and the risks of deterioration in the provisioning of specific services.



Examples of ecosystem services for production sectors

Source: PBL

Figure 1.1. Biodiversity and ecosystem services in a sectoral perspective.

Drivers and pressures of biodiversity loss

The main drivers of biodiversity loss are land-use change and land-use intensification, landscape fragmentation, the exploitation of natural populations through hunting, gathering, forestry and fisheries, infrastructure development and the construction of dams and waterworks in coastal and river systems, climate change, pollution by for example nutrients, CO_2 enhancement, and invasive species (PBL, 2010). The MSA indicator, used throughout this report, summarises the impact of many of these drivers on the composition and abundance of species and their populations. Although the impact of invasive alien species is not included in the MSA, such species have major impacts on naturally-occurring species and ecosystems. On small islands in particular, introduced species have devastating impacts and a high percentage of known extinctions can be attributed to invasive species (see also Leadley et al., 2014). Loss in agro-biodiversity is partly a parallel process to the loss of 'wild' species biodiversity, as the intensification of production systems tends to reduce both 'wild' biodiversity and the genetic diversity of crops and livestock.

Globally, the main driver of deforestation is agricultural expansion, which accounts for more than 50% of deforestation worldwide. This percentage is even higher for tropical regions. Other drivers are mining, infrastructure extension and urban expansion. The direct contribution of forestry to deforestation is, at 2%, very small (Kissinger et al., 2012). Exploitation of natural populations and intensive land use may lead to degradation in situations where the amount harvested (output) is larger than the rate of renewal or amount added (input) over a longer timescale. For example, intensive land use can lead to the depletion of nutrients if the harvests consistently contain more nutrients, such as nitrogen, than have been added in the form of fertilizers, manure or nitrogen fixation (see Sutton et al., 2011). Soil is degraded if erosion by water or wind exceeds the formation of soils on agricultural fields. In grazing systems, degradation occurs if, over a period of time, more vegetation is removed than is produced and in particular if the root systems of plants are affected. In marine and freshwater systems, fish stock depletion takes place when fishing activities go beyond the maximum sustainable yield level. Restoring degraded ecosystems is often difficult and requires specific management, adapted to specific situations. Successful restoration can often lead to profitable results where the benefits largely exceed the costs (see for example de Groot et al., 2013).

Mainstreaming biodiversity to address drivers and pressures

To address the pressures on and underlying causes of biodiversity loss, the mainstreaming of biodiversity across society is required. In general, the process of mainstreaming (integration) entails developing strategies to bring issues that have emerged as legitimate societal concerns into a context where interests and decision-making have tended to ignore that issue. The conflicts that may arise from this cannot be neglected (Halpern et al., 2008; Kok et al., 2010; Nunan et al., 2012). Mainstreaming biodiversity can then be defined as ‘the process of embedding biodiversity considerations into policies, strategies and practices of key public and private actors that impact or rely on biodiversity, so that biodiversity is conserved and sustainably used both locally and globally’ (GEF/STAP, 2013). The emphasis on both public and private actors in mainstreaming biodiversity is based on the recognition that the traditional consideration of mainstreaming as a matter for predominantly public policy with little attention for the contribution of business and civil society is outdated (see Karlsson-Vinkhuyzen et al., 2014). This is not to say that mainstreaming biodiversity as a public policy approach is not necessary, but rather that a broader approach to mainstreaming is required that does justice to the possible role that non-government actors, such as the private sector and civil society, can play in mainstreaming biodiversity.

Successful mainstreaming requires that biodiversity is related to the core values and interests of different actors in decision-making (including economic decision-making) in the sectors that strongly influence the world’s biodiversity, now and in the future. This report therefore explores how the sustainable use and conservation of biodiversity is (or can be made) more relevant in specific, sectoral contexts with the aim to find levers to move decisions and actions in a more biodiversity-friendly direction. Where interests can be aligned and synergies between biodiversity and sectoral activities exist, public policy can play a supporting and facilitating role.

1.4 Approach

In this study, the primary production of food, fibre and biofuel on land (mainly related to agriculture and livestock) and water (fisheries and aquaculture), wood production (timber, paper, biofuel) and water management (secure supply of freshwater, water for food production, hydropower and flood protection) and their cross-sectoral relationships are considered. The sectors associated with the production of these goods are dependent on the natural resource base and well-functioning ecosystems, but at the same time they are responsible for a major part of biodiversity loss in terrestrial, freshwater and marine systems in terms of MSA. For practical reasons this study has limited itself to these sectors. Other relevant sectors that could be the subject of a follow-up analysis would include mining and other resource extraction industries, energy production and heavy industry; obviously these sectors have different relations with natural resources than the sectors included in this study (organic renewable resources versus inorganic depletable resources). Medicines and cosmetics, for example, and tourism could also be the subject of further study.

The analysis of each production sector starts with a description of the sector, including a further breakdown of the sector, identification of the main actors and analysis of trends in the sector. This provides a first understanding of specific contexts in which biodiversity concerns need to be embedded. This analysis is followed by an identification of the benefits that biodiversity and ecosystem services provide for the specific sector and impacts that sectors have in terms of contributions to biodiversity loss. Identifying the dependencies shows the risks for sectors if biodiversity loss continues as is expected in business-as-usual scenarios. Although GBO-4 (sCBD, 2014) shows that targets that address the underlying causes of biodiversity loss will not be met if current trends continue, the analysis in this report shows that – within the sectors covered – many initiatives are taken that point in the right direction. This is consistent with the increase in societal responses identified in another supporting analysis for GBO-4 (target-by-target trend analysis in Leadley et al. 2014). This report analyses initiatives within sectors that move in a biodiversity-friendly direction, to make sure that we build on and learn from what is already happening in sectors and avoid the suggestion that only national governments can act (Hajer, 2011). Barriers and levers for change are derived from this analysis. While this report tries to paint a globally-relevant picture, we also recognise that this report may reflect the regional perspective of its authors.

For the analysis of 'biodiversity-friendly production' and 'nature-based solutions' in the sectors that can contribute to meeting the long-term biodiversity goals, we explored alternative scenarios using a model-based, back-casting approach. We quantitatively analysed three alternative pathways that are all designed to meet the Biodiversity 2050 Vision as part of a broader set of long-term sustainability goals, including a two degrees climate stabilisation goal, eradication of hunger, feeding the world's population and access to clean energy and water. Using Aichi Biodiversity Target 5 (limiting or halting biodiversity loss by 2020) and Target 11 (expanding protected areas to 17% of terrestrial area and inland waters by 2020), the 2050 vision was quantified as halving the rate of loss in 2020 and maintaining it at 2020/2030 levels by 2050 (depending on the region). Together with the protected areas target, this translated into a target for 2050 of 65% measured in MSA; or in other words preventing over half of the loss that is projected to take place in the coming 35 years (PBL, 2012).

PBL's integrated assessment model framework IMAGE/GLOBIO (Stehfest et al., 2014) was used to identify actions that are needed to meet these goals in the coming decades (see Chapter 2 and Annex B for more detail on both the scenario analysis and the models used). These pathways should not be seen as blueprints to meet the goals, but rather as an aid to show the solution space and to identify the potentials of various technological and behavioural options, synergies between them and trade-offs that need to be faced. These three pathways were elaborated further for agriculture and forestry, while the consequences of land-based measures for aquatic biodiversity were examined for water management. For marine fisheries and marine aquaculture a first analysis of the implications of the pathways for fish stocks is presented.

While the emphasis in this study is on production (primary producers and the ecosystems and natural resources they depend on), we take a broad perspective on sectors and the supply chains of which they are part, to include both the production as well as the consumption side. Production sectors include a diverse range of actors, from smallholders and subsistence farmers, family farmers, fishermen, industrial farmers and small and medium enterprises to internationally-operating businesses. This therefore includes subsistence farmers and fishermen, as well as commercial (primary) producers that are part of national, regional and/or global supply chains, providing quite different contexts for mainstreaming biodiversity. The supply chain perspective brings in traders, processing industries, retailers, financers and consumers that may influence primary production through their sourcing and consumption. We analysed the possible role of various actors in the supply chain as 'agents of change' to contribute to embedding biodiversity on the production side. This is schematically depicted in the 'hourglass' in Figure 1.2. This shape indicates how a focus on strategic actors (concentration points) in supply chains can provide levers for change (Clay, 2004).

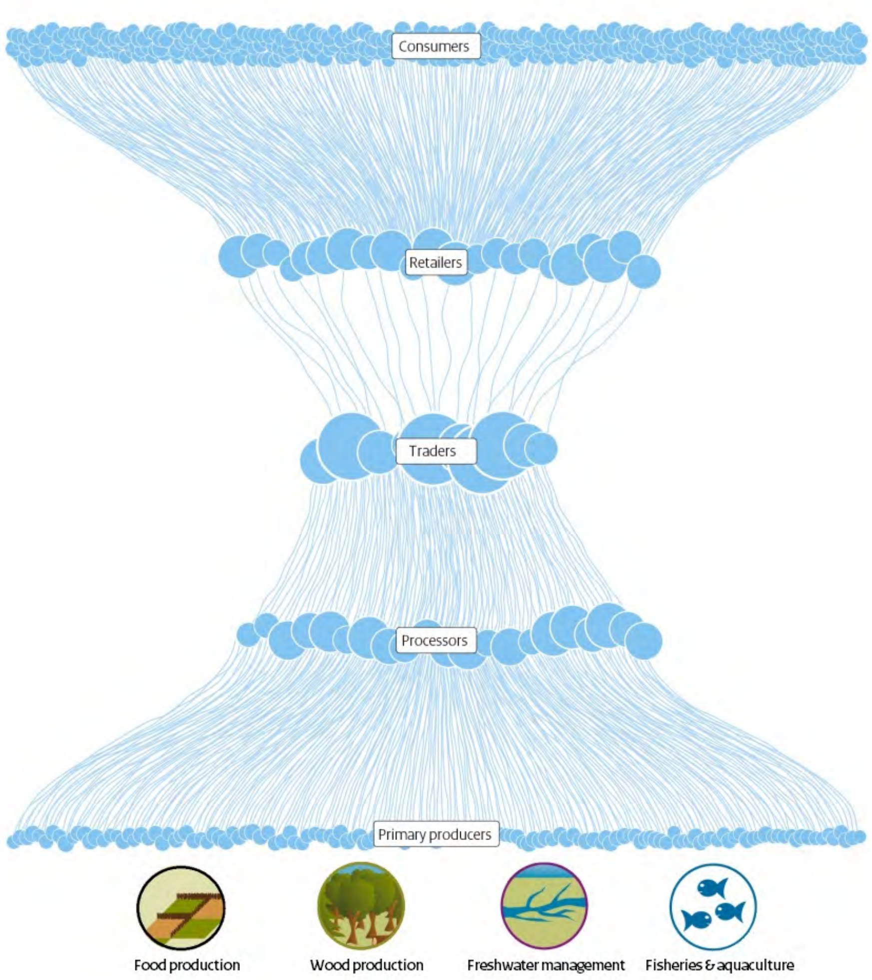


Figure 1.2. The 'hourglass' of primary production, the supply chain and consumption.

Based on an analysis of: i) initiatives taken by important actor groups within the sector; ii) barriers and levers for change derived from that, and iii) the most potentially powerful options within sectors that contribute to reducing biodiversity loss and improving its sustainable use (derived from the scenario analysis), we identified priority actions for the sector for the coming decade and strategies to implement them.

Building on the analysis of the four sectors covered, the last part of the report addresses the role that countries, the business community and civil society and international organisations can play to enable and ensure that biodiversity concerns are embedded in sectors. We have identified four strategic directions for action to realise the mainstreaming of biodiversity in sectors. In doing so, we realise that there are also limits to the synergies between sectoral, economic interests and biodiversity and hence to mainstreaming as a policy strategy. Mainstreaming policies therefore always need to be part of a broader strategy that also includes biodiversity conservation and protection measures.

1.5 Report outline

This report unfolds as follows. Chapter 2 provides context for the sectoral analysis. First of all, the consequences for biodiversity and the provision of ecosystem services of a business-as-usual scenario are identified. The three alternative pathways that are designed to meet the Biodiversity 2050 Vision while also meeting a broader set of long-term sustainability goals are then outlined. In Chapters 3 to 6 we look at how biodiversity can be addressed in the production of food, fuel and natural fibre, wood, water management and fisheries. In Chapter 7, various strategic directions for mainstreaming are presented, as well as the possible contribution of different actors, and especially governments, in making that happen.

Chapter 2. Biodiversity futures

2.1 Introduction

Biodiversity decline is expected to continue if current trends persist. A wide range of efforts will be required to stop this long term downward trend and halt the further loss of biodiversity. The fate of biodiversity depends directly and indirectly on human production and consumption patterns. Biodiversity loss is mainly driven by increasing demands for food, wood and fibre, energy and freshwater, further exacerbated by expected climate change. The demand for these goods is of primary concern, as they are being produced on agricultural fields or extracted from and collected in natural and semi-natural ecosystems. Hence it drives land-cover and land-use changes with consequences for biodiversity and a variety of ecosystem services. Today, agricultural land, managed more or less intensively, makes up about one third of the global land area. Although traditional agricultural landscapes nurture a large diversity of species, land conversion is causing the loss of suitable habitat for many species and is therefore one of the main causes of biodiversity loss to date. In addition, biodiversity in remaining natural and semi-natural areas is affected by various pressures such as urbanisation and infrastructure, forestry, pollution, fragmentation, climate change and invasive species (Alkemade et al., 2009; Sala et al., 2000; PBL, 2010; SCBD, 2010; SCBD, 2014).

The activities and pressures with bearing on biodiversity losses link closely with human development in terms of volume and orientation, and are therefore inextricably linked with activities by economic sectors to satisfy consumption. Keeping the main causes indicated above in mind, a limited number of major categories of economic activities and actors (referred to as ‘sectors’) are selected in this report for the further analysis of options to improve the current development pathways. The focus in this report is on food production, wood production, water management, and marine fisheries and aquaculture; described in more detail (also more region-specifically) in Chapters 3 to 6.

These four sectors not only contribute to biodiversity loss, but they also depend on biodiversity and benefit from the ecosystem services (ES) nature provides (Cardinale et al., 2012). Relevant ES for agriculture are reduction of erosion risk, pollination and suppression of potential pests by other organisms. Wood production and fisheries depend directly on the productivity of ecosystems. For freshwater, flood regulation and biological water purification are important ecosystem services. Although many of these services can be replaced by technical measures or by managed production systems (such as aquaculture or wood plantations), increased biodiversity loss may eventually affect the resource base of these sectors (Foley et al., 2011; de Groot et al., 2012).

This chapter provides the background for the sector analysis in the following chapters. It starts (Section 2.2) by sketching the main trends that can be expected under a business-as-usual scenario, that is if no additional policies are implemented. This is called the Trend scenario. The outcomes of the Trend scenario are analysed for their implications for driving forces and pressures within sectors under study in this report (Section 2.3). The implications of the pressures for biodiversity and the provision of ecosystem services on which sectors depend are then presented (Section 2.4). The Trend scenario shows ongoing biodiversity loss and an expected decline in ecosystem services, which increases the risk of undermining the natural resource base for sectors. The Trend scenario provides the backdrop for alternative scenarios that aim to halt biodiversity loss and ensure the sustainable use of the natural resource base for sectors. We present (in Section 2.5) three alternative pathways for this, each designed to meet the same set of global sustainability objectives in line with the 2050 Vision for Biodiversity, including limiting and halting biodiversity loss and realising a global network of protected areas. Biodiversity-beneficial interventions are considered in each step from primary production to consumption: improve the sustainability of primary production, produce more efficiently and/or with enhanced processes that reduce environmental pressure, reduce losses in the chain from primary production to consumption, change consumption patterns in a more biodiversity- friendly direction and recycle or re-use post-consumption waste products (van Oorschot et al., 2012). For the scenario-analysis in this study, we draw upon the recently-published scenario study `Roads from Rio+20’ (PBL, 2012). Only relatively minor adjustments were made for the purpose of this study. The assumptions behind these pathways are presented in this chapter; in the next chapters they are further elaborated for each sector.

2.2 Trend scenario: key developments until 2050

General characteristics

The Trend scenario is a benchmark, not a forecast, and serves to understand the context and challenges relating to achieving more biodiversity-friendly development in the sectors included in this study. A ‘surprise-free future’ is constructed building on earlier studies (OECD, 2012; PBL, 2012). This means that, under the Trend scenario, key variables continue more or less unchanged from recent history, assuming no major shocks with global impacts. Basic socio-economic mechanisms continue to operate in the same fashion and no specific new policies are introduced to meet sustainability goals (‘dynamics-as-usual’). Important current trends include the gradual introduction of new technologies and the involvement of businesses and civil society in decision-making, while economic inequalities remain. The Trend scenario also assumes that the tendency towards modernisation along the same lines of the ‘western’ model continues, albeit with regional specificities.

The Trend scenario assumes that world development continues to focus on economic development and globalisation. It also assumes a further increase in the per capita consumption of food, the production of material goods and services and the use of energy, although with a tendency towards saturation at higher income levels. New and more ambitious environmental policies are not assumed, with the exception of measures that contribute directly to human health, such as reducing air and water pollution, as these go hand in hand with increasing per capita income (PBL, 2012).

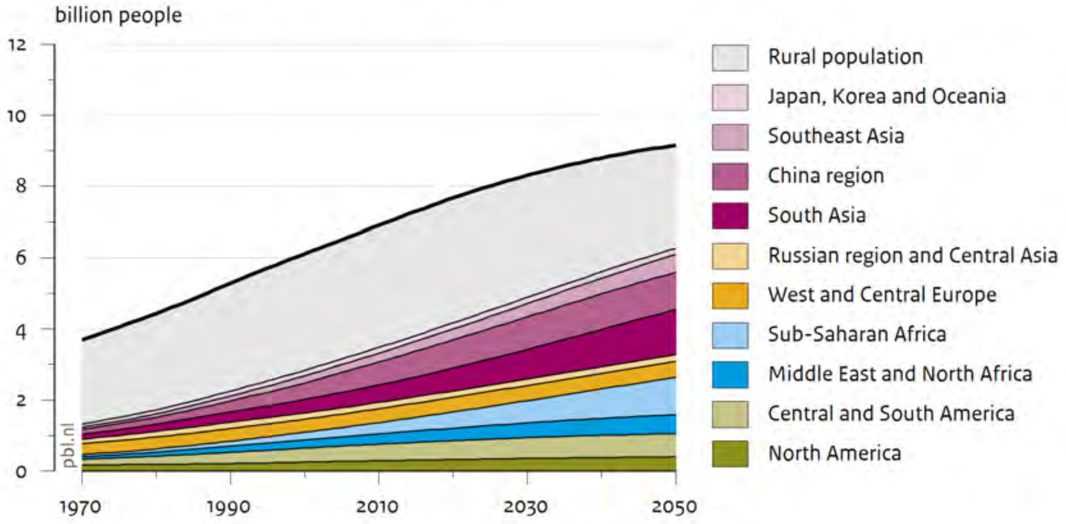
Main trends in population, economic activities, food, natural resources and energy use are (PBL, 2012):

- by 2050 the population has increased to 9.2 billion, from around 7 billion in 2010;
- GDP increases fourfold between 2010 and 2050;
- food consumption increases around 1.7 times;
- wood consumption increases around 1.3 times;
- agricultural land (cropland and pastures) expands by 4 million km^2, a 10% increase;
- total forested area decreases by 1.5 million km^2;
- energy use increases 1.7 times;
- freshwater use increases 1.6 times.

The global population is projected to grow until 2050, mostly in the current low-income countries with more youthful populations in Africa, South and Southeast Asia and the Middle East (UNDESA, 2012; Figure 2.1). China and the OECD countries are projected to experience significant population ageing and hence reduced growth. The world’s population is becoming increasingly urbanised: currently, around 50% of the world's population lives in urban areas and this is projected to rise to nearly 70% by 2050 (UNDESA, 2012).

Global demographics under the Trend scenario

Global rural and urban population per region

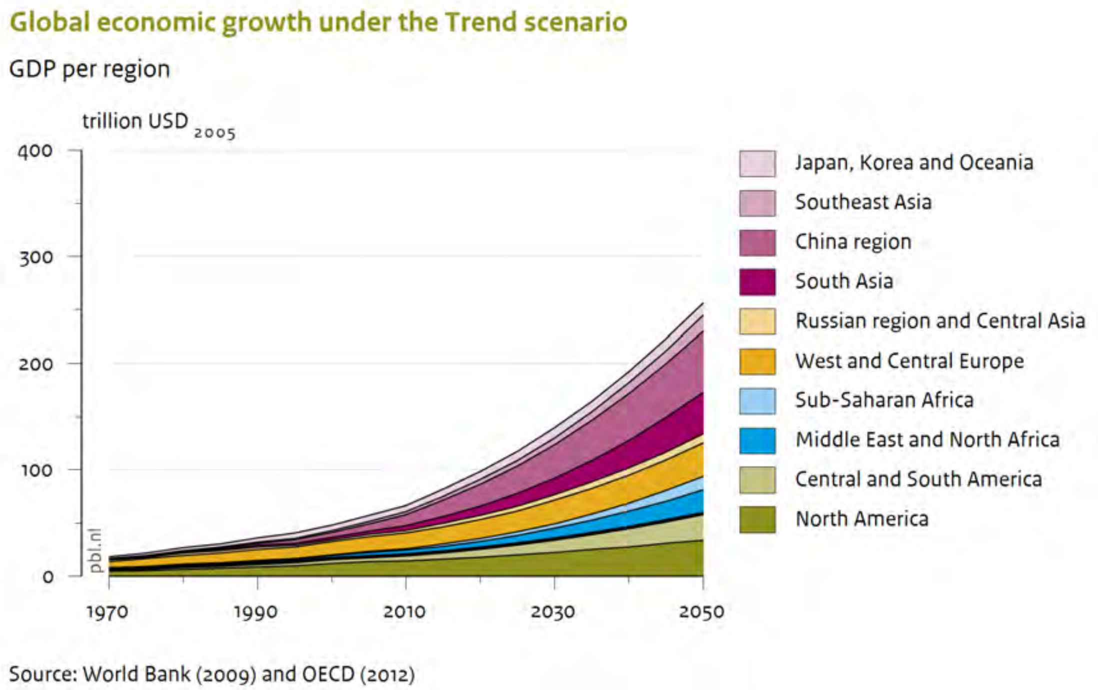


Source: UNDESA (2009, 2010)

Figure 2.1. Global demographics under the Trend scenario: global rural population and urban population per region (based on UNDESA, 2009; 2010).

The global economy is projected to grow further at approximately historical rates, with the highest growth rates assumed in developing countries. The global economy has nearly quadrupled over the last 40 years. Under the Trend scenario, it is assumed that economic growth in terms of GDP continues at a similar pace (see Figure 2.2). The projection describes long-term structural trends rather than short-run business cycles and other deviations from the trend due to economic and/or political crises. These can have profound regional and global impacts over periods of up to a decade, but are assumed to have no lasting impact on the underlying drivers of economic growth. Periods of economic stagnation, such as the global crisis since 2008, can reduce the use of natural resources. At the same time, investments in knowledge and new technologies decline, and attention for environmental problems and longer-term sustainable development can suffer from the focus on solving the immediate economic problems.

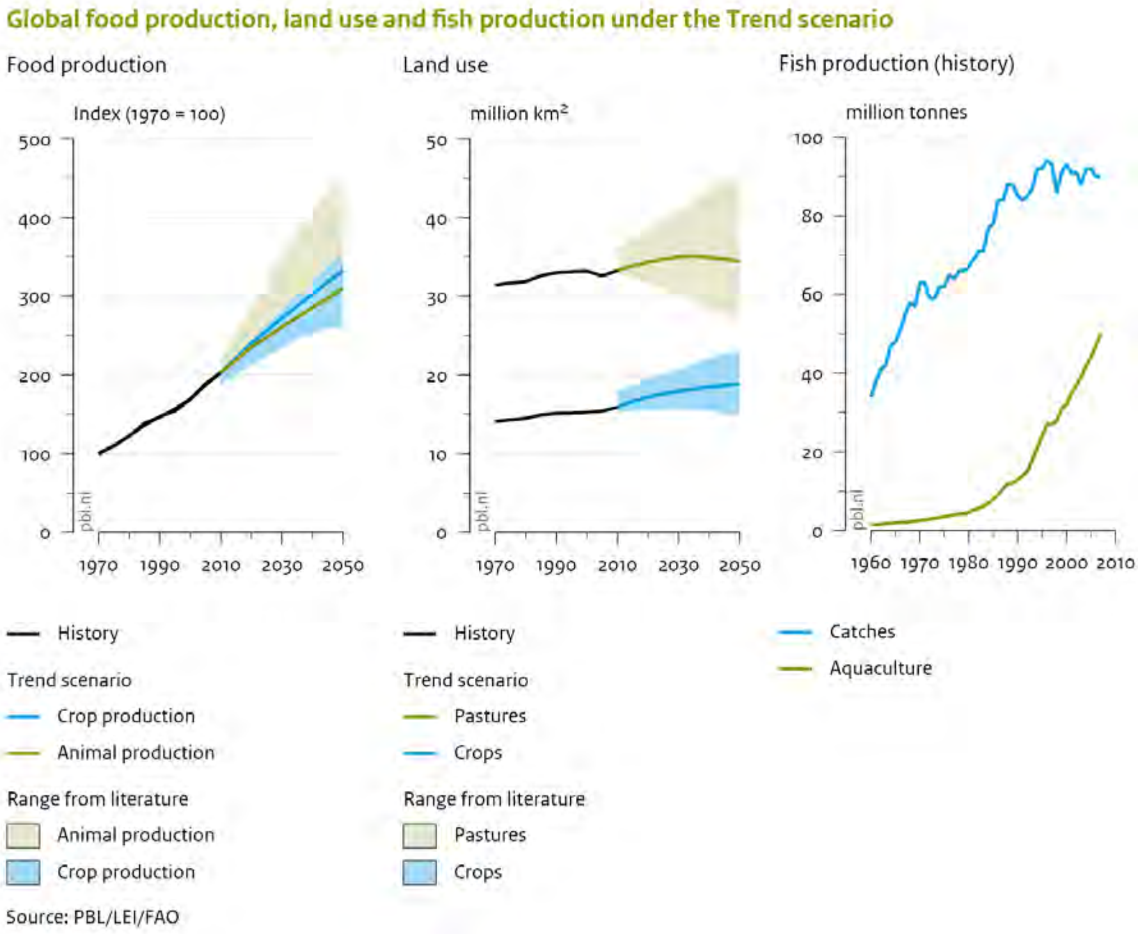
Regional developments will be very different, leading to an important shift in the global balance in terms of economic leverage. While Gross Domestic Product (GDP) growth in OECD countries is projected at around 1.5–2% per year, in current low-income regions growth rates will reach 3–5% per year due to the large potential for growth in labour and capital productivity. For Latin America, the Middle East and Africa, projections are higher than the historical rates as these regions are assumed to profit from globalisation and favourable demographic development. For the Asian regions, growth rates will be similar to or slightly lower than the historical rates as a result of the assumed maturing of their economies. For sub-Saharan Africa, GDP growth is forecast to remain relatively low until 2030, after which rapid growth is assumed to 'take-off', as happened earlier in Asia.


Global economic growth under the Trend scenario

GDP per region

Source: World Bank (2009) and OECD (2012)

Figure 2.2. Global economic growth under the Trend scenario (World Bank, 2009; OECD, 2012).


Global food production, land use and fish production under the Trend scenario

Food production

Land use

Fish production (history)

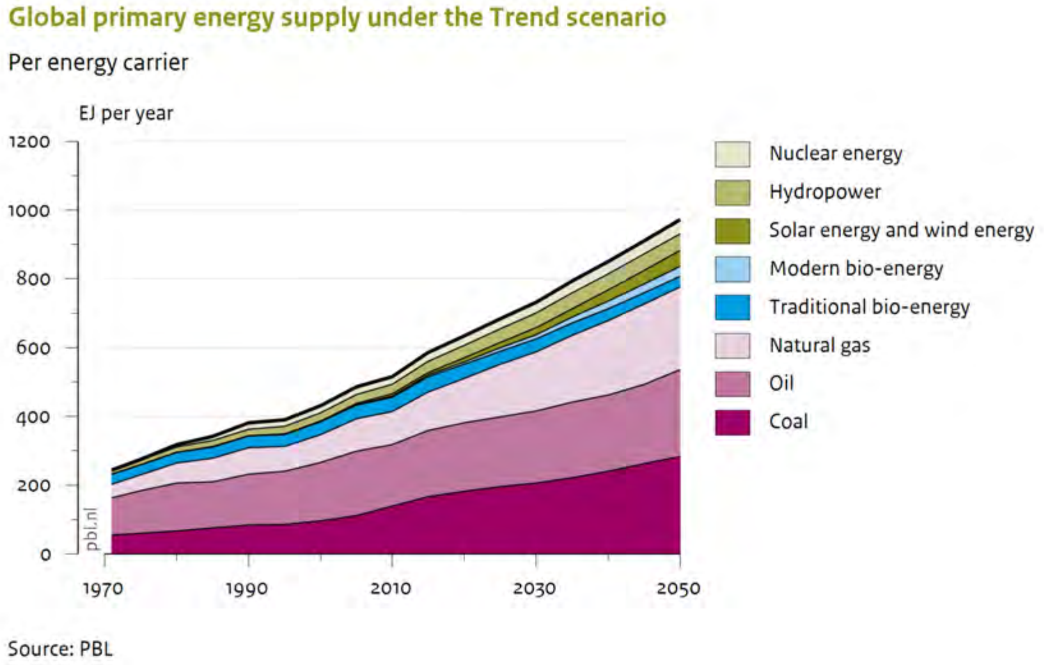
Source: PBL/LEI/FAO

Figure 2.3. Production of food crops and animal products under the Trend scenario.

As a result, by 2050 the OECD share in the global economy will have fallen to less than 32%, from 54% in 2010. At the same time the emerging economies Brazil, Russia, India, Indonesia, China and South Africa (BRIICS) are expected to contribute more than 40%. The share of agriculture in GDP will continue to decline as a result of the structural shift towards manufacturing and services.

World food production will be driven by significantly increasing demand in the coming decades, due to population growth and changes in diet. Total food intake (calories) per person will increase, mostly in current low-income countries now facing under-nutrition. The share of basic staple foods in the food basket will decrease, while the share of animal products in diets is expected to increase, in line with historical trends under increasing income. Marine fish catches are expected to decrease or at best stabilise, while aquaculture will be increasingly important for the fish supply. Land will be required to support agricultural production, and the implications for total land use are shown in the next section on drivers of biodiversity (Figure 2.3).

Global energy consumption and supply is projected to increase by 65% in the 2010–2050 period (van Vuuren et al., 2012; Figure 2.4). The major part of this increase will be in current low-income countries. The total per capita energy consumption in high-income countries will not change much, but there will be a continued shift towards more electricity and natural gas. In many low-income countries, per capita energy use will increase strongly (up to twice the current level), with the largest increases in oil products and electricity use.



Source: PBL

Figure 2.4. Global primary energy supply under the Trend scenario.

Energy supply will continue to be dominated by fossil fuels, assuming no fundamental change in current policies, as their price in most situations is projected to stay below that of alternative fuels. In the longer term, higher production costs and thus higher prices are projected for oil and gas as conventional resources become depleted. As a result, the use of coal is expected to increase strongly, particularly for electric power generation. Energy from non-fossil sources is also expected to increase substantially under the Trend scenario. While the use of traditional energy forms such as fuel wood and charcoal will gradually decrease in absolute terms, modern uses of bio-energy and other renewable energy forms will increase considerably. Altogether, the emission of carbon dioxide and other greenhouse gases from the energy sector is bound to increase further, contributing to ongoing climate change.

Global wood demand and production is projected to increase by a third. This will be driven by population and welfare growth. Most of the increase in wood demand comes from a growth in paper use, which will increase by more than 50%, and to a lesser extent to meet increasing demands for roundwood for construction purposes, which increases by a third. At a global level, the demand for traditional wood fuel will decrease to 80% of the 2010 values by 2050. This is caused by the shift towards of more modern (fossil) energy forms such as gas, oil products and electricity, made possible by higher incomes and enhanced access.

Global freshwater extraction is expected to increase by 55%, mainly for use in industry, electricity generation and households, while water for irrigation – today the dominant use – may even decrease slightly. Deep groundwater reservoirs will increasingly be at risk of depletion.

2.3 Drivers of biodiversity loss under the Trend scenario

The main causes of biodiversity loss are expansion of agricultural land and intensification of land use, fragmentation and infrastructure, climate change, water flow alteration, exploitation of natural ecosystems – including fisheries, forestry, hunting and gathering – and tourism. In the sections below we present the developments under the Trend scenario of a number of drivers of biodiversity loss for each sector. Their impacts on biodiversity and ecosystem services are presented in Section 2.4.

Agricultural land-use change (cropland, pastures and bio-energy)

The major cause of biodiversity loss is habitat loss resulting from changes in land cover. Historic and recent conversions are mostly changes from natural vegetation into agricultural land, and to a lesser extent into other purposes such as built-up areas, mines, recreational areas and so on.

The area of land for agriculture expands until 2050, but far less than the increase in agricultural production as the average productivity of the land increases as well (Figure 2.5). On balance, increases in the average productivity of the land (yield per hectare) provide the major contribution to the increase in agricultural output. Crop yields increase as a result of technical progress, improved seeds, better management, mechanisation, pest and disease control, and so on. These measures contribute to intensification but may have negative consequences for the number and abundance of original species. Intensification occurs especially in regions where yields are currently far below their potential, based on prevailing climate and soil conditions. Livestock production tends to shift from pastoral systems requiring vast grazing areas to mixed and landless production systems. The latter implies that more food crops will be used to feed livestock, but the crop areas required will be relatively small compared with the grasslands that would have been needed for grazing. In total, some 4 million km^2 of agricultural land, or around 10% of the extent in 2010, is added to support the 70% increase in production.

The expansion of agricultural land will be distributed very unevenly across the world. Significantly higher biodiversity losses are projected regionally compared with the global average, especially in the tropical forest and savannah biomes. In other regions, such as the former Soviet Union, agricultural activities are expected to be discontinued, if and where the physical and/or economic conditions no longer provide sufficient incentives for farming. Normally, abandoned agricultural land would revert to a natural or semi-natural state, unless soil degradation is too severe to sustain that process. However, the recovery of natural ecosystems after agricultural use can take a long time – up to 150 years – before reaching a mature state with a species composition similar to the undisturbed, pristine state (e.g. Pena Claros, 2003).

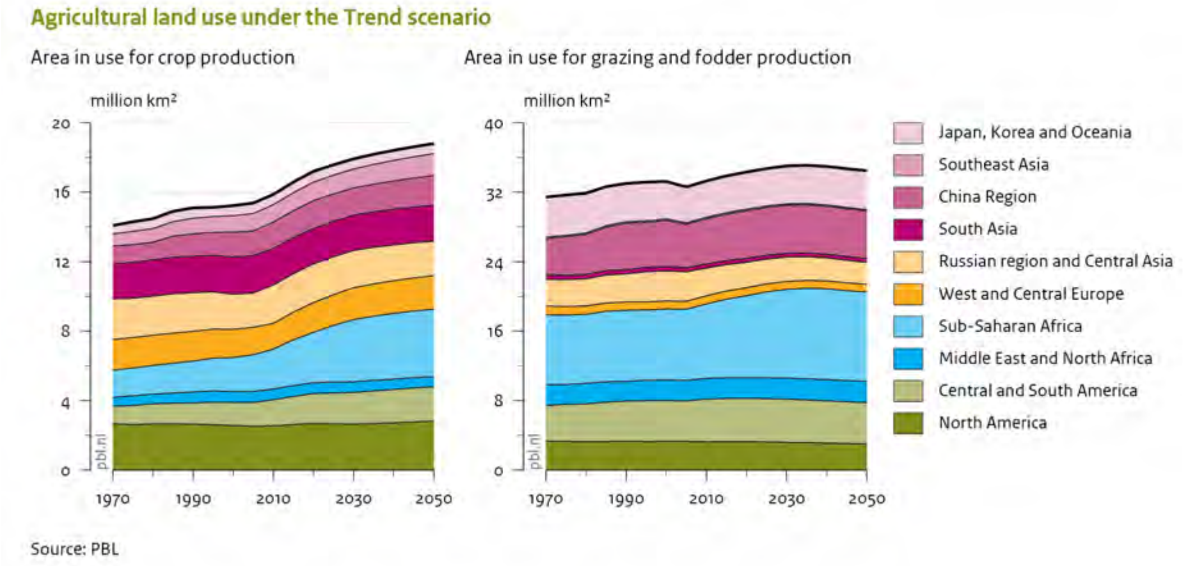


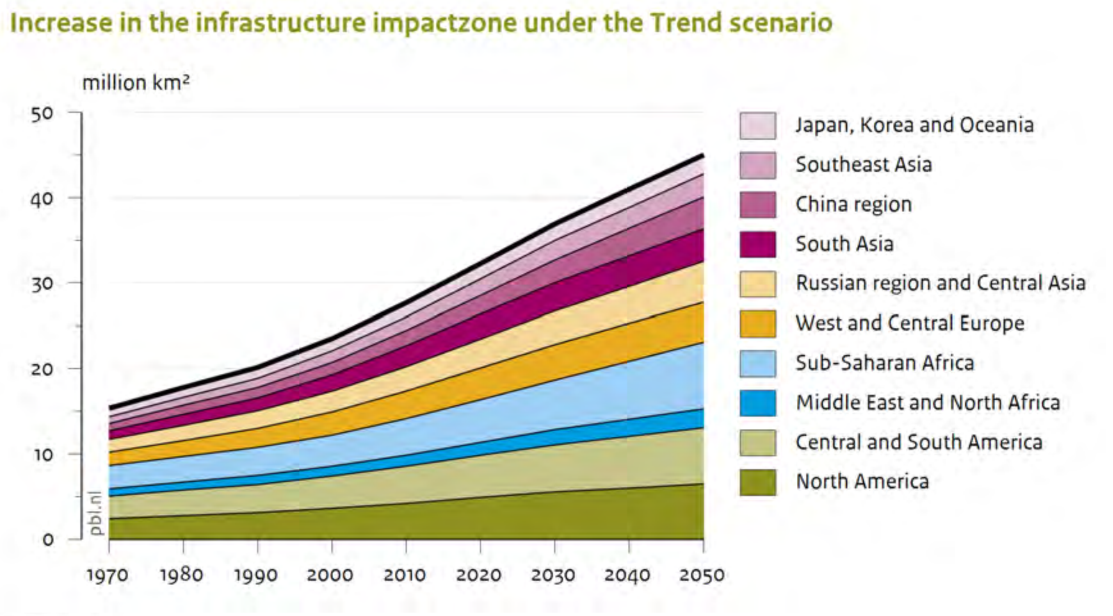
Figure 2.5. Agricultural land use under the Trend scenario.

As well as the extent of agricultural land, the intensity with which it is used contributes to changes in species composition and biodiversity loss (MacDonald, 2000). Intensification is projected to continue, leading to an increase in harvested food crop yields of just below one percent per year on average. While this is all-important for limiting the expansion of agricultural land, it also implies negative impacts on biodiversity in the more intensively-managed areas. Additionally, higher inputs of capital (mechanisation) and fertilizers and other chemicals, the regulation of groundwater tables and other management options can have negative impacts on biodiversity as well as on groundwater and surface water bodies (see below under Disturbance and Pollution).

Disturbance: fragmentation, encroachment and infrastructure

In addition to direct loss of habitat and environmental degradation, human activities have negative effects on nature and biodiversity through disturbance of the remaining natural and semi-natural areas. Fragmentation is the division of large, continuous natural ecosystems into smaller patches as a result of the establishment of agriculture and associated access roads. This implies that species requiring large areas for sustaining viable populations will decrease in number. Where human activities such as agriculture and mining provide easier access to the surrounding nature areas, encroachment increases as humans enter the land for hunting and gathering, settlement, recreation and other purposes. This affects the species distributions directly, as some species are targeted for hunting and gathering, as well as indirectly due to more frequent human presence decreasing the attractiveness for species. The area affected by these kind of activities is referred to as the infrastructure impact-zone, or encroachment area (see figure 2.6). Recreation in aquatic ecosystems, such as lakes, coastal waters and rivers may have similar or even larger impacts, but is currently not accounted for. Infrastructure effects relate to roads and the intensity of their use. While the direct surface area occupied by roads is small, as is the case for built-up urban area, the presence and distribution of species is seriously affected at distances up to hundreds of meters from the roadside (Benitez-Lopez, 2010).

Under the Trend scenario, the impact of infrastructure on biodiversity increases significantly as more people with higher average incomes are bound to lead to more road capacity and more intense traffic (see Figure 2.6). Fragmentation and encroachment depend on agricultural land; hence they do not change much up to 2050.



Bron: PBL

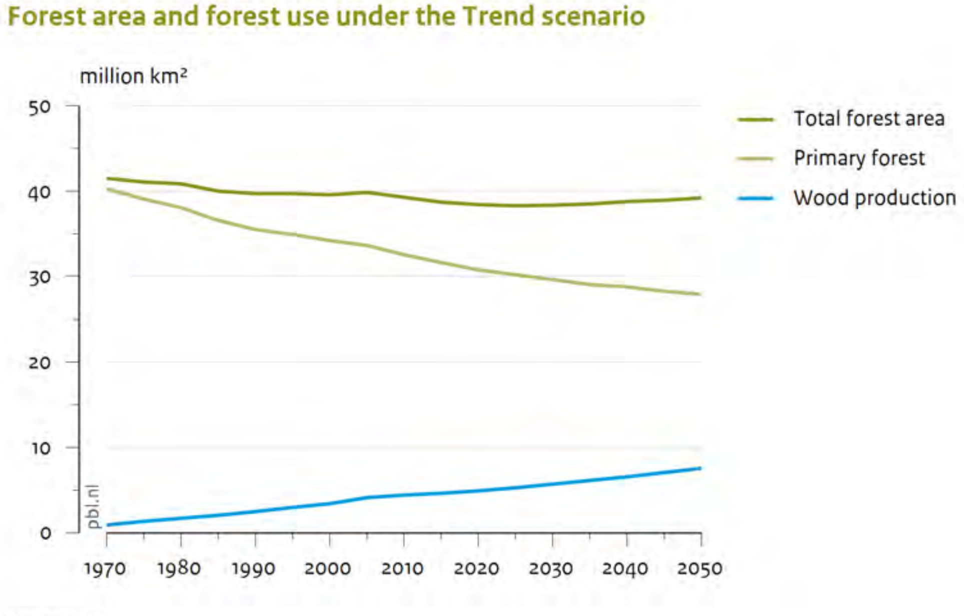
Figure 2.6. Growth of the infrastructure impact zone under the Trend scenario.

Forestry

The harvesting of wood products from natural and semi-natural forests and woodlands and the establishment of artificial wood plantations have an impact on forest biodiversity. The area affected and the degree of impact differs between production systems, which are subject to economic considerations. Depending on the species composition of the forest, the market value of the wood species and other factors such as accessibility and labour costs, different forest management systems are in place. For modelling purposes, a few generic forestry types are included: trees are felled by clear-cutting forest patches (natural or planted), by selective logging of trees, or by harvesting of dedicated wood plantations. Plantations produce the highest volume of harvestable wood per hectare, but due to the use of a single or a few species and the intensive management, they have relatively low MSA values (Alkemade et al., 2009). Applying selective logging has a relatively low impact on biodiversity, as the forest remains in place, but selective logging requires much larger areas than wood plantation to produce the same amount of wood. Clear-cutting is somewhere between the other two systems. In particular in tropical forests, ‘reduced impact logging’ (RIL) practices ensure that the effects of selective forestry operations are less than those of regular selective logging.

Wood is also harvested when forest areas are converted to agricultural land. Depending on the region and on local conditions, more wood is put on the market or is burned for – sometimes illegal – land clearing. The production of traditional biofuels (wood fuel and charcoal) is secured in part by harvesting residuals from industrial forestry operations, but also by dedicated clear-cutting at increasing distances from expanding urban areas in developing regions.

Note that the areas considered in the IMAGE modelling are for larger scale, mainly commercial forest operations. These deliver the vast majority of wood products. In addition to that, more dispersed and small scale collection and harvesting of wood is considered an inherent feature in forest areas in encroachment zones. These areas are not included in the (semi-)commercial forestry sector, but will add to the forest extent in use for wood extraction, as e.g. reported by FAO-stat.



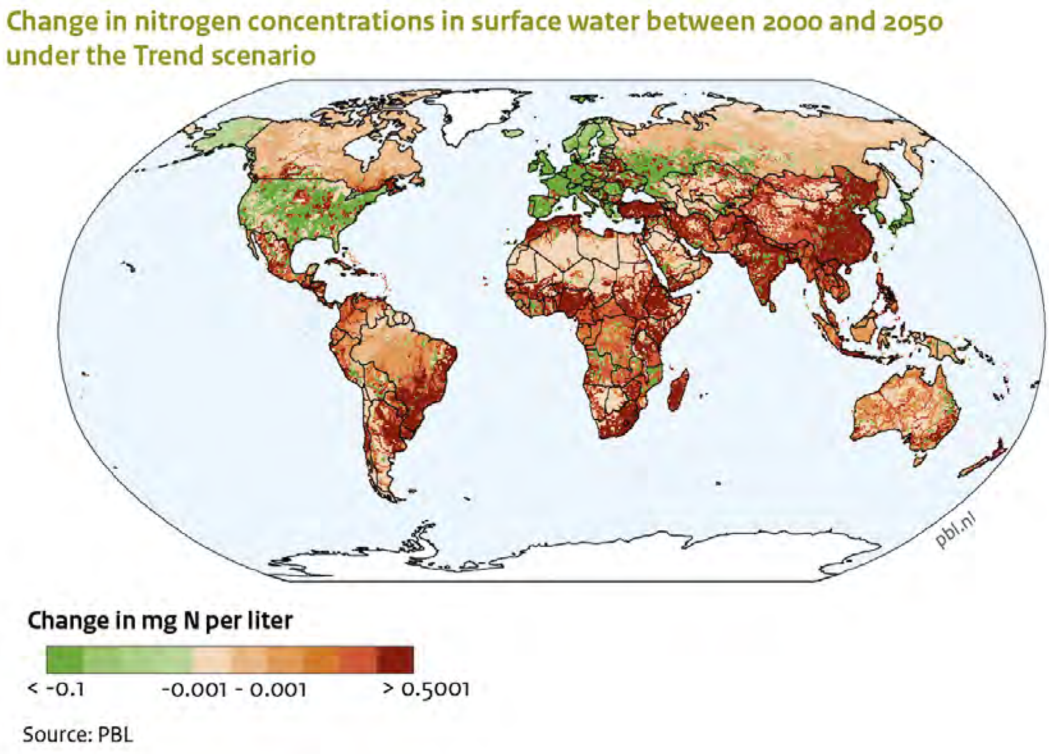
Source: PBL

Figure 2.7. Forest area and forest use under the Trend scenario. Under the Trend scenario, the global forest area decreases, mostly due to agricultural expansion. The forest area that is managed for wood production according to the IMAGE forestry module increases between 2010 and 2050 by about 70% (excluding the effect of historical forest use before 1970).

Under the Trend scenario (see Figure 2.7), the forest plantation area increases slowly to reach 124 million hectares in 2050 (from 100 million ha in 2010). In addition, formerly unmanaged forest areas are taken into production for selective logging and clear-cutting to meet growing demand. In total, the area of forest required to meet demand increases from 4.4 million km^2 in 2010 to 7.5 million km^2 in 2050. As mentioned this excludes large forest extents where some form of lower intensity wood harvesting and collection is taking place.

Pollution: nitrogen and phosphorus compounds

Two ways of water and air pollution are considered for their impact on biodiversity. First, the excess application of fertilizers on agricultural land leads to the pollution of groundwater and surface water with impacts on freshwater biodiversity, and ultimately also on coastal seas. This is a particular problem if application rates are poorly balanced with plant uptake due to striving for maximum yields. Nitrogen (N) and phosphorus (P) emissions are expected to increase in many parts of the world as increased fertilizer use is needed to increase agricultural productivity, despite improvements in the utilisation efficiency. The elevated concentration of nutrients in freshwater bodies leads to eutrophication, and thereby to significant biodiversity loss in lakes, rivers and wetlands.


Change in nitrogen concentrations in surface water between 2000 and 2050 under the Trend scenario

Source: PBL

Figure 2.8. Change in nitrogen concentration in surface water from 2000 to 2050 under the Trend scenario.

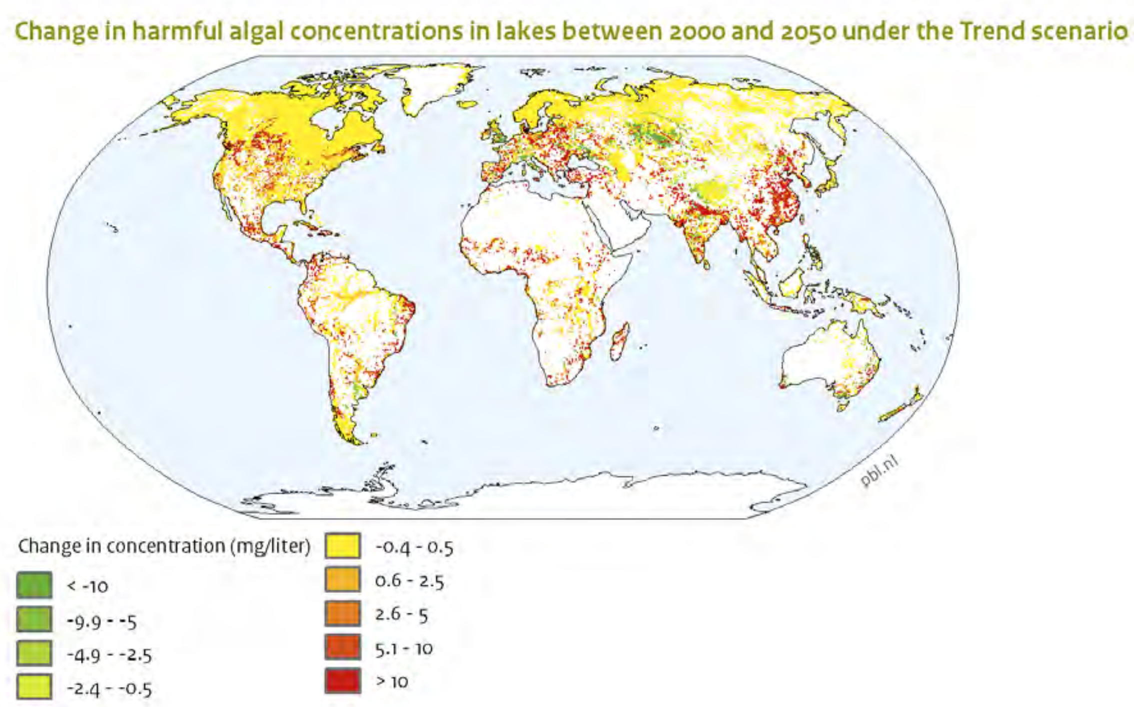
Secondly, the deposition of N compounds from the atmosphere induces eutrophication in natural ecosystems on land with consequences for many species (Bobbink et al., 2010). Due to differences in the sensitivity of species, eutrophication changes the original species composition of ecosystems. The amount of N deposition depends on the emission of air pollutants (Figure 2.8). The spatial deposition pattern depends on the atmospheric concentration of N, the weather and the specific deposition rates. The sensitivity of natural systems is translated into a critical N load per ecosystem (Bouwman et al. 2002), which is the yearly amount of N that can be absorbed by ecosystems with no detectable impact on species composition.

Water quality is affected by elevated concentrations of nutrients such as N and P from agricultural land and from concentrated point sources such as sewage and industry outlets. In lakes in particular, this leads to eutrophication (Figure 2.9), with consequences for species abundance and even extinction. In lakes, eutrophication caused by nutrient loading is expected to increase by 20–30 % globally. The water quality is also affected in rivers and wetlands, both from upstream and adjacent land-use activities.

Climate change

Climate parameters, such as average temperature, high and low temperature extremes and episodes, precipitation sums, drought and excessive rain periods, determine broad-scale distributions of species. Run-off and water temperature also influence freshwater and marine biodiversity. Changes in climate therefore affect the species composition of ecosystems. Note that the most recent IPCC report indicates that climate change impacts are larger than in earlier research (IPCC/WGII/AR5, 2014). In addition, climate change induced sea-level rise can bring about loss of vulnerable ecosystems, such as coastal wetlands, river deltas and mangrove stands.

Climate change results from changes in atmospheric concentration of radiative forcing agents, the net effect of emissions of greenhouse gases to the atmosphere and their effective atmospheric lifetime. Natural variability, as well as indirect and feedback effects, also play an important role in the degree of climate change. As far as human influences are concerned, the emissions of greenhouse gases play the primary role. CO_2 from fossil fuel combustion is the major contributor, followed by methane (from energy, industry and agriculture) and nitrous oxide (from industry and land use), changes in land-use CO_2 fluxes and carbon stocks, and a range of industrial gases. Tropospheric ozone from air pollution and direct and indirect aerosols are also important, although the latter are subject to very large uncertainties (IPCC/WGI/AR5, 2013). Total global greenhouse gas emissions, aggregated into CO_2-equivalents, continue to grow rapidly under the Trend scenario to over 700ppm in 2050 (from around 300ppm, pre-industrial level). By the same year, the global average temperature will have risen to almost 2.5 degrees above the pre-industrial level. Note that this temperature effect is the transient in 2050, the equilibrium effect of the higher forcing will not be reached until more than a century ahead. Elevated CO_2 concentration affects species directly through its impact on plant growth and indirectly through its impact on climate.


Change in harmful algal concentrations in lakes between 2000 and 2050 under the Trend scenario

Source: PBL

Figure 2.9. Lakes with harmful algal blooms under the Trend scenario.

Water flow regime

For biodiversity in freshwater systems, a driving factor is the disturbance of water flows with consequences for the survival and distribution of species. Agriculture is the largest consumer of freshwater for irrigation, but other users such as households, industry and electricity producers also withdraw large volumes of water. The run-off is further disturbed by the building of dams and reservoirs, the drainage of wetlands and other riverbed modifications. The withdrawal of water is expected to increase and the building of dams will continue, so that more rivers will be affected by water flow disturbance.

Fisheries

Fisheries are the dominant factor that impact on marine biodiversity. The increased fishing effort has resulted in decreases in many fish populations (e.g. Worm et al., 2006). Of the 'commercial' fish populations, 23% are overexploited and another 61% maximally exploited (FAO, 2014). There are also signs of overfishing in some freshwater bodies (FAO, 2012).

2.4 Biodiversity and ecosystem services at risk under the Trend scenario

Terrestrial biodiversity

The combined effect on terrestrial biodiversity of the projected changes in the drivers of biodiversity loss under the Trend scenario is expressed in terms of the mean species abundance of original species relative to their abundances in undisturbed (or intact) ecosystems (MSA). The MSA for terrestrial ecosystems is derived from the GLOBIO model (Alkemade et al., 2009; see Box 2.1 for an illustration of the MSA in different ecosystems and Annex B for a further methodological description).

Box 2.1. The mean species abundance indicator illustrated.

The mean species abundance indicator measures the change in populations of species relative to intact ecosystems. The range in MSA values and the corresponding land use and impact levels are visualised for grassland, forest and water systems. The value of the MSA indicator gradually changes due to human impacts from highly natural ecosystems (MSA of 90 to 100%) to highly cultivated or deteriorated ecosystems (MSA of about 10% or less), as illustrated in the pictures below for forest, grassland and water.

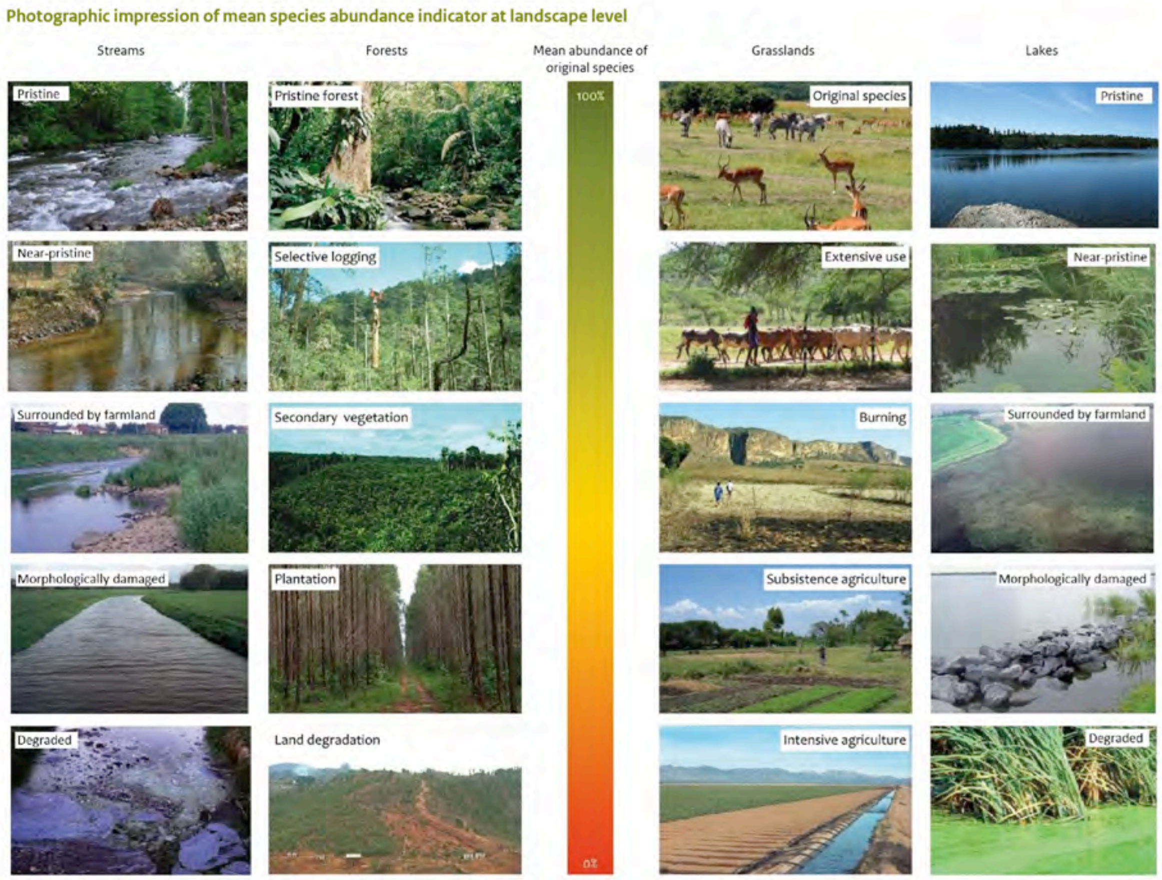
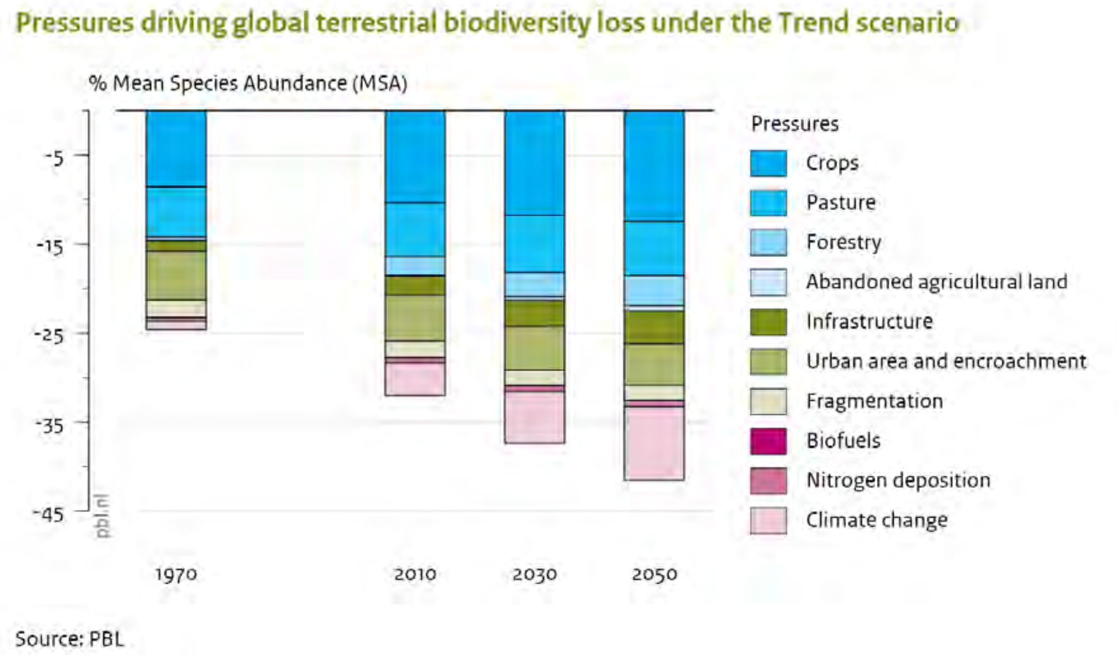


Figure 2.10 shows that the impact of many factors increases under the Trend scenario. While the impact of agriculture increases slightly, other factors show an even stronger increase. Land-use related effects (crops, pasture and forestry) together amount to two thirds of the total loss of terrestrial MSA today. However, the role of agriculture in the additional loss between 2010 and 2050 is relatively small compared with other factors such as climate change. Factors that relate to infrastructure and urban development are expected to increase steadily.

To identify the contributions of the different sectors to biodiversity impacts (expressed as MSA loss), the pressure factors are allocated to sectors by estimating the share of the drivers for which each sector is responsible. For example, terrestrial MSA loss associated with crops and pastures is directly linked to the agricultural production of food, feed and fibre. However, the contribution made by land use and land-use change related emissions responsible for climate change is also allocated to agriculture. Fragmentation and encroachment are also closely linked to agriculture, though human settlements and infrastructure play a role as well.

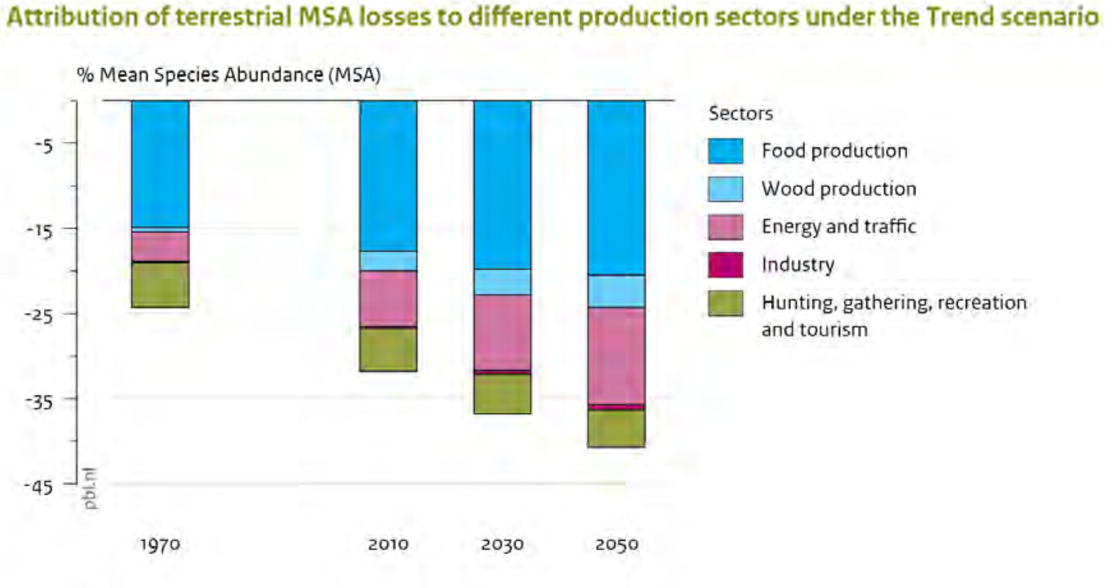
As shown in Figure 2.10, climate change is expected to become one of the dominant drivers of further biodiversity loss in the next half century and beyond, and by far the biggest contributor to climate change is the energy sector, including traffic. In addition, land use for bio-energy production and emissions of nitrogen compounds leading to N deposition are also allocated to this sector. Its importance is shown in Figure 2.11, but for the reasons mentioned in the introduction to this report, it is not analysed separately in this report.


Pressures driving global terrestrial biodiversity loss under the Trend scenario

Source: PBL

Figure 2.10. Global terrestrial MSA loss by pressure factor under the Trend scenario (PBL, 2012).

We attributed the impact of emissions from manufacturing and the occupied space of factories and industrial complexes to the industry sector. The energy used by industry is accounted for in the energy sector, so that the contribution from industry is minor. Mining is not explicitly included in the model so could not be covered. The impact of wood production on terrestrial biodiversity is a clear case, as forestry is a separate driver causing loss of MSA in the GLOBIO model used here. Finally, several drivers are associated with the direct use of natural ecosystems for hunting and gathering and for recreation and tourism; these are aggregated into the category 'hunting, gathering, recreation and tourism' .



Source: PBL

Figure 2.11. Attribution of terrestrial MSA losses to different production sectors under the Trend scenario.

Altogether, agricultural production – comprising food, fuel and fibres – is the sector to which most terrestrial biodiversity loss is attributed. The energy and traffic sector is of increasing importance, whereas the wood production industry, and direct use sectors make a minor but considerable contribution.

Aquatic (freshwater) biodiversity

As with terrestrial biodiversity, freshwater systems show loss of biodiversity due to various types of human activities. The impacts on the MSA can only be estimated for a limited number of pressure factors (Janse et al., 2014). The factors included in the GLOBIO model are wetland conversion, impacts of land use in river catchments including pollution by nutrients (eutrophication) and hydrological changes. The impacts vary between different types of freshwater systems: with lakes, rivers and wetlands, the overall impact is shown in Figure 2.12.

The MSA loss in fresh water is attributed to two main sectors: the agricultural production sector and the water management sector. The impacts of local land use and upstream land use of a catchment are primarily associated with agricultural production. Eutrophication is currently attributed to agriculture for about 80%, but the impact of urban emissions will increase sharply (Bouwman, 2011; van Drecht, 2009). The water management sector includes all activities that manipulate the flow in rivers and water bodies. Hydrological disturbance is therefore attributed to the water management sector.

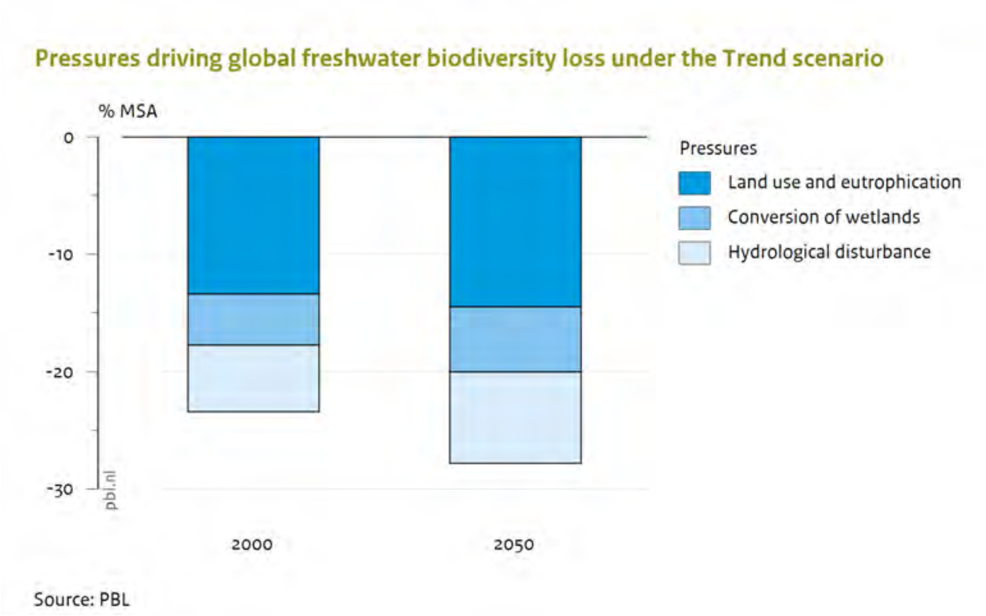
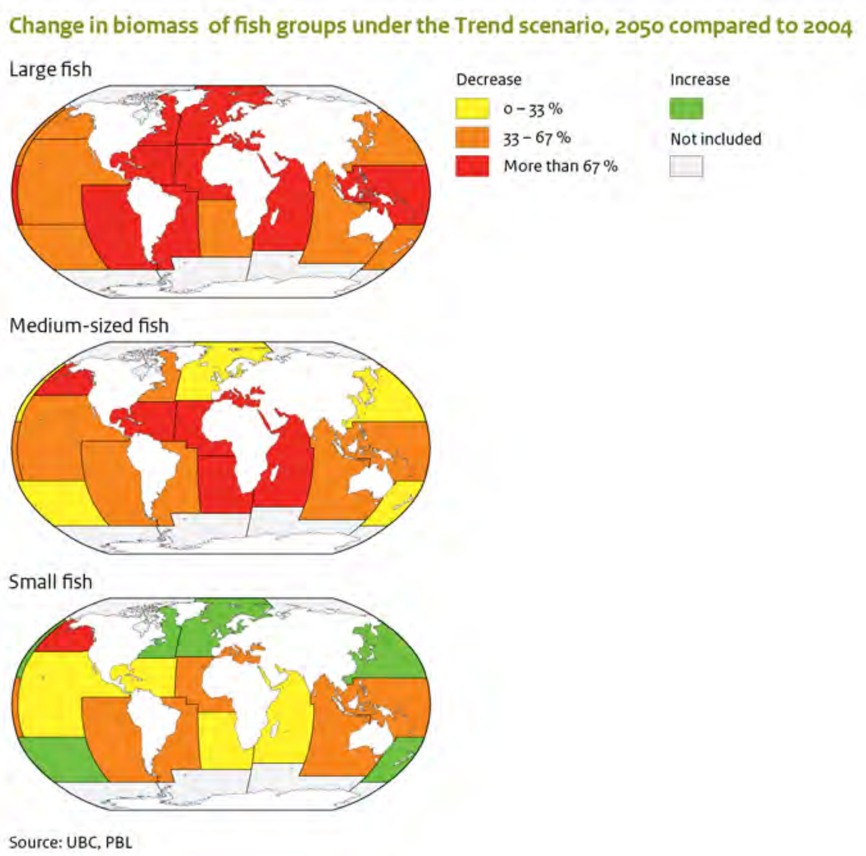


Figure 2.12. Aquatic MSA loss per category and main cause.

Marine biodiversity

Fishing is by far the most prominent activity impacting biodiversity in marine systems to date. However, in coastal regions pollution from various sources and building activities also play a role. In the future, climate change will increasingly affect marine biodiversity. Here we focus on fisheries as the main driver of biodiversity loss in the oceans. During the last few decades, fishing activities have increasingly led to the overexploitation of a growing number of fish stocks. Under the Trend scenario, fishing activities are assumed to increase at similar rates to keep catches more or less stable. Nevertheless, catches are expected to decline and the overexploitation of fish stocks is expected to increase. Figure 2.13 shows the changes in biomass in different sizes of fish stocks, showing the decline of large and medium sized fish stocks and some increase in small fish groups.


Change in biomass of fish groups under the Trend scenario, 2050 compared to 2004

Large fish

Medium-sized fish

Small fish

Source: UBC, PBL

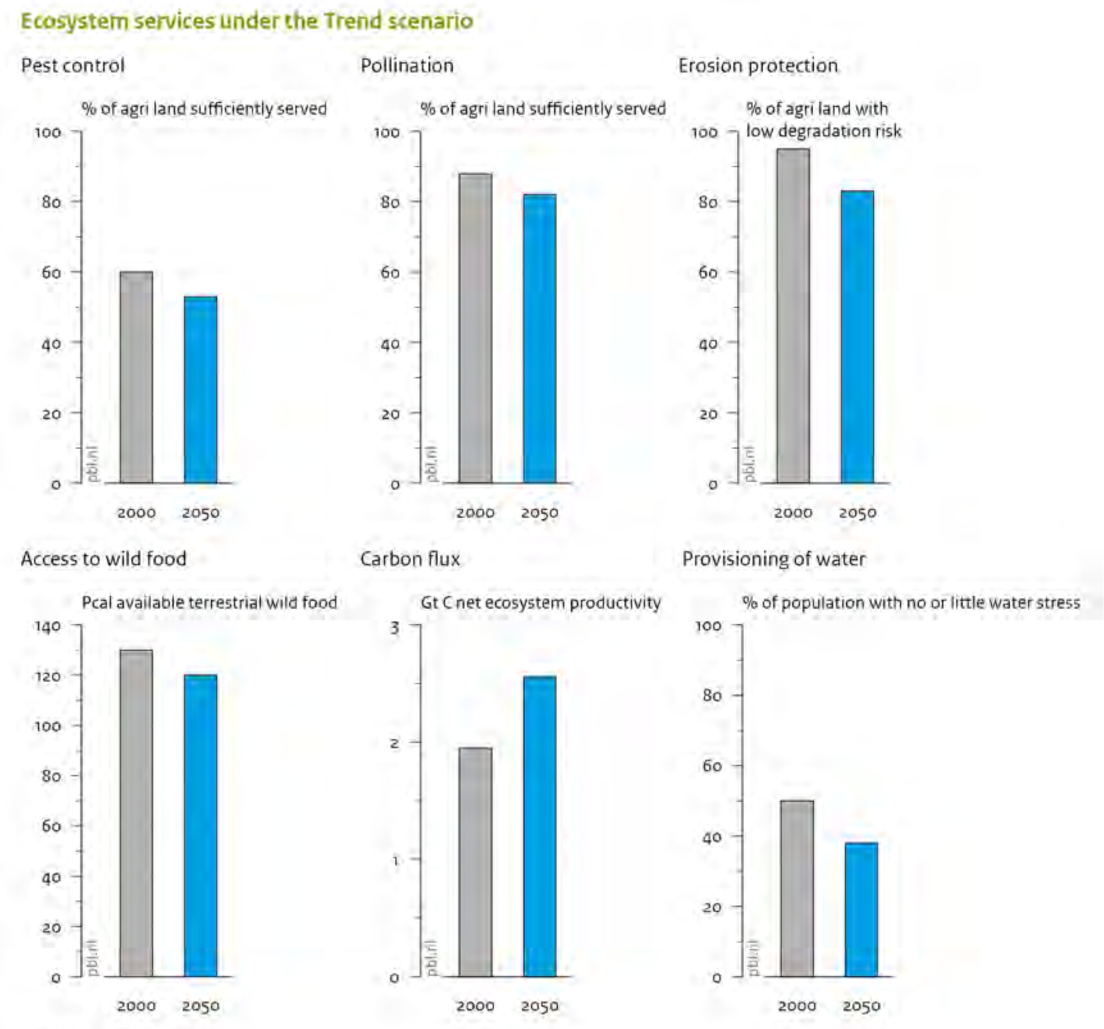
Figure 2.13 Change in biomass of fish groups under the Trend scenario, 2050 compared with 2004.

Clearly, in this analysis the biodiversity impacts depend entirely on the effects of catching fish for the human food supply. As a result, the impacts reported here fall under the fisheries sector. Other pressure factors may include climate change, ocean acidification from elevated atmospheric CO_2 concentration, eutrophication from excess nutrient loading and other forms of pollution such as oil spills, chemicals and waste materials. These potential factors are not addressed here.

Ecosystem services

As well as biodiversity loss, discussed in the preceding sections, the capacity of ecosystems to provide services for a range of human needs is also declining (MEA, 2005). The production of food, wood and freshwater is in itself a provisioning ES and depends on various supporting and regulating services (see Figure 2.14). These supporting services can be partly replaced by technical means, but this can be costly. The loss of ecosystem services indicates the non-sustainable use of ecosystems, and a further decline moves away from reaching the Aichi targets on biodiversity. A decline in ES also indicates a decrease in the potential resource base for the production of food, fibre, fuels and freshwater. The decline of ‘natural capital’ can therefore have consequences for development prospects.

ES can decline as a consequence of overexploitation. Provisioning services decline due to unsound and unsustainable management, leading to overexploitation and the degradation of ecosystems and reduced production capacity. Well-known examples include overgrazing and resulting soil degradation, marine fish stock depletion and water pollution. The conversion of land impacts ecosystems services in various ways. It often leads to the increased production of goods, in agriculture, forest plantations and aquaculture, but at the same time many regulating and supporting and cultural services decline. Many of these services contribute to the production of food (e.g. through pollination, pest control, avoiding erosion). The kind of role depends on factors like location, scale and management practices. Technical means are commonly used to replace insufficient ES, such as fertilizers to restore fertility and pesticides to control pests and diseases. Modification of natural and semi-natural ecosystems may reduce (unintentionally) the capacity to deliver services. For example, coastal dunes, river beds and wetlands can help reduce flood risks, while modification by building seaside hotels or forest resorts will reduce these services.



Source: PBL

Figure 2.14. Ecosystem services under the Trend scenario.

ES were analysed using global proxies for the potential supply of a series of services (Schulp et al., 2012). The proxies were based on studies that relate ecosystem services to global data on patterns of land cover and land use, ecosystem productivity or water flows. Various models were used to estimate how these develop under the Trend scenario. Ecosystem services are not currently being delivered sufficiently everywhere as pest control or erosion risk protection, which would ideally be delivered on all agricultural land. Figure 2.14 not only shows that current ecosystem service provision is not sufficient, but more importantly it shows a decline over time at the global level, albeit not very drastic. The only exception is the carbon flux, expressed here as the net terrestrial ecosystem productivity (the net uptake of carbon into the terrestrial biosphere), which increases over time. Without going into full regional details, it is worth noting that the global averages do not reveal the large differences between world regions, both in terms of the levels in 2000 and the degree by which they decline up to 2050. In addition, local conditions may vary considerably within regions, so that very serious impacts at the finer scale cannot be ruled out.

Pest control: depends on the availability of suitable habitats for predators adjacent to agricultural fields and on the habitat quality of soils. The percentage of global agricultural land that meets this requirement declines over time, and was already low in 2000 in North America and South Asia. Chemical or managed biological pest control may be required to complement the natural control for new crops or varieties or if invasive species enter the area. This will also need to be stepped up to compensate for the decline in natural processes.

Pollination: similar to pest control, natural pollination requires suitable habitats for the insects and other pollinators that provide the pollination services. The service declines by a relatively small percentage at the global scale, but more in sub-Saharan Africa, the China region and Southeast Asia. This implies that some crops may become less viable unless the shortfall in natural pollination is compensated by management such as bee-keeping.

Erosion protection: the indicator used here is a compound of factors contributing to risk of water erosion. Land use of varying intensity and land cover play a role, but so do rainfall intensity, soil properties and landscape (slopes). The presence of natural elements between and adjacent to agricultural fields provides protection from the risk, and hence this is used as a determinant of the ES. Globally, 95% of agricultural land (croplands and pastures) benefits from the ES erosion protection, but this is projected to decline, in particular in the Middle East, Africa, China and Southeast Asia. It must be noted that the indicator reported here covers the issue of erosion risks only partially (see Box 2.2).

Access to wild food: wild food, especially meat, is an important additional food source of high nutritional value, especially in poor rural areas. The global availability of wild food declines from $130x10^{15}$ to $120x10^{15}$ calories, with most of the decline observed in regions currently rich in a wild food supply: sub-Saharan Africa, South and Southeast Asia. Wild food availability drops the most in South Asia, by 28%.

Carbon flux: terrestrial ecosystems play an important role in climate change as they sequester carbon in living and dead biomass and soils. Management of the ecosystems influences the net flux from the atmosphere into the biosphere, and the uptake is enhanced under higher atmospheric CO_2 concentrations[2]. Altogether, the carbon flux into the biosphere, measured as the net ecosystem productivity (NEP), is projected to increase until 2050. Given the expected doubling in total CO_2 emissions over the same period, however, the percentage taken up by the biosphere will decrease from 24% to 16% (Stehfest et al., 2014).

Water stress: defined as the degree by which the renewable water supply in a river basin (or sub-basin) exceeds the demand for withdrawal in the same river basin. The annual average ratio of demand to supply is called the water exploitation index (WEI); a high ratio indicates a higher risk of shortages (which may be temporary and/or local) and puts pressure on

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[2] Oceans are also a sink of carbon but, based on the current state of knowledge, function largely autonomously, driven by the higher CO_2 concentration. The response of the oceans to ecosystem changes is too uncertain to take into account here.

ecological flow requirements. The WEI is classified in categories of water stress: below 0.20 (no or mild water stress) sufficient water is considered to be delivered, above 0.2 water stress gradually increases with the effect that an increasing proportion of people in a river basin may suffer, at least during a period of the year, from water shortages. Already today, many people live in severely water-stressed basins, for example in the Middle East, North Africa, South Asia and Europe. By 2050, the percentage of people with sufficient water will decrease from 50% to 38% of the total population of 9.2 billion, and the number of people living with severe water stress is projected to increase from 1.6 to 4.3 billion. By 2050, no less than 47% of the total population will be faced with severe water stress.

Box 2.2. Land degradation

Land degradation might present an additional threat to biodiversity and ecosystem services in the future. Many types of land and ecosystem degradation are distinguished, but human-induced soil degradation and ecosystem productivity loss are the most relevant for this outlook. Degradation may occur as the result of unsustainable exploitation of vegetation and organic carbon (humus), which reduces water infiltration and water storage capacity, nutrient availability, soil stability, structure and erosion, and finally affects soil fertility and agricultural productivity. The changes in vegetation cover also result in the amplification of local temperature variation, climate change impacts and increased risks of floods and drought. Land degradation has led and still leads to loss of potentially suitable land for crops, livestock production and forestry for timber, pulp and wood fuel, which may be significant in the context of growing demands for food. Estimates of the extent of global land degradation range between 15 and 43 million km^2 of land, which is about 9% to 33% of the global terrestrial surface (Rozanov et al., 1991; Oldeman et al., 1991; FAO, 2011; Bai et al., 2008). Using various sources, Scherr and Yadav (2001) estimate the current annual loss at 0.05-0.1 million km2 of land. If this trend were to continue, an additional 2–4 million km2 of agricultural land would be lost by 2050 (in addition to a total of about 40 million km2 of arable and grazing land to date). The large range of estimates can be explained by differences in definitions, factors, data sources, methods, thresholds and scales. Although these figures have a different character and high uncertainty, they do suggest that degradation, prevention and restoration are significant issues to be taken into account in the projections up to 2050.

2.5 Pathways to secure long-term sustainability

To explore opportunities for achieving a more sustainable future than projected under the Trend scenario, alternative pathways are used in this report. These are updated and extended from scenarios that were developed earlier in the PBL study for the Rio+20 conference (PBL, 2012). These pathways were designed to address not only biodiversity concerns, but a series of long-term human development and environmental concerns simultaneously.

Goals met by the pathways

The goals and long-term targets for 2050 that are met in the pathways include key elements of human development: eradication of hunger, universal access to safe drinking water, improved sanitation and modern energy), as well as climate change, terrestrial biodiversity (following the CBD ambition to limit and halt further biodiversity loss and realise a global network of protected areas), water scarcity, interference with P and N cycles and environmental human health (PBL, 2012; see Table 2.1). Using the Aichi Biodiversity targets to limit or even halt biodiversity loss by 2020 (Target 5) and expand protected areas to 17% of terrestrial area and inland waters by 2020 (Target 11), the 2050 vision is quantified in these pathways as halving the rate of loss in 2020 and maintaining it at 2020/2030 levels by 2050 (depending on the region). Together, this translates into a target of 64% measured in MSA for 2050 (PBL, 2012).

After 2050, the risk of further biodiversity loss is not mitigated by measures taken up to 2050. In particular, climate change pressures are expected to increase further. However, it seems safe to assume that the level of effort required after 2050 will be less than that before 2050. The expected levelling off of population growth will reduce additional demands for food and other products and, gradually, the saturation of consumption in material terms will further contribute to reducing the pressure to convert nature areas. In the pathways, pressure from climate change reduces beyond 2050 due to mitigation policies that limit climate change to 2°C; however the most recent findings of IPCC/WGII/AR5 (2014) indicate that climate impacts on biodiversity are more severe than previously assumed. This indicates that even more efforts will be necessary to protect biodiversity loss if climate mitigation policies fail to realise the 2°C objective.

Characterisation of pathways

All interventions considered in the pathways have their own drawbacks, and different actors in different parts of the world will value benefits, costs, efforts and impacts differently. Due to this, no attempt was made to identify a single 'best' or 'most desirable' or otherwise 'optimal' future, but to explore three different pathways, all subject to meeting the same set of long-term sustainability targets. A short overview of the different pathways explored is given in Table 2.1.

Table 2.1. Characterisation (or emphasizes) of the pathways (derived from PBL, 2012)**.**

Pathway	Main assumption
Global Technology (GT)	Achieves the 2050 targets, with a focus on large-scale technological optimal solutions, such as intensive agriculture and a high level of international coordination; for instance through trade liberalisation.
Decentralised Solutions (DS)	Achieves the 2050 targets, with a focus on regional priorities and ecology-friendly technologies. Energy, food and wood are produced locally or regionally and agriculture is interwoven with natural corridors. National policies regulate equitable access to food.
Consumption Change (CC)	Achieves the 2050 targets, with a focus on changes in human consumption patterns, most notably by limiting meat intake per capita, by ambitious efforts to reduce waste in the agricultural production chain and through the choice of a less energy- and material-intensive lifestyle.

In line with these narratives, specific assumptions and model parameters and settings were developed to assess the quantitative outcome of the three pathways, compared with the Trend scenario and with each other. The core assumptions on population and economic activity are shared by the Trend and the alternative pathways, while other indicators are adjusted in the pathways. For example, food consumption is higher in all pathways to ensure eradication of hunger, and a different diet is assumed as part of the Consumption Change pathway.

Without going into detail, for which we refer to PBL (2012) and the specific sector chapters 3 to 6 in this report, main differences in the pathways include:

- Higher food consumption in those regions where undernourishment is not eradicated by 2050 under the Trend scenario. This is accomplished by raising average food consumption alone, or specifically raising consumption for those groups at the low end the food intake range.
- In Consumption Change, consumer preferences are assumed to change in favour of less resource-intensive choices, such as less animal products in the diet, less motorised traffic, more end-use energy savings, more re-use and recycling, reduced waste including post-harvest losses in the food chains, and so on.
- In Global Technology, and to a lesser extent in Consumption Change, less agricultural land is required due to enhanced crop and livestock productivity. In Consumption Change this is also a result of the dietary shift to fewer animal products. Productivity increase is enhanced by applying technologies, focusing on reducing external impacts such as pollution, and the use of biological techniques such as improved varieties and crops, biological control of pests, high productive tree species in plantations, and so on.
- In Decentralised Solutions there is more conservation of biodiversity on agricultural land and in managed forests, associated with mosaic landscapes with patches and strips of natural land mixed in with agricultural land. Improved agricultural productivity is achieved through ecological intensification methods, using a mixture of techniques including mixed cropping, optimising natural pest control such as Integrated Pest Management, and so on.
- Reduced climate change mostly due to low carbon energy systems, including energy savings induced by higher prices. The technology mix differs between the pathways as a result of less or more constrained access to energy resources, and assumed pathway-specific preferences for certain technologies, such as nuclear power and carbon sequestration and storage (CSS). In developing countries, a gradual shift from wood fuels for cooking and heating to other fossil fuels is assumed.
- In Global Technology, protected areas reach 17% at the highly aggregated level of realms. The new protected areas are established where they are least in conflict with agricultural expansion. In the Decentralised Solutions pathway, however, the protected areas are assigned at the highly detailed level of 779 different eco-regions (Olson et al., 2001). Furthermore, new protected areas are placed close to existing agriculture, creating more intense competition with agricultural expansion. The Consumption Change pathway has an intermediate level of ecosystem detail but new areas are also allocated close to existing agriculture. In both the Decentralised Solutions pathway and the Consumption Change pathway, the total protected area is higher than 17%.

- The pathways show in addition to important synergetic effects – counteracting mechanisms as well. For example, the use of bio-energy is expanded to combat climate change, with positive effects on future biodiversity loss, but this also requires additional land and other resources with likely negative impacts on biodiversity in the short term (van Oorschot et al., 2010). In the latter case, timing is also important: converting natural land to produce more bio-fuels will affect biodiversity instantaneously, while the benefits from reduced climate change only manifest themselves decades later.

Consequences of the pathways for nature areas and protected areas worldwide

The pathways comply with Aichi Target 5 – halving or even halting further loss of nature areas (PBL, 2012; shown in Figure 2.15). The pathways would considerably reduce the loss of nature areas – and of wilderness in particular – compared with the Trend scenario for 2050. The differences between regions in the pathways are often larger than the global comparison, signalling different distributions of land use. Nature areas include deserts and mountain areas which in some regions represent a large share of the surface area.

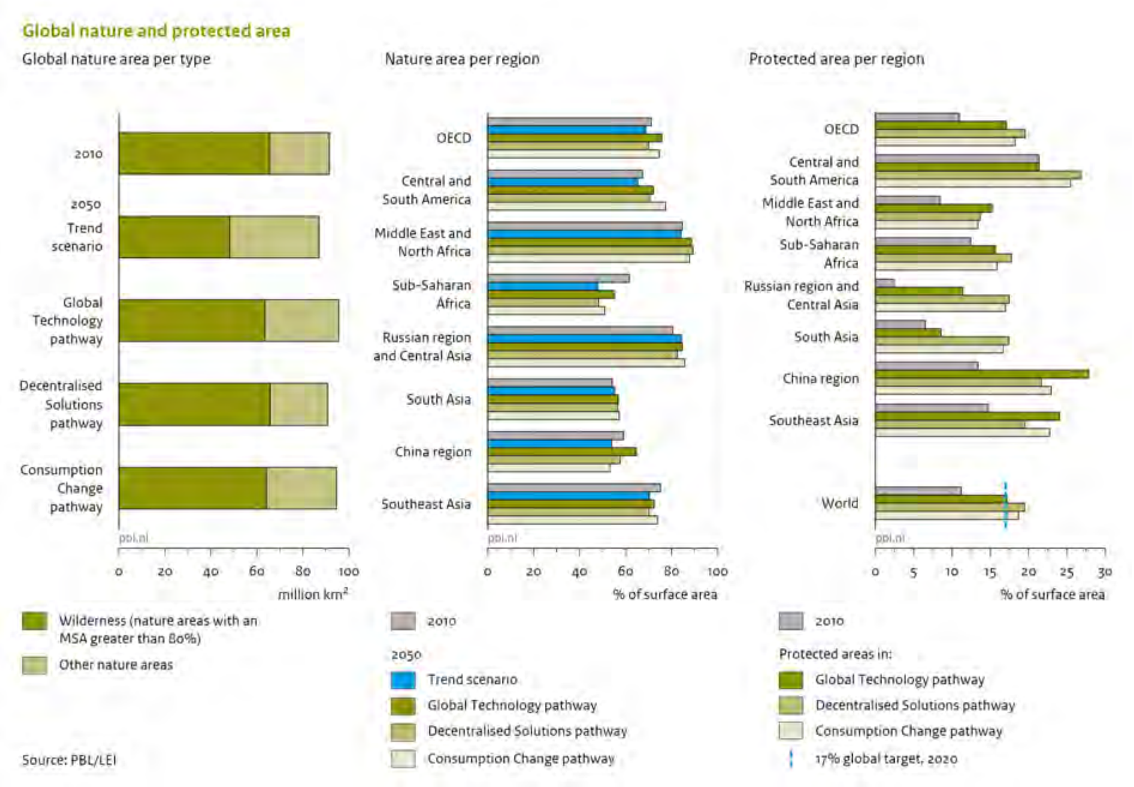
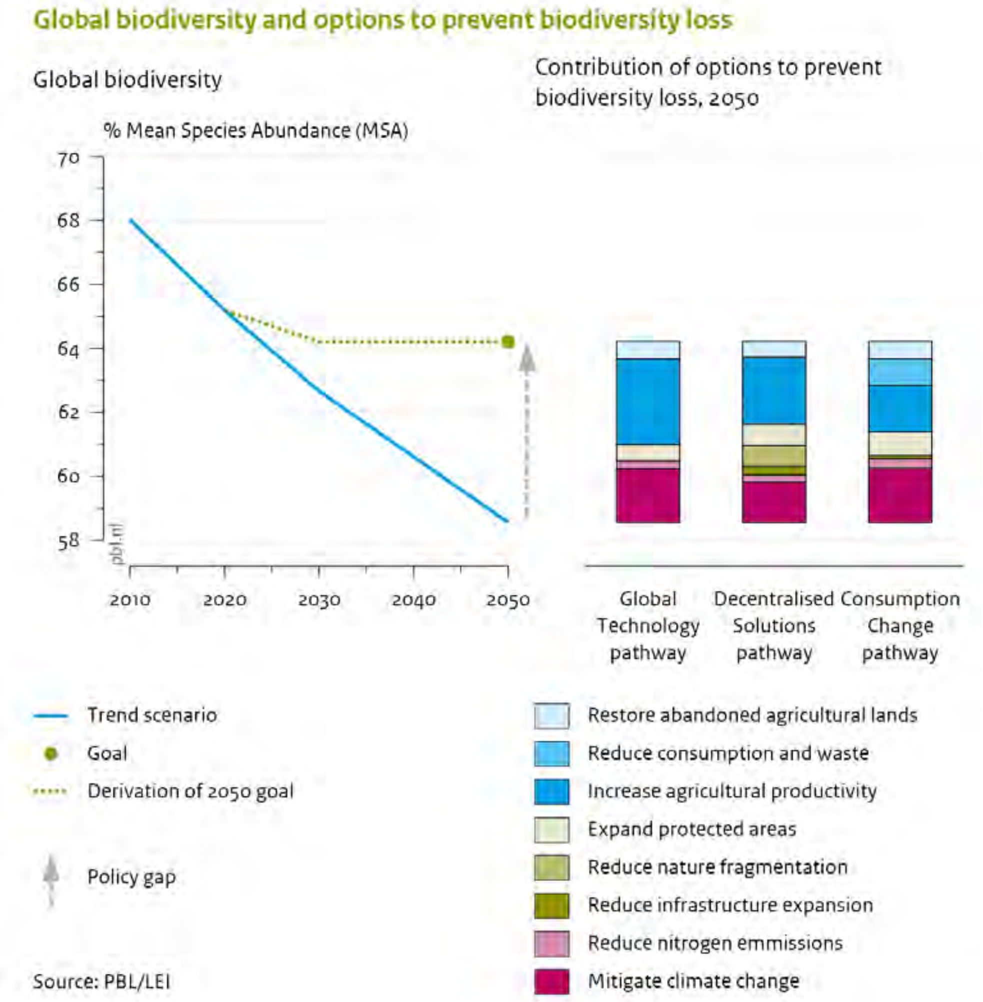


Figure 2.15. Global nature area and protected areas under Trend scenario and pathways. The pathways will considerably reduce the loss of nature areas, and of wilderness in particular. The different allocations of protected areas in the pathways causes differences in the efforts that would have to be undertaken in regions to achieve the Aichi Target on the expansion of protected areas to 17% of terrestrial and inland biomes in ecologically-representative systems (Updated from PBL, 2012 for this report).

The pathways were designed to meet Target 11 – the effective protection of at least 17% of terrestrial areas and inland water areas in ecologically-representative systems (PBL, 2012). The Aichi Biodiversity Target 11 on protected areas requires effective protection of at least 17% of terrestrial areas and inland water areas in ecologically-representative systems. In 2010, 11% of the terrestrial area (excluding Antarctica and Greenland) was already protected. Three alternative routes were included in the pathways that each lead to an expansion of the global protected area to at least 17%. The expansion mechanisms ensure that, where possible, an ecologically-representative network remains. The expansion in the pathways varies in the level of aggregation of ecosystems and allocation rules using priority areas from different sources (Kapos et al., 2008; OECD, 2012). This leads to different levels of competition with other land uses. In the allocation process, we assumed that existing protected areas will remain, even if more than 17% of an ecosystem is already protected (see Figure 2.15).

Results of the pathways for halting biodiversity loss and provisioning ecosystem services

All pathways come close to meeting the biodiversity target of halting and reducing projected biodiversity loss compared with the Trend scenario (set at 64% MSA by 2050). The contribution of different options to achieve these targets are in Figure 2.16.


Global biodiversity and options to prevent biodiversity loss

Global biodiversity

Contribution of options to prevent biodiversity loss, 2050

Source: PBL/LEI

Figure 2.16. Global biodiversity and options to prevent biodiversity loss (Updated from PBL, 2012 for this report).

As a result of the alternative development of drivers in the pathways, global terrestrial biodiversity loss tapers off gradually, and the loss of most ecosystem services declines. As mentioned before, all this is realised while simultaneously achieving important progress towards social, economic and other environmental sustainability targets.

In the pathways, the agricultural area expands less than under the Trend scenario, despite the somewhat higher food production to reduce undernourishment. This is due to more rapid increases in yields as a result of better technology and the accelerated adoption of improved management practices. Part of the reduction in agricultural land is compensated by more area to grow bio-energy feedstock to contribute to reduced GHG emissions from the energy sector (see below). Altogether, the lower impact of agriculture on biodiversity, resulting from smaller areas (Global Technology and Consumption Change) and higher MSA values on agricultural fields (Decentralised Solutions), is an important factor in halting overall biodiversity (see Figure 2.17). At the same time, ecosystem services such as pest control, pollination and erosion protection perform better than under the Trend scenario, with positive impacts for the agricultural sector (Figure 2.17). For more details, see Chapter 3.

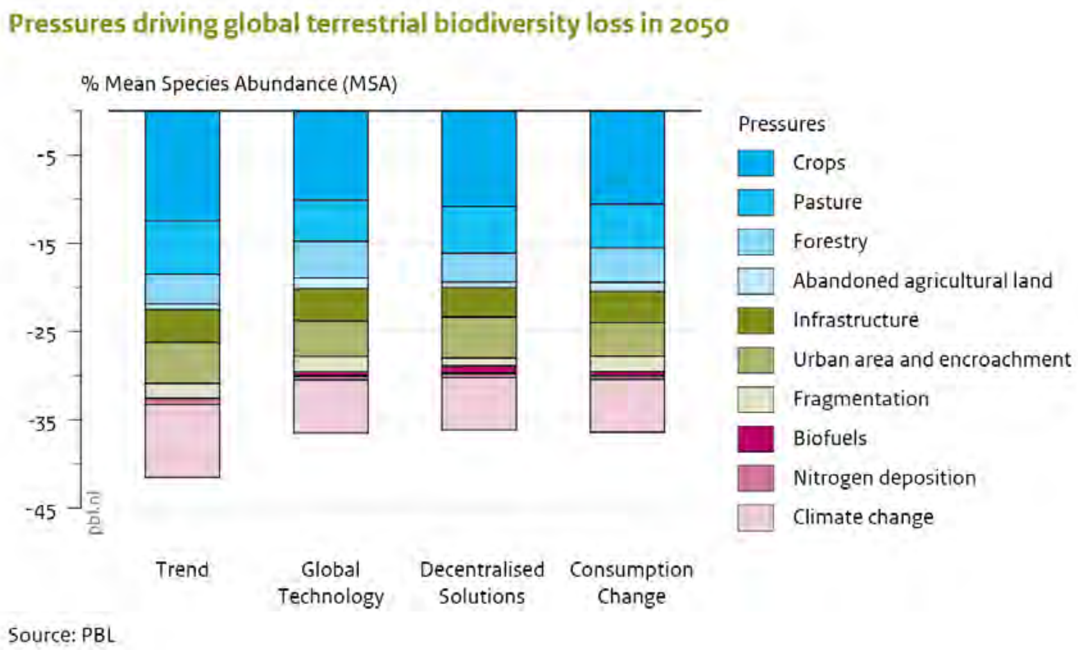
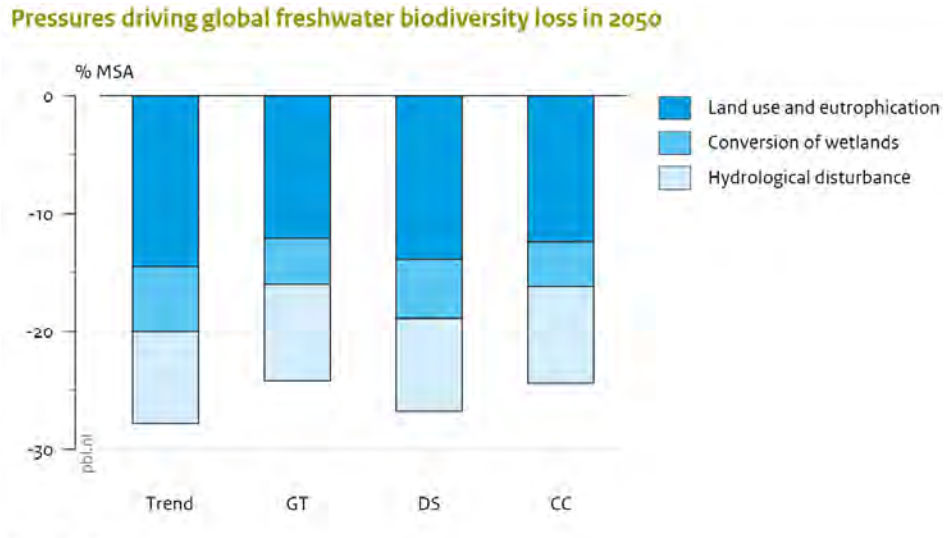


Figure 2.17. Global terrestrial MSA loss by pressure factor in 2050: the Trend scenario and the pathways.

Food crop yields and livestock production efficiency increases most in the Global Technology pathway to match the higher food production with the goal to reduce biodiversity loss. In the Decentralised Solutions pathway, the harvested yield increases less, due to lower yield increases expected for ecological intensification. As intended, the resulting MSA of the crop areas is higher. In Consumption Change, agricultural intensification is also moderate, as the total agricultural production is reduced due to a less meat-oriented diet and the assumed reduction in post-harvest losses along the food supply chain. Improvements in technology also lead to higher fertilizer use efficiency and hence to lower surpluses. As a result, the pollution of freshwater bodies is less than under the Trend scenario, as is the impact on freshwater MSA losses; see Figure 2.18. More details can be found in Chapter 6.

In the pathways, the atmospheric concentration of greenhouse gases levels off to around 540 ppm in 2050 and the temperature rises to 1.75 degrees above pre-industrial levels, consistent with the long-term goal to limit global warming to 2 degrees. This means that the total energy consumption is lower in all pathways and that drastic technological transitions in the energy sector away from fossil fuels are required. Evidently, climate change mitigation is an important element of response strategies. In the supply of bio-energy as one of the means to reach the two degrees climate target, land-use and air and water pollution effects are accounted for.

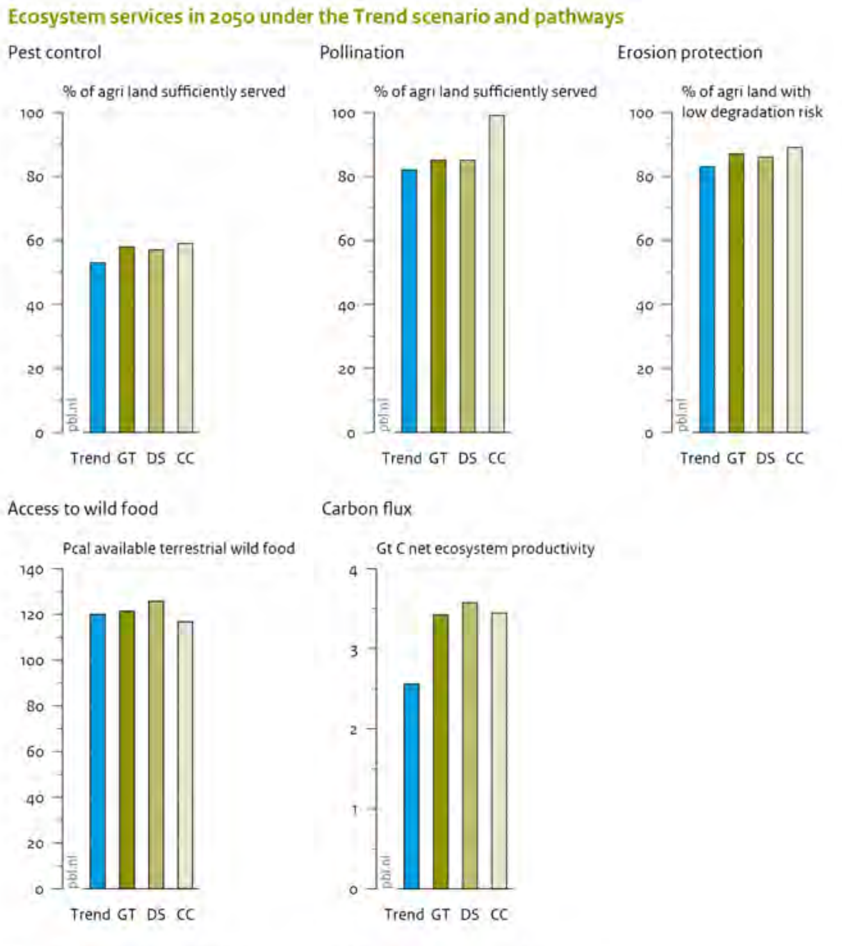
As far as wood production is concerned, the pathways assume that a larger share of wood products is supplied from forest plantations. This is facilitated by more agricultural land taken out of production, allowing for the establishment of plantations on abandoned fields. In addition, reduced impact logging becomes standard practice for all forests where selective logging is applied, and in the Consumption Change pathway the demand for newly-cut wood products is lowered as a result of more re-use and recycling of waste products. Improvements in the agricultural sector, leads to lower rates of deforestation, implying reduction of wood that can be harvested from the conversion process. For more details, see Chapter 4.



Source: PBL

Figure 2.18. Global freshwater MSA loss by pressure factor in 2050: the Trend scenario and the pathways.

Figure 2.19 shows the implications of the pathways for the different ecosystem services. It shows that in general ecosystem service provision increases in the pathways compared to the Trend scenario.



Source: PBL, no pathways data for provisioning of water ecosystem service available

Figure 2.19. Ecosystem services under the Trend scenario and pathways in 2050.

The following chapters discuss options, opportunities and barriers for some of the most directly biodiversity-relevant sectors. Special emphasis is put on prospects for pursuing the more sustainable directions of natural resource use illustrated by the global scenario analysis, in conjunction with and guided by the primary interests and concerns of the sectors.

Chapter 3. Food production

3.1 Introduction

Agriculture has tremendously increased the availability of food since mankind moved from hunting, fishing and gathering to a sedentary lifestyle. Currently, most food comes from croplands and pasture, as well as fishing and increasingly from aquaculture. In some regions, hunting and gathering are still important for providing food. Food production causes an ever increasing loss of biodiversity, mainly due to a growing global population and increasing welfare. Food production in the form of agriculture (including livestock production) is by far the largest contributor to terrestrial biodiversity loss as indicated in Chapter 2.

At present, most of the food consumed is no longer produced in self-sufficient families or communities, but travels a long way from producer to consumer. A globally increasing share of all consumed food is processed and arrives in packaged forms at the consumer. Farmers depend on certain inputs such as seeds, fertilizers and machinery to produce high yields. The complete 'food system' that makes this happen is not a neutral supply chain; actors (such as food processing companies and retailers) within this food system largely shape both supply and consumer demand (Lang *et al.*, 2009; Pinstrup-Andersen, 2002; Pinstrup-Andersen & Watson II, 2011). This notion is important when exploring potential changes and interventions in the food system to produce in a more biodiversity-friendly manner.

Although a special chapter in this report is dedicated to fisheries (Chapter 6), fish and fisheries are, for reasons of completeness, sometimes referred to in this chapter as well. As agriculture does not only produce food, but also fibre (such as cotton) and bio-energy, many data (for example on land use and crop production) refer to the agricultural sector as a whole.

This chapter starts with a description of the food sector (Section 3.2), followed by an account of its dependency on biodiversity and ecosystems services, but also of its impact on these (Section 3.3). Next, a brief overview is given of what actors within the food sector are already doing in favour of biodiversity (Section 3.4). This is followed by an analysis of long-term options to reduce the impact of food production on biodiversity and make better use of its benefits (Section 3.5). The chapter ends with priorities for the coming years and possible actions for different actors in the food system to make this happen (Section 3.6).

3.2 Description of the food sector

The food sector is a very large and diverse sector. It consists of many different actors, from subsistence farmers, family farms, industrial farms (specialised in one or two crops or animal species) and small-scale traders to large food companies and supermarkets. Nowadays, more than 50% of the global population lives in cities and depends on food that is produced by other people elsewhere. The bulk of market sales of all food worldwide emanates from a small number of relatively well-capitalised producers in the more favourable agro-ecological zones (Evans, 2014). Although some commodities (such as soy and sugar) are traded globally, around 90% of all food is still consumed in the country of production.

In terms of calories and protein, most of the food worldwide is directly or indirectly (feed for animal production) produced on cropland for annual and perennial crops. Other significant quantities of food are produced on grasslands (such as meat and dairy), and to a much lesser extent through hunting and gathering. Croplands and pastures not only produce food, but also fibre (such as cotton, sisal and wool) and bio-energy. A small fraction of the croplands is used for the production of stimulants and drugs, such as tobacco, opium and quinine.

Farmers are a very diverse group, in many respects. Farm size can differ from less than 1 hectare to over 10 000 hectares. The majority of farmers worldwide are smallholders, who generally partly produce for their own consumption, and partly sell crop and livestock products. Furthermore, the production system and intensity varies from livestock farming on semi-natural grasslands to intensive crop production. In regions with mainly smallholder farmers, the extent of agricultural land and conversion of forests and wetlands into agriculture is largely connected with local developments such as population density change. In regions dominated by large-scale farming operations, the growing global demand for commodities such as palm oil, soy bean and beef, combined with local opportunities, is generally the main driver of expanding farmland (Lambin & Meyfroidt, 2011).

The diversity of actors in the food sector is expressed in Figure 3.1, which shows that 1 billion smallholders (mainly in Africa and Asia) feed around 5 billion people, whereas around 15 million medium- to large-scale farms feed about 1 billion people, who mainly live in cities. In between, there is a group of 50 million farmworkers on small- to medium-sized farms, that also feeds around 1 billion people. This diversity is extended in the rest of the food system. In the case of smallholders, much of the food is sold locally and unprocessed, whereas in industrialised food systems much of the food is processed and sold through retailers or outlets such as restaurants. Some of the food companies are global brands, well-known to many consumers, while other companies or entrepreneurs have only regional or local importance. Likewise, there are large differences in the input industry (such as seed companies and livestock breeders) that provides most of the inputs in industrialised food systems, whereas its role is limited in many smallholder systems.

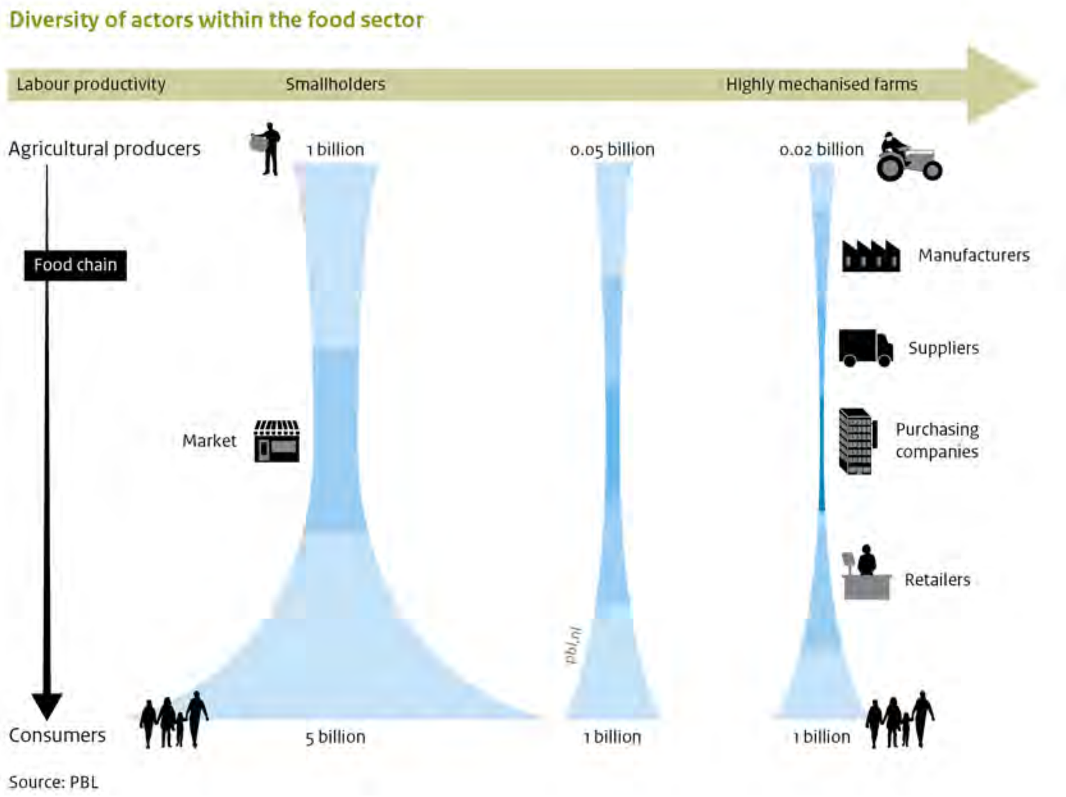


Figure 3.1. Representation of the actors within food systems.

The actors in the food sector not only physically move and transport food, but often also have a major influence on consumption patterns as well as on the way in which and the location where the basic commodities are produced. In North America and Europe, supermarkets, fast food restaurants and caterers have a large impact on consumption patterns and a similar, but more rapid, shift is taking place in emerging and developing countries (Reardon *et al.*, 2012). Food companies are starting to realise the effect of food consumption and production on biodiversity and to get involved in various initiatives to make food production more sustainable. Differences in the way food is being produced, processed and sold are relevant when evaluating options to make production more sustainable (Section 3.4).

Food security, feeding growing global population and climate change are major challenges

Despite the fact that food production has increased significantly over the last 50 years, over 800 million people are still food-insecure (FAO, 2012a). The challenge for the future is not only to feed over 9 billion people, who generally will be wealthier in 2050, but also to improve food security. Food security is defined as a situation in which all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (World Food Summit, 2009). Food insecurity is generally caused by poverty or short-falls in local production, and not by a shortage of global food production. Feeding an additional 2 billion without losing more biodiversity will be challenging, especially since it is expected that, with increasing income, diets will change towards more meat and dairy, the production of which demands more land and resources (Chapter 2 and (PBL, 2010, 2011, 2012)). At the same time, biodiversity-rich diets make a significant contribution to healthy and sustainable lifestyles (FAO, 2010b).

3.3 Benefits from ecosystem services and impacts on biodiversity

This section describes the dependency of agriculture on ecosystem services, as well as the (generally negative) impact of agriculture on biodiversity. The focus is on impacts at the primary stage of food production (crop and livestock production), as the largest impacts occur at this stage.

Benefits from ecosystem services

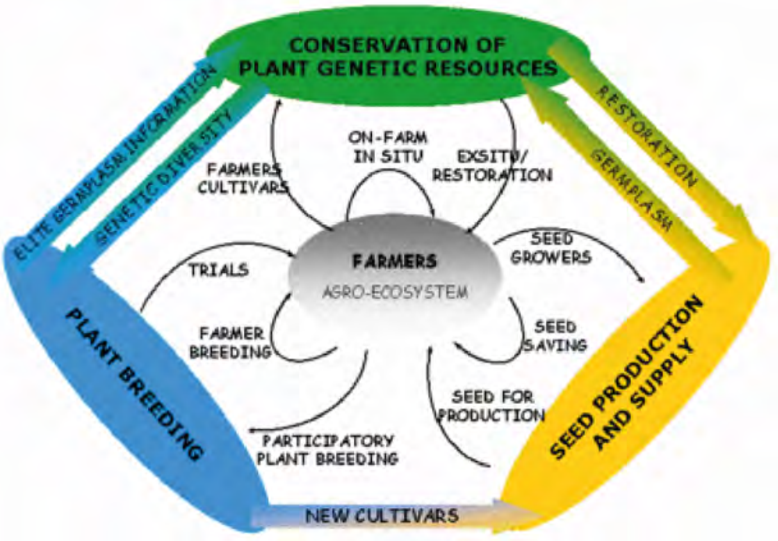
In terms of ecosystem services, food production is a provisioning service (MA, 2005). Food production itself is crucially dependent on a number of supporting and regulating services such as soil formation and nutrient cycling. Regulating services that enable food production include climate regulation, water regulation, erosion control, water purification, pollination and biological control of crop and livestock pests and diseases. For some services, for example biological pest control, man-made alternatives are available, such as pesticides. However, these alternatives lead to additional costs and negative environmental and health-related impacts. Many regulating services depend on the existence of certain landscape elements such as hedges (against wind erosion), uncultivated land (reservoir for biological control) and wetlands (water regulation and purification) (Grashof-Bokdam & Van Langevelde, 2005; Marshall & Moonen, 2002).

Low-input farming systems depend to a great extent on ecosystem services such as nutrient cycling, erosion control and biological control. Despite their use of pesticides and fertilizers, high-input farmers also use ecosystem services such as pollination, biological control and nutrient recycling through the decomposition of plant residues. However, these farmers are often not aware of the ecosystem services that are provided, even in high-input systems. A more explicit consideration of ecological processes would also benefit such high-input systems, thereby encouraging a more biodiversity-friendly agriculture. However major knowledge gaps remain with respect to the economic opportunities and consequences provided by ecosystem services (Bommarco *et al.*, 2012).

Agro-biodiversity

Agro-biodiversity is the product of long selection processes and different agricultural and cultural practices. Historically, agro-biodiversity has provided farmers with the opportunity to adapt to local environments and socio-economic requirements. However, genetic diversity, local varieties and minor crop species are being lost due to globalisation and the upscaling of farming systems that favour genetically-uniform, high-yielding varieties (FAO, 1999). Of the world's current food supply, 70% comes from just 12 plant and 5 animal species (FAO, 2010a). The genetic variety within these plant and animal species is also limited, as large areas are sown with only one or two varieties or there is dependence on a limited number of breeds. Genetic improvement has been the major factor in determining the current high productivity varieties.

Seeds and plant genetic resources - a basis for life



Source: FAO

Figure 3.2. Seeds and plant genetic resources development (FAO, 2014a).

Agro-biodiversity is preserved mainly in farming systems (in situ) or in gene banks (ex situ) (Figure 3.2). Natural areas are home to wild relatives of crops. In addition to agro-biodiversity, farmland biodiversity also exists, which provides space in and between fields for natural organisms that deliver ecosystem services such as pollination and biological control (MA, 2005).

Smallholders in particular contribute to agro-biodiversity, while also benefitting from it by cultivating plants that grow in infertile soils or are drought-resistant. These plants are cultivated alongside main staple crops. Another use of agro-biodiversity is the edible wild plants that serve as a dietary supplement to achieve a nutritious menu (FAO, 2010b).

Main impact of crop and livestock production through land use

The main impact of crop production on biodiversity is through land use (Table 3.1; Figure 3.3). The original vegetation is cleared and is replaced with cultivated crops, which generally results in a decrease in many originally-occurring species and an increase in some others. Often, species from elsewhere will settle to these areas. As a result biodiversity in terms of MSA drops to 10-30% on croplands. The impact on biodiversity largely depends on the intensity of use. A general tendency towards decreasing biodiversity with intensification is often noted (see for example (Alkemade *et al.*, 2009; Donald *et al.*, 2006; Reidsma *et al.*, 2006)). Livestock production also has a large effect on both terrestrial and aquatic biodiversity. Livestock production on vast rangelands will have limited or even a positive effect on biodiversity, depending on the intensity (Alkemade *et al.*, 2013). In the case of intensive livestock production, the impact of feed production is included in cropland use. Globally, about 30% of all crop production is being used as animal feed (FAO, 2006).

Table 3.1. Impact of various forms of food production on biodiversity.

Activity	Impact on terrestrial biodiversity	Impact on aquatic biodiversity	Benefits from ecosystem services [2]
Croplands	Land use / removal of vegetation, encroachment Emission of nutrients (N, P etc), pesticides Contribution to climate change Infrastructure	Leaching of N, P, pesticides Water use / changes in water management Soil erosion and sedimentation Introduction of invasive species	Primary production Nutrient cycling Water cycling Regulation of water, air and soil quality Pest and disease control Pollination
Grasslands	Land use / change of both plant and animal species composition, encroachment Contribution to climate change	Leaching of N, P Water use /changes in water management Soil erosion and sedimentation Introduction of invasive species	Primary production Nutrient cycling Water cycling Regulation of water, air and soil quality Pest and disease control Pollination
Intensive livestock production[1]	Emission of nutrients (N, P etc) Contribution to climate change	Leaching of nutrients (N, P etc)	Nutrient cycling Pest and disease control
Hunting, gathering and fishing	Change of both plant and animal species composition, encroachment	Changes in species composition	Primary production Water cycling Regulation of water, air and soil quality Pollination
Aquaculture	Land use, coastal areas	Conversion of wetlands and coastal zones Introduction of invasive species Emission of nutrients (N, P etc)	Primary production Nutrient cycling Pest and disease control

[1] The main impact of intensive livestock production is through feed production. This is captured under cropland and pastures.
[2] Often a selection as many ecosystem services are involved.

FAO data indicate that, over the last 10–15 years in sub-Saharan Africa, the deforested area is almost as large as the deforested area in South America. According to the same source, crop yields are not increasing very rapidly in sub-Saharan Africa. Increased cereal production is still roughly equally based on increased agricultural area and increased crop yields. In countries such as Uganda, Kenya, Tanzania, Ethiopia and Nigeria the population has doubled over the last 20–30 years, resulting in an increase in food demand.

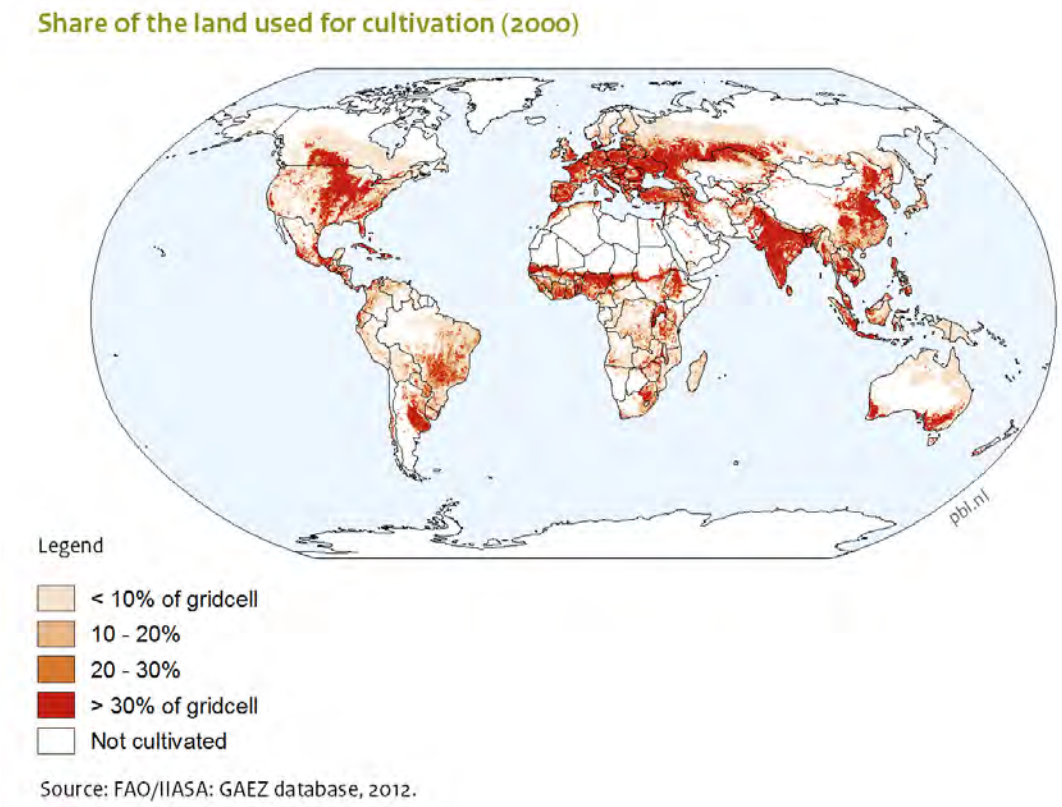


Figure 3.3. Share of the land used for cultivation (2000). Source: IIASA & FAO, 2012

Water use

Freshwater is, apart from land, the natural resource needed most for crops and livestock. Human water abstraction for agricultural production represents 70% of the global abstraction rivers, lakes and wetlands (de Fraiture & Wichelns, 2010). Whereas 20% of the cultivated land is under irrigation, this represents 40% of the global agricultural production (FAO, 2008). This water abstraction impacts biodiversity through water table depletion, salinisation and changing water regimes downstream. Verhoeven *et al.* (2006) show that 50% of the world's wetlands have been lost in the 20th century, mostly through conversion to agricultural land (see also Chapter 5).

Greenhouse gas emissions and impacts of climate change

It is estimated that food systems are responsible for about 25% of the total global greenhouse gas emissions (Vermeulen *et al.*, 2012). Major forms of greenhouse gas emissions are methane (mainly related to ruminants and rice production) and nitrous oxide. Nitrous oxide emissions mainly stem from the use of manure and nitrogen fertilizer. Carbon dioxide emissions are related to land use and land-use changes (often termed 'indirect emissions'), the use of fossil fuels in farm machinery, the transport of food and feed and refrigerating, and the production of fertilizers. The livestock sector is responsible for about 14.5% of the total greenhouse gas emissions (Gerber *et al.*, 2013). This includes not only direct emissions from the livestock sector, but also indirect emissions such as those related to feed production (including emissions related to deforestation), fertilizer manufacture and transport.

The impact of climate change on the food sector will make increasing food production while limiting the impacts on biodiversity even more challenging for at least three reasons: (i) climate change (leading to higher temperatures, different rainfall patterns and more extreme events such as droughts) is expected to affect crop production negatively, with regional differences (IPCC, 2014); (ii) climate change mitigation policies (often in combination with motives regarding energy security) are stimulating the cultivation of bio-energy crops which creates an extra pressure on land, and (iii) there is a pressure on agriculture (especially on the livestock sector) to reduce its own greenhouse gas emissions.

Nitrogen and phosphorus losses

While nitrogen, phosphorus and other nutrients are essential for plants and animals, losses of these nutrients have a large negative impact on both terrestrial and aquatic ecosystems (Galloway *et al.*, 2002; Galloway *et al.*, 2008; Rockstrom *et al.*, 2009). This impact is generally not recognised, and less-known to the general public. In lakes and coastal areas these nutrients can cause algae blooms and hypoxic zones (Diaz & Rosenberg, 2008). Nitrogen deposition can also lead to the disturbance of terrestrial ecosystems (Bobbink *et al.*, 2010). Terrestrial biodiversity is affected by nitrogen deposition which leads to eutrophication of terrestrial ecosystems (Alkemade *et al.*, 2009; Bobbink *et al.*, 2010; Dise *et al.*, 2011). Livestock is one of the main sources of ammonia, through emissions from stables and manure. Leaching of nitrogen and phosphorus to fresh water and consequently to coastal areas is mainly related to diffuse pollution from agricultural land. This diffuse pollution is generally correlated with the overuse of manure and fertilizers. In some cases, direct emissions to rivers occur from livestock operations. As the global livestock production is expected to increase, so are the losses of nutrients from this sector (Bouwman *et al.*, 2011).

Land degradation one of the main threats to food production

The degradation of agricultural land leads to areas permanently lost on the one hand and declining yields over vast areas on the other. Typical examples of land degradation are salinisation of irrigated land, overgrazing of rangelands, loss of top soil, soil organic carbon and water holding capacity, depletion of nutrients, and eventually loss of soil fertility. Underlying causes of land degradation include poverty, issues regarding property rights and a lack of knowledge on appropriate management. It should be noted that land degradation is currently masked by certain management practises, for example a high use of mineral fertilizers or soil tillage operations.

Displacement of effects on biodiversity

One of the difficulties in determining the exact effect of a certain food product or production system on biodiversity is that food production causes not only in situ (local) effects, but also effects elsewhere, through partly coupled commodity and land markets. For example, if production in an area with currently high yields is reduced and natural elements are reintroduced (a ‘land sharing approach’), this will most likely lead to an increase in biodiversity at that location. Assuming no change in food demand, this will require more food production elsewhere, which may lead to deforestation, possibly resulting in a net loss of biodiversity (Phalan *et al.*, 2011). This mechanism is comparable with ‘indirect land use changes’ related to biofuel production (Searchinger *et al.*, 2008).

Figure 3.4 summarises the current and projected contribution of the different pressures from the food, biofuel and natural fibre sector on biodiversity loss at the global level. It shows that most pressure is from the use of land for crop production (including feed production).

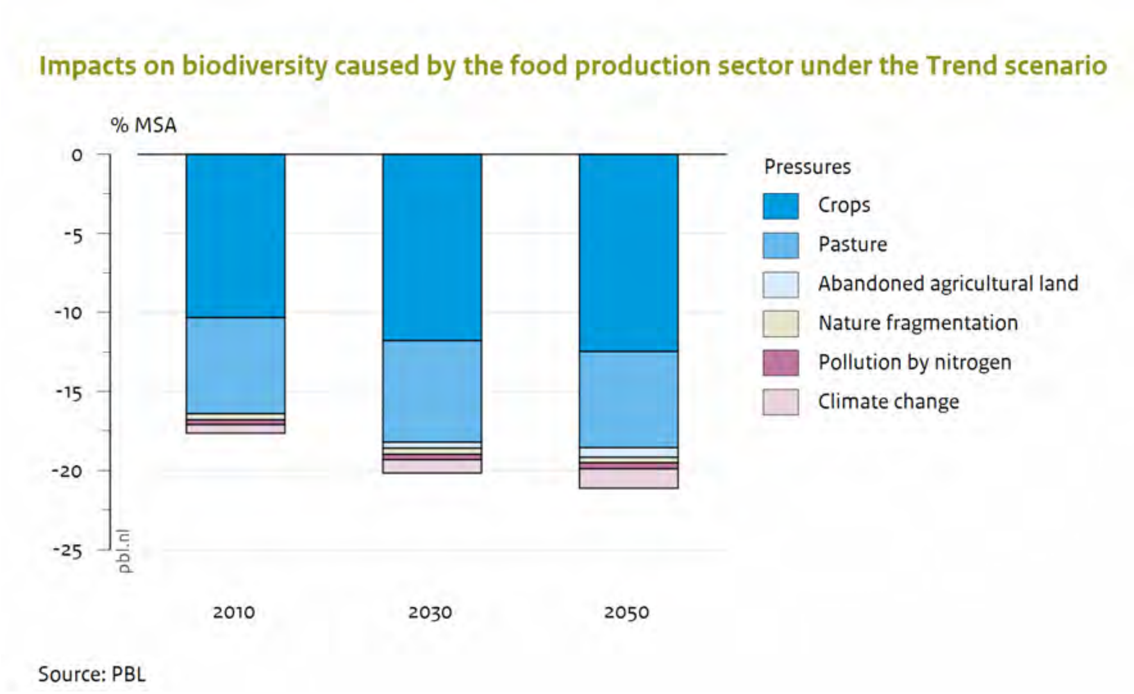


Figure 3.4. Impacts on biodiversity from the food production sector under the trend scenario.

3.4 What is the food sector already doing in favour of biodiversity?

As illustrated in Section 3.2, the food sector is very diverse. The large number of actors is one of the complicating factors in assessing what different actors are already doing in favour of biodiversity. A second factor is the huge diversity in farms, as well as in the way the rest of the food system is organised. A third complicating factor is that food production not only directly affects in situ (local) biodiversity (where the food is being produced), but also indirectly through indirect land use and land-use changes. This global effect on biodiversity can be mitigated by actions such as increasing yield per unit area and reducing food waste and losses, although very often such actions are not registered as implemented for the purpose of biodiversity. Finally, the effect on biodiversity is difficult to monitor as it is a multifaceted and multi-layered concept. Individual biophysical options to increase local and especially global biodiversity generally have a relatively small effect, implying that every minor improvement counts, and that the combination of options on the supply and demand side is imperative. There are as yet no breakthrough technologies available, such as renewable energy for the mitigation of greenhouse gas emissions for example (PBL, 2012).

Bio-physical improvements in the various food system activities

A list of bio-physical improvements to reduce the impact of food production on local and global biodiversity is presented in Table 3.2. On the supply (production) side, three main directions have been distinguished: (i) reduce pressure on global land use; (ii) reduce losses and emissions, and (iii) improve local biodiversity and land and water management. On the demand side, reducing food losses and the lower consumption of meat, dairy and fish are major routes.

These improvements with regard to the impact on biodiversity should be considered with the general global trend in mind, in other words the increased pressure on biodiversity caused by the food sector at large. This is mainly due to the population increase and a shift in diet towards the higher consumption of meat, dairy, fish, fruit and vegetables – products that generally require more natural resources. On the production side, the proportion of large farms in agricultural production is still increasing, with commonly negative impacts on local biodiversity, for example due to the removal of landscape elements (Tscharntke *et al.*, 2012; Tscharntke *et al.*, 2005).

Table 3.2. Improvements in various food system activities.

	Supply side options			Demand side options
Main direction	**Increase crop and grassland yields and feed efficiency**	**Reduce nutrient and pesticide losses and greenhouse gas emissions**	**Stimulate local farmland biodiversity, improve land and water management**	**Reduce food losses and waste, lower consumption of meat, dairy, fish**
General goal / effect	Reduce pressure on global land use	Reduce impact on terrestrial and aquatic ecosystems	Improve local biodiversity and functioning of ecosystem services, reduce water use	Reduce pressure on global land use / marine resources
Food system actor **Farmers, ranging from smallholder farms to large industrial farms**	Sustainable intensification with judicial use of inputs such as fertilizers, improved rotations, improved storage, improved grassland management	Precision farming techniques, better integration of crop and livestock systems, integrated pest management	Many options available: improved land and water management, improved water-use efficiency, agroforestry, mixed cropping, integration of natural vegetation, seed exchange network, redesign farming system; organic farming	-
Producer of agricultural inputs	Develop robust disease-resistant breeds, drought-resistant seeds Improve farming techniques Develop more targeted, less harmful pesticides Feed companies shift to raw materials that compete less with food production; more productive and yet robust animal breeds	Develop less harmful pesticides, improve fertilizers, develop improved farming techniques	Improve local seeds and breeds, develop precision farming techniques	Develop fruit and vegetables with longer shelf life; reduce food losses
Food producing, processing and trading companies	Improve storage, reuse of food wastes and losses as food, feed or fuel			Better packaging, storing, distribution, reduction of food waste Development of meat substitutes
Retailers, restaurants and other food services and consumers				Choice editing towards less demanding products, reduce food waste
Mainly covered in pathway	*Global Technology*	*All*	*Decentralised Solutions*	*Consumption Change*

Farmers

Farmers around the world generally aim to increase crop and livestock productivity, as this is often aligned with economic and social motives. Over the last decades, crop yields have steadily increased, although for certain crops and regions yield increases have levelled off (Ray *et al.*, 2013). Wheat and rice yields are decreasing in parts of India, but also in other areas crop yields are hardly increasing. There is a huge difference in crops yields between regions. In low-income regions in particular, there is a large gap between actual and potential crop yields. This is mainly related to the lack of access to markets, inputs and capital, combined with a lack of access to the best agronomic practices and technologies. This is generally caused by a lack of good road infrastructure, lack of knowledge transfer and training, governmental regulation and barriers in trade agreements. By increasing the output of crop and livestock products per hectare, improvements in food security and natural area protection could be combined. Important preconditions are that this is done in an environmentally-friendly way (‘sustainable intensification’) and in such a way that it enhances the socio-economic position of smallholder farms and contributes to poverty alleviation in general (FAO, 2011). In Africa, progress has been made in recent years to implement this approach. In 2003, many African countries agreed to allocate 10% of their national budgets to the agricultural sector as part of the Comprehensive Africa Agriculture Development Programme (CAADP). Agricultural sector spending increased, on average, by more than 7% annually between 2003 and 2010 (IFPRI, 2013) and a number of countries met the 10% goal. Within the concept of sustainable intensification, aspects like biological pest control and the judicious use of mineral fertilizer (in combination with organic soil amendments) were strongly promoted. In many Asian countries too, the focus has shifted to combining good crop yields with lower environmental impacts and sparing biodiversity. An example is the cooperation of farmers and researchers in Iran to breed new crop varieties from old landraces and modern cultivars and to use mixtures instead of one variety (Doornbos, 2014).

More recently, especially in low-income regions, programmes have been implemented to reduce post-harvest losses, as currently quite a large share of food is lost during storage, either due to a lack of good storage facilities or due to the absence of a good road infrastructure to transport the harvest to cities (Gustavsson *et al.*, 2011).

Various actions have also been taken to reduce nutrient losses and pesticide use. Over the last 20 years, farmers – especially in richer countries – have reduced nutrient losses to the environment, often in response to governmental policies. For example, the use of nitrogen fertilizers has been reduced by around 20% in the EU. Due to stricter authorisation policies and the implementation of Integrated Pest Management (IPM) or similar techniques, the use of hazardous pesticides and consequent environmental burden has been reduced in several European countries (MIRA, 2010; Strassmeyer & Gutsche, 2010; Van Eerdt *et al.*, 2007). The mean reason for this success was not the environmental benefits of IPM, but the fact that IPM was often cheaper and more effective than regular pesticide use (IAASTD, 2009). In recent years, actions to reduce pesticide use have also been taken outside the developed world, for example in Vietnam where farmers who use less pesticides obtained yield gains and lower costs (Normile, 2013).

When it comes to sustainable land and water management and the promotion of local biodiversity, farmers have deployed many actions. Examples of these are the maintenance, and sometimes creation, of landscape elements, buffer strips and field margins. Landscape elements can reduce soil erosion caused by water and wind, improve the micro-climate and offer shelter to wildlife, including pollinators (for example bees) and predators of insects and rodents that might affect crops. Farmers sometimes create flower-rich buffer strips to stimulate ‘functional agro-biodiversity’. It should be noted, however, that in many regions around the world, landscape elements are still disappearing or are not well-maintained, to increase short-term profits. For this reason, governments in the US and Europe have introduced agri-environmental schemes (AES) to promote farmland biodiversity. AES is administered through the Conservation Titles of the Farm Bills in the US and Pillar 2 of the Common Agricultural Policy (CAP) in the EU. Farmers are compensated by transfers of public funds to reduce the negative externalities of agricultural production and thus increase agro-biodiversity (Baylis *et al.*, 2008).

In China, the US and Europe, there are also national programmes on sustainable land and water management. China introduced the Sloping and Land Conservation Program (SLCP), which aims to convert 14.67 million hectares of cropland to forest. Farmers are compensated in kind (grains) and in cash. The contracts vary depending on the type of conversion (grass for two years, economic forest for five years and ecological forest for eight years). The success of the SLCP differs across regions (Song *et al.*, 2013). Other examples of sustainable land and water management are efforts to increase water-use efficiency, especially in irrigated areas. The proper management of grazing areas has also gained more attention in recent years. In developing countries in particular, this might not only contribute to productivity and livelihoods, but also to carbon sequestration, water service protection and biodiversity conservation.

Organic farming is another route to increase on-farm biodiversity and reduce the use of pesticides. Globally, less than 1% of all farmland is farmed organically according to the official standards (FIBL, 2014). In practise, larger areas are implicitly farmed according to organic production standards. Especially in regions with high average yields, organic farming leads to yields that are 20–30% lower compared with conventional agricultural practises (de Ponti *et al.*, 2012; Seufert *et al.*, 2012). This increases the area needed for food production, unless consumers simultaneously change their diets when shifting to organic products.

In general, farmers can adopt better management practises through improvements in enabling conditions such as education and good access to knowledge, markets and finance, technological improvements, environmental legislation or support from other actors in the food system.

A case from Brazil illustrates the impact of legislation, its implementation and access to credit on farmers' decisions and practices. With the adoption of a new policy resolution in 2008, the granting of rural credit in the Amazon biome became subject to proof of compliance with legal environmental regulations. This resolution affected farmers' production decisions and facilitated the channelling of finance into practices that reduced deforestation (Assunção *et al.*, 2013). Certification schemes can also play a role in enabling farmers to adopt better production and management practices. The effects of certification schemes vary across locations and products. However, evidence suggests that – with the right conditions and support – certification schemes can create opportunities for farmers to employ better production practices (Lemeilleur, 2013). Governments can also assist farmers through agri-environmental schemes to promote farmland biodiversity or payment for ecosystem services (PES).

Agricultural input producers

Seed producers have an important role to play in increasing crop productivity and preserving genetic diversity (agro-biodiversity). However, the focus on production increase often leads to a narrowing of the genetic base of plant and animal production. Crop productivity increases are important for food security and for reducing land and water use for agriculture. Over the last decades, several crop varieties that are more resistant to certain pests and diseases have been developed, which has helped reduce the amount of pesticides used. After a number of years, viruses or insects often adapt, so continuous development of new varieties is necessary. Some of these crops are genetically modified (e.g. Bt crops contain genes from a bacteria and therefore produce a crystal protein that is toxic to many pest insects). This is however a controversial technology, with strong supporters and opponents (IAASTD, 2009).

As most seed producers and animal breeders are commercial farms, the focus is on species and regions with good market opportunities, so that crops and animal breeds that are relevant to low-income countries are often neglected. For example, seed producing companies have taken initiatives to stimulate biodiversity, such as 'Operation Pollinator', which is an international initiative to restore natural habitats and food sources to revive the fortunes of the bumblebee. In addition to the work of seed companies, there are farmers who develop seed exchange networks at a local scale to adapt their own selections to local needs and decisions. This type of dynamic in situ conservation maintains a genetic agro-biodiversity that adapts to environmental changes such as climate change (Pautasso *et al.*, 2013).

Food processing and trading, retail and food service companies

In a direct sense, neither food processing and trading companies nor retailers have a large effect on biodiversity. However, food companies, retailers and other companies have a pivotal role in linking production and consumption and are in a position to both improve production practices and influence consumption patterns.

Many actions have already been undertaken to reduce food waste and losses, as this generally is in line with economic motives. Examples are improved storage and packaging.

Many large food producing, processing and trading companies have indeed identified biodiversity (including aspects such as deforestation) as a serious topic over the last ten years, sometimes as a result of campaigns by NGOs. Resource scarcity and the need to guarantee a continued and safe supply of basic commodities at reasonable prices are other important motives, especially for food processing companies. This has resulted in a number of initiatives, both within companies as well as the concerted actions of groups of companies in cooperation with governments and NGOs. One example is the emergence of the international 'round tables' for a number of commodities such as soy, palm oil, cacao, fish, beef, coffee and aquaculture. In the round tables, private sector companies in the food chain, private investors and banks and NGOs work together to achieve sustainable production in the food chain and to reduce biodiversity loss. The round tables have introduced certifications and accreditation systems for products and services throughout the food production chain. These schemes have only been operational for a few years and have probably not yet reached their full potential as reaching an agreement on the criteria within the round tables can be a lengthy process. Moreover, not all individual members of these round tables have accepted the certification criteria yet. The certification and standards differ across the round tables (PBL, 2014).

In addition to the round tables, companies in the food processing industry also actively initiate pilot projects to promote sustainable farming amongst farmers in their value chain. This is especially true for developing countries, where companies support smallholder farmers through the diffusion of knowledge on sustainable farming and the relevance of biodiversity. Food processing companies also provide financial support when reducing biodiversity loss leads to revenue losses.

Another approach is the pre-competitive cooperation between companies. Examples are the Sustainable Agricultural Initiative (SAI) Platform, which supports the development of sustainable agriculture worldwide, and The Sustainability Consortium (TSC), which designs science-based measurement and reporting systems.

Smallholder farms or sectors in developing countries are involved in pilot projects to enhance production and reduce biodiversity loss. Large agricultural input producers and food processing companies also support pilot projects in developing countries to improve productivity, such as Water Efficient Maize for Africa, and Sustainable Harvest – Agriculture, Resources, Environment (SHARE) in India. In addition, there has been an increasing number of similar initiatives without the interference of large companies, such as the 'La Via Campesina' movement. This movement promotes small-scale sustainable agriculture and opposes corporate-driven agriculture.

In developed countries, governments encourage corporate social responsibility (CSR) in international companies, including the impact on the environment and livelihoods. An increasing number of private sector companies in the food sector are incorporating sustainability goals in their company strategy. Sustainability is either becoming part of the CSR or companies are composing separate sustainability objectives.

Consumers

There are three main options available to consumers. The two biophysical options are to reduce food waste and dietary changes towards a lower consumption of animal products. The third route lies in purchasing behaviour, by preferring for example certified products or products from companies with a good reputation.

Reducing food losses is currently high on the agenda, and retail and food service companies and consumers are playing an important role. The potential to reduce food waste is quite large, and in some countries actions to reduce food waste have already resulted in large reductions. For example, avoidable household food waste was cut by 21% between 2007 and 2012 in the UK (WRAP, 2013). Pilot projects among informed consumers in the Netherlands also easily achieved a waste reduction of 20% (PBL, 2013).

Companies, governments and NGOs are campaigning to reduce food losses (e.g. FAO Save Food, Damn Food Waste). Currently, food losses have been estimated at roughly one-third of global production, which is about 1.3 billion tonnes a year (Gustavsson *et al.*, 2011). The highest waste per capita occurs at the end of the food chain (at the retail and consumption stage) in North America (estimated at 115 kg/year/capita), which is almost 20 times higher than in sub-Saharan Africa (estimated at 6 kg/year/capita). Most losses at the production to retailing stage occur in developing regions. Roots and tubers are especially vulnerable at this stage. Where future food security is based to a large extent on an increased production of roots and tubers, a solution to the problem of waste reduction is urgently needed.

Modern consumption patterns have a significant impact on the environment as the growing middle class in the world (especially in emerging economies) is consuming more and more (see UNEP, 2012). A shift to more sustainable consumption and production patterns has therefore been adopted by the UN. The retail sector plays a very important role as the most crucial link between suppliers and consumers in effecting this global shift, but in general only limited actions have been taken by both retailers and consumers to reduce the consumption of meat, dairy and fish.

Over the last ten years, some consumers have become aware of the environmental impacts of their food choices, leading to initiatives such as ‘Meat-free Monday’ and other similar initiatives (such as that supported by the city of Ghent in Belgium on Thursdays). In general, retailers have been very hesitant to influence consumer behaviour.

Cross-chain initiatives

In developing countries, the Sustainable Agriculture Network (SAN) – a coalition of leading conservation NGOs – promotes efficient and productive agriculture, biodiversity conservation and sustainable community development by creating social and environmental standards. SAN links responsible farmers with conscientious consumers by means of the Rainforest Alliance Certified seal of approval. SAN develops, manages and owns the Sustainable Agriculture Standards, but also provides training courses on good agricultural practices. This Rainforest Alliance certification and training is applied to producers of cattle, coffee, cacao, ferns and cut flowers, fruit, palm oil and tea in developing countries. SAN promotes the consumption of certified products in developed countries. In Kenya, for instance, the Kenya Tea Development Agency (KTDA) launched a sustainable agriculture project together with Rainforest Alliance and Unilever. KTDA initiated schooling and certification for tea production for smallholder tea growers. The evaluation of the training and certification showed improved knowledge on good agricultural practice, productivity and income (Waarts *et al.*, 2013). In developed countries, NGOs are promoting biodiversity in various ways, by lobbying governments and industry, by campaigning, and by supporting various initiatives to more directly influence famer practises.

Barriers and levers

When reviewing recent initiatives in the food sector as a whole, a number of barriers emerge, as well as some important levers.

One major barrier is the very large number of actors, with not only over one billion people active in farming, but also seven billion consumers (Figure 3.1). Even the intermediate actors, such as food companies, retailers and restaurants are large in number, especially in low-income regions where the consolidation process (towards fewer actors) is still on-going (Reardon *et al.*, 2012). A second barrier is the tension between short-term gains and long-term interests. Many subsistence farmers literally depend on the next yield, while commercial farmers in richer countries are usually operating in a competitive setting, with strict financial obligations to meet.

Furthermore, farmers in low-income countries do not have access to technologies, knowledge and inputs, due to barriers such as government regulation, trade agreements, insecure property rights, lack of infrastructure and training. Finally, payments for ecosystem services are not widely applied, because they require clear definitions and measurable ecosystems and good institutional governance settings. The success of PES systems depends on the regional circumstances, even in the case of systems implemented at national level.

Considering the input industry, the main barriers are the conflicts of interest between seed and pesticides producing companies and biodiversity objectives. Both the seed market and the chemical fertilizer market is dominated by a limited number of firms. Another barrier might be issues relating to Intellectual Property Rights (IPR). Although IPR protect the diversity of seeds, they can also limit the spreading of seeds with properties favourable for biodiversity conservation. This is especially true for smallholders who cannot afford to pay for the use of the IPR protected seeds. Consequently, the distribution of the ‘favourable’ seeds is limited. Also, farmers lack knowledge on the potential of agro-biodiversity (Tscharntke *et al.*, 2012). Finally, the first priority of companies is usually to maximise profit, which might conflict with consumer efforts to reduce food waste and decrease consumption.

On the other hand, there are also relevant levers for change. Many farmers are willing to change their production practises, provided that they are enabled to do so. This could for example take place through knowledge transfer, financial motives or better established property rights. Many food companies and retailers are already active, for example because they are worried about the continuity of their supply, or their public image. What is often needed is a better coordination of actions, also to prevent too high transaction costs. Pre-competitive cooperation between companies could be a useful way forward. Companies are joining forces to track and analyse data about the environmental impact of their global production networks (O'Rourke, 2014).

Finally, many instruments are in the hand of governments. These may be financial instruments such as better targeting of subsidies, abolishment of distorting subsidies and import tariffs and investments in research and knowledge infrastructure. Rural infrastructure and education are very important in low-income countries.

3.5 What are the long term options?

The Trend scenario projects a global biodiversity loss of more than 9% MSA compared with 2010, with the largest loss of almost 15% in sub-Saharan Africa, at the expense of tropical ecosystems. This section describes the potential contribution of the food sector to limit the loss of biodiversity along the three pathways introduced in Section 2.5. Each of the three pathways arrives at a reduced biodiversity loss of 65% MSA by 2050, reducing projected biodiversity loss by half compared with the Trend scenario (Figure 3.5), and attaining Aichi Target 5 (halving or even halting further loss of nature areas) and Target 11 (protected area expansion and management, see Figure 2.20). The three different pathways achieve these targets along different routes, with important roles for consumption change and increase in agricultural productivity. It is important to note, however, that the target is set at a global level. The loss in certain regions or biomes might be higher, which also depends on the pathway (Figure 3.6).

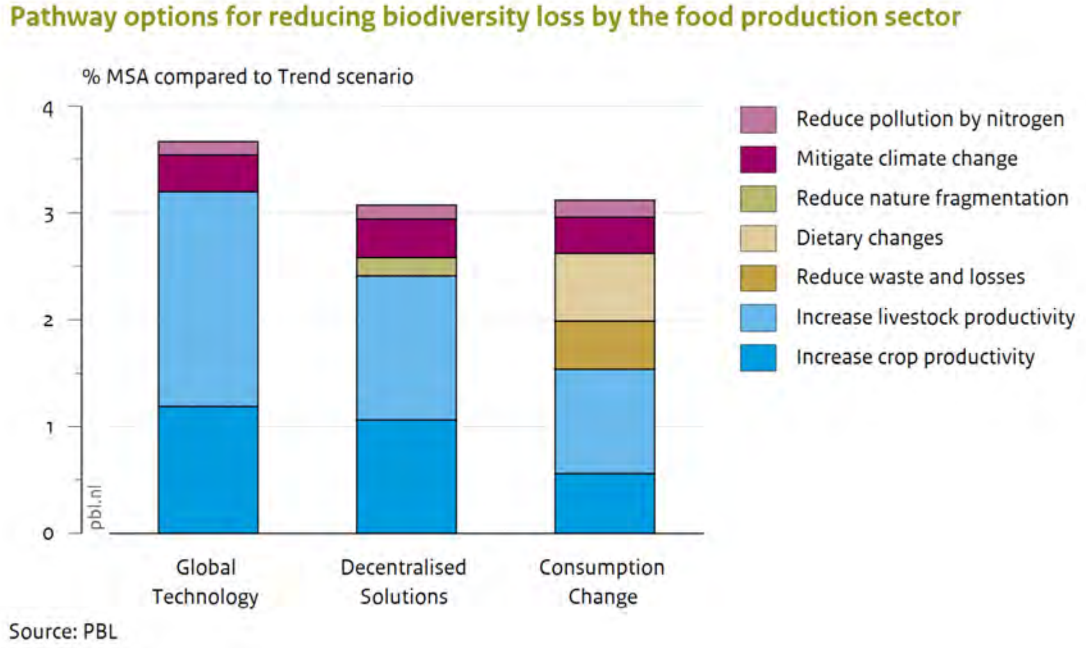


Figure 3.5. Different pathways to prevent global biodiversity loss by the food production sector.

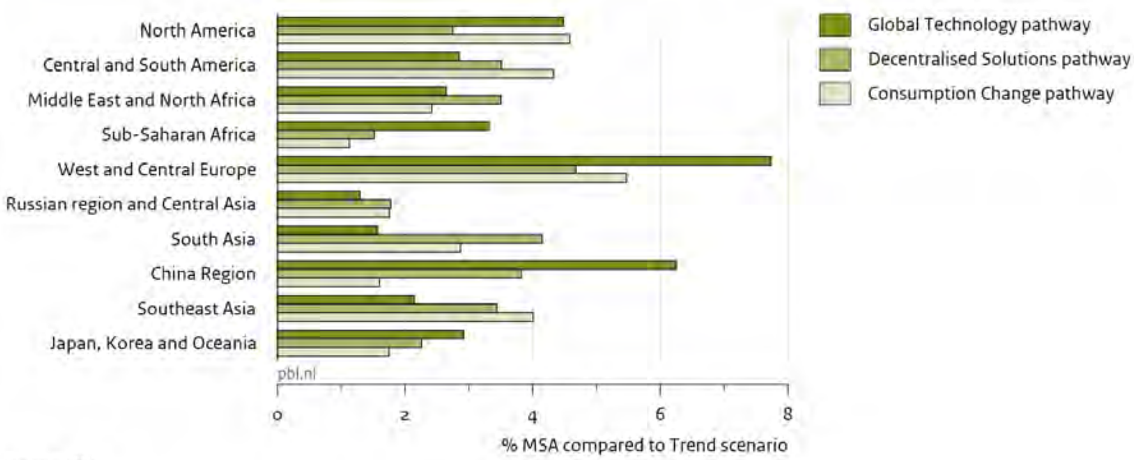
The Global Technology pathway puts emphasis on increasing yields in large-scale agri-technological landscapes and strictly separating land-use functions (Table 3.3). The result is a reduced total claim on land compared with the Trend scenario due to higher productivity on less land, and therefore providing opportunities for effective conservation of remaining nature areas. Policies on the protection of natural land are often needed to avoid alternative use of land. Low external environmental impacts (including preservation of soil carbon) would be achieved thanks to a strong emphasis on resource efficiency through technological improvements, agronomic optimisation of the farm environment and animal breeds and crop varieties that perform best under these optimised conditions. Examples are precision irrigation, combining drip irrigation with decision support systems using remote sensing to help farmers withdraw only the necessary amount of water for crops, avoiding waste water and competition of weeds, and pollination and biological control of pests performed by insects in greenhouses. It should be stressed that in many regions, an increase in productivity can be achieved using current technologies. In the pathway, a decrease in biodiversity and ecosystem services is expected in the monotonic agricultural landscapes due to increased land-use intensity and a lack of refuge for species. In addition, the remaining nature areas, although large, will be separated by large agricultural landscapes, reducing connectivity between natural areas.

Table 3.3. The design of the future pathways for the food system (PBL, 2012).

	Trend	Global Technology	Decentralised Solutions	Consumption Change
Access to food	Inequality in access to food still exists due to income inequality	Same as Trend	Inequality in access to food due to income inequality converges to zero by 2050	Inequality in access to food due to income inequality converges to zero by 2050
Trade	Development towards abolishment of trade barriers	Full liberalisation of trade in agricultural products	Same as Trend	Same as Trend
Consumption	Continued increase in food consumption with saturation at high income levels; share of animal products in diet also continues to increase	Same as Trend	Same as Trend	Meat consumption per capita levels off at twice the consumption level suggested by a supposedly healthy diet (Stehfest *et al.*, 2009)
Waste	Continuation of current situation	Same as Trend	Same as Trend	Waste reduced by 50% (15% of production)
Agricultural productivity	Increase due to growth in agricultural production (global average yield increase) and area expansion	In all regions, 30% increase in crop yields and 15% increase in livestock \`yields\` by 2050, compared with Trend	In all regions, 20% increase in crop yields and 15% increase in livestock \`yields\` by 2050, with least possible impacts on biodiversity	In all regions, 15% increase in crop yields by 2050, compared with Trend
Allocation of agriculture/ Nature	Large regional differences. Shift towards large-scale production; smallholders still comprise majority of production systems in sub-Saharan Africa, Southeast Asia, China region.	Agriculture highly concentrated to retain highly distinct land functions	Production area shared with nature elements to reinforce an ecological network, environmentally-friendly production; keep at least 30% of the landscape as nature elements	Same as Trend

The agricultural productivity increases would reduce the area for crops by 250 million ha compared with the Trend scenario, especially in the industrialised countries and China and, to a lesser extent, in sub-Saharan Africa. Highly intensive and concentrated production limits agricultural expansion in the Global Technology pathway, which results in higher MSA values compared with those under the Trend scenario, especially in regions with large nature areas (e.g. the Congo basin). Whereas the Trend scenario leads to a biodiversity loss of 9.4%, Global Technology shows a smaller loss of 5.1%, implying an avoided loss of 4.3%. In regions with low or negative population growth, increasing productivity leads to a net decrease in crop area resulting in a net positive effect on biodiversity compared with the current situation (Figure 3.6).

Reduced biodiversity loss per region, caused by the food production sector



Source: PBL

Figure 3.6. Options for preventing biodiversity loss by the food production.

Decentralised Solutions describes a pathway towards more ecologically-oriented agriculture where technology is adapted to smaller-scale agriculture. It provides innovative ecological solutions (often labeled as ecological intensification) that combine technological advances and ecosystem services (Pretty *et al.*, 2011; Tittonell, 2013). Crop yields and livestock efficiency is 20% higher than under the Trend scenario. Ecosystem services as carbon sequestration – promoted in organic agriculture – improve soil quality and water and nutrient retention and help mitigate climate change. Other examples of ecological solutions are intercropping, agroforestry and the use of set-aside land for pollination and pest control. These forms of agriculture can result in mosaic landscapes, consisting of a mixture of agricultural land and a greater proportion of natural elements. The increased focus on harnessing ecosystem services prevents overexploitation and, therefore, land degradation (Pereira *et al.*, 2005; Reyers *et al.*, 2009). The consequences are manifold, including 1) a slightly lower production intensity and related larger claim on land compared with the Global Technology pathway, 2) an increase in biodiversity and ecosystem services in agricultural fields and surrounding areas, or, for example, river streams influenced by them, 3) reduced negative effects of fragmentation on remaining nature areas since natural elements within agricultural fields form corridors and stepping stones for species, and 4) reduced nutrient emissions.

In the Decentralised Solutions pathway, the avoided biodiversity loss (4.7%) is the result of a higher MSA of agricultural land compensating for the crop area that is larger than under the Trend scenario. Compared with the Trend scenario, the MSA increases, mostly in the present monoculture landscapes of Europe and South and Central America and in highly-populated areas with large crop areas such as South Asia (Figure 3.6).

In the Consumption Change pathway, there is a reduced demand for agricultural products. The entry points to reduce demand are reduced meat and dairy consumption and reduced food losses. The consumption of animal food products has a greater environmental impact than that of plant-based protein-rich products (PBL, 2011) as only 10% to 30% of animal feed is ultimately converted into edible livestock products. Therefore, reducing the consumption of meat, dairy and eggs would technically be one of the most efficient options for reducing total crop production demand. The starting point of the Consumption Change pathway is a diet with less meat consumption, based on dietary recommendations by the Harvard Medical School for Public Health (the Willett diet). The main characteristic of this diet is the low beef and pork intake, resulting in 10 g beef, 10 g pork and 46.6 g chicken meat and eggs per person per day

(Stehfest *et al.*, 2009; Willett, 2001). In most regions, the average per-capita consumption of meat and eggs is far above the Willett diet. From 2050 onwards, the Consumption Change pathway assumes a maximum per-capita intake of twice the Willett diet level in regions that are currently over, or are projected to pass this threshold. Applying this reduces meat and egg consumption compared with the Trend scenario in many regions, except for Africa and some Asian regions (Figure 3.7).

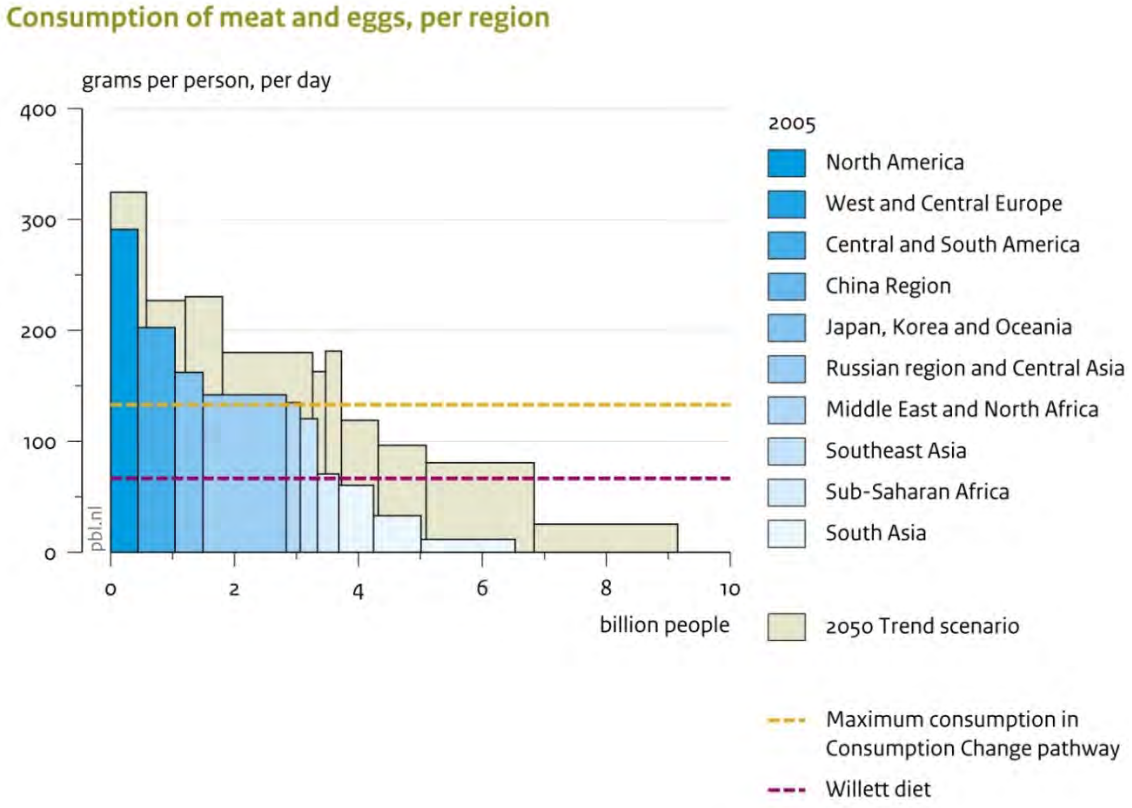


Figure 3.7. Global consumption of meat and eggs by region compared with the Willett diet and the maximum consumption in the Consumption Change pathway.

The second main option is to reduce food losses and food waste. Food losses are currently estimated at roughly one third of global production, which is about 1.3 billion tonnes a year (Gustavsson *et al.*, 2011). The highest waste per capita occurs at the end of the food chain (at the retail and consumption stage) in North America (estimated at 115 kg/year/capita). In developing regions, most losses occur at the production to retailing stage. The Consumption Change pathway assumes a reduction of 50% in food waste and losses (equaling 15% of the production) by either creating consumer awareness or improving storage, infrastructure and market conditions.

The Consumption Change pathway has the greatest effect in the Americas and Europe, where pasture areas in particular will decrease by almost 40%. The MSA gain from the food sector alone ranges from 5.5% to 6% in these regions (Figure 3.6). At a global scale, 9% of pasture land is spared, resulting in 1% avoided loss of MSA. This pathway also significantly decreases N and P emissions, thus reducing the impact on aquatic biodiversity.

Comparison between pathways

All three pathways offer sufficient options to halt further biodiversity loss in 2050. A combination of pathways might result in larger gains for biodiversity. However, substantial efforts will be needed to fulfil the conditions underlying these pathways. A new, more effective approach to sustainable food, fuel and natural fibre production should be based on a shared vision with long-term goals and consistent short-term targets, combining strengthened government actions with those of civil and corporate actors worldwide. The paragraphs below describe some of the challenges for the food sector related to the three pathways.

In the developed regions of the world where population growth is limited, the crops and livestock sector is by far the most important actor for reducing biodiversity loss in all three pathways (Figure 3.5). Here, agricultural productivity is already high. Therefore, a yield improvement under the Global Technology pathway of the same magnitude as reached in the past 20 years (1.3%) will be challenging, especially when the latest FAO outlook (FAO, 2012b) projects an annual 0.67% increase for the period 2006–2050 (Figure 3.8).

The opportunities for developing countries to reach the productivity assumptions in the pathways are much better. However, innovative solutions will be needed to reach this productivity growth without negative effects on the environment in those regions with low soil fertility common in the tropics.

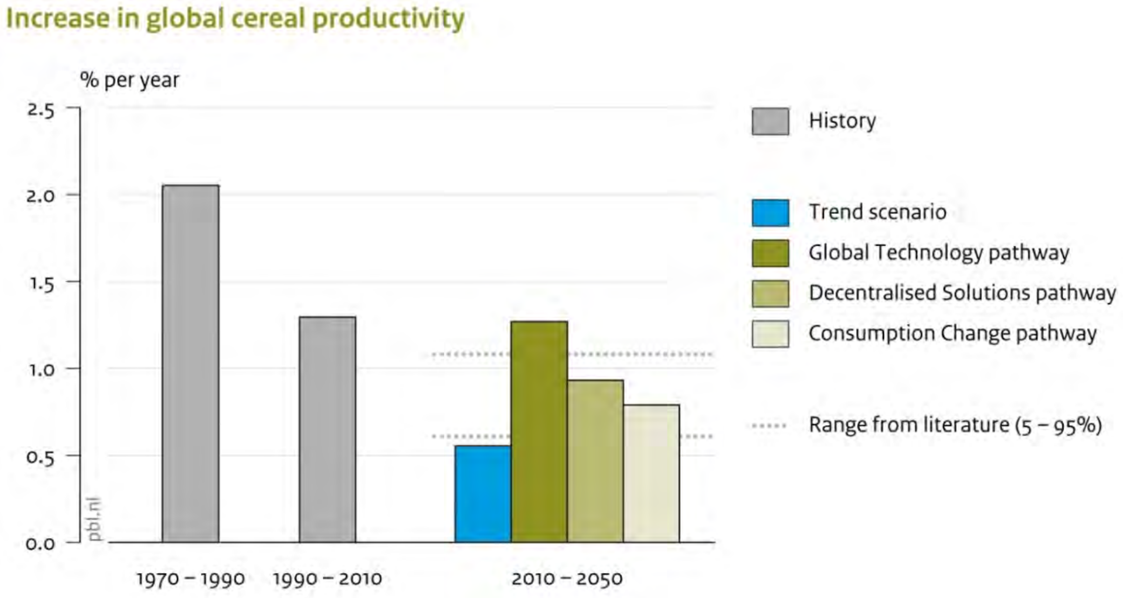

Increase in global cereal productivity

Figure 3.8. Cereal productivity growth under the Trend scenario and the pathways (PBL, 2012).

The agricultural areas in the Global Technology pathway risk losing part of their refuge functions and regeneration capacity, thereby putting adaptation to climate change at risk.

In Decentralised Solutions, the productivity increase will largely be achieved through ecological solutions. In the currently intensively-managed landscapes of the United States and Europe, remnants of biodiversity are relatively scarce, putting ecological solutions at risk. This pathway therefore requires a profound change in these intensive farming systems. Time and investment will be needed to improve degraded ecosystem services. Moreover, the current globalised system challenges the resilience of agro-ecosystems by spreading invasive pests and diseases. The evidence for compatibility between an agricultural production goal and reduced pest problems by the conservation of biological enemy density is still scarce. More theoretical and empirical work is needed to study functional redundancy and niche complementarity in biological control (Straub *et al.*, 2008). This knowledge is needed for the design of new agricultural systems that combine ecological resilience with efficient technologies. This is important because most of the currently-known ecological solutions are labour-intensive, while people increasingly want to avoid labour-intensive agricultural practices.

The option of the sustainable sourcing of tropical commodities by developing countries and international companies has shown success, and offers opportunities for raising knowledge, capacity and investments in sustainable production in tropical regions. Sales of certified products such as coffee and fish have rapidly increased in Europe since 2000. However, the global supply of sustainable commodities is larger than the current demand and consumer awareness of the environmental impact of imported commodities is still low in emerging economies (PBL, 2014). Agreement on sustainability criteria appears to be a lengthy process and few public reports exist on the positive effects of sustainable sourcing.

Diminishing the consumption footprint (measure of demand of consumption on natural resources) is especially promising in the affluent regions. In these regions, the footprint can be reduced by 30% by reducing food waste and the consumption of livestock products (PBL, 2013; Westhoek *et al.*, 2014). Such a consumption change is not only helpful for biodiversity protection, but also improves human health. However, companies and governments are currently not very keen on raising consumer awareness and even less on restrictive behavioural changes. Higher consumer awareness is also needed to reduce food losses.

3.6 Priority actions to further reduce biodiversity loss

As summarised in Section 3.4, there are many opportunities as well as barriers for farmers, governments and other actors in the food value chain to take action to reduce biodiversity loss. However, current efforts are still insufficient to meet the biodiversity goals. The pathways discussed in Section 3.5 provide insights into what may be needed to make this happen. As individual options such as crop and livestock yield improvements, stimulating farmland biodiversity and the better functioning of ecosystem services and changes in consumption all have a limited effect, the best result will come from a combination of actions.

Not all actions are sensible and feasible everywhere, so they need to be tailored to local conditions and the local context. Two archetype situations can be distinguished, being regions characterized by high yield gaps between the actual and potential yields, versus regions where yields are close to the maximum attainable. The latter regions are certainly not only to be found in high income countries, but also in many emerging regions. In the regions with high yield gaps sustainable intensification of crop and livestock production has to largest potential to stimulate biodiversity, while in intensively-farmed areas the ‘ecologisation’ of agriculture and a reduction in food losses and waste and a change in diet generally have the largest potential. Of course, this distinction between regions with current low versus high crop yields is an oversimplification, and many regions will be in between these two poles.

The key question is, how can the various actions be achieved? Within the context of this report, only general directions can be presented, and it should be noted that many actions are site-specific, and that in many cases there are trade-offs which renders it impossible to give general recommendations. A trade-off of the ‘ecologisation’ approach is that lower inputs (e.g. fertilizers and pesticides) and large natural areas interwoven with agricultural land will stimulate local biodiversity, but could lead to lower crop yields, which implies that more land is needed at the global scale. It might also cause a higher total input of certain resources, as water, seeds, pesticides and fossil fuels. A general note is that the key to change is often not in the hand of farmers and livestock keepers, but of other actors such as governments, private actors and food companies and large retailers, as well as civil society.

Sustainable intensification of crop production in regions with high yield gaps

The sustainable intensification of crop production is an objective that is high on the agenda because of its promise to simultaneously address food security and rural livelihoods on the one hand, and a more benign impact of agriculture on the environment on the other. According to the FAO (FAO, 2011), sustainable intensification includes ‘production systems and crop management technologies that increase productivity without adverse effects on natural resources, enhancing climate change resilience and input-use efficiency' (FAO, 2014b). 'Protecting crops sustainably, managing biodiversity and ecosystem services and strengthening livelihoods' are other key areas of sustainable intensification. Although many agree with the paradigm of sustainable intensification, there are also some concerns. Some fear that the concept of sustainable intensification will be used to promote GM crops or to implement a more industrial type of farming. The FAO indicates that the explicit aim of sustainable intensification is to simultaneously strengthen rural livelihoods. With a relatively small increase in investment in agricultural inputs, several millions of farmers in the poverty trap - a self-reinforcing mechanism causing poverty to persist when production remains low through lack of inputs - could increase their crop productivity twice or even more (Figure 3.9). This would be enough to double global cereal production (Tittonell, personal communication). Moreover, improvements in infrastructure, education, resourcing and the wider enabling environment will expand the choices available to farmer-entrepreneurs, offering the opportunity to increase productivity (Juma & Spielman, 2014).

Governmental intervention is crucial to enhance enabling conditions such as rural infrastructure, education and knowledge, to remove distorting subsidies or import tariffs, fight corruption and improve access to markets. Access to credit and clear property rights are also crucial enabling conditions. More budget and attention should be spent on the agricultural sector to promote biodiversity as well as rural livelihoods. In addition to enhancing crop production, the sustainable development of livestock production is also crucial. Appropriate grassland management and increased overall livestock production efficiency are key elements. Governments can support research on local alternative fodder crops or cropping systems that are more favourable for biodiversity, such as the cultivated water fern in India (Eisler *et al.*, 2014).

Complementary to governments, private actors such as food companies, retailers and food service companies (restaurants) also have a crucial role to play. This could be in their long-term interest, as a stable and sustainable food supply at a reasonable price is in the interest of these actors. Companies can introduce more sustainably-produced ingredients in their products, such as RSPO certified palm oil. There is a growing understanding by corporate agribusiness, particularly among the bigger players, that CSR is not going to be enough in an increasingly communicative and connected world (Evans, 2014). A 'social licence to operate' means adapting business models to be sustainable and inclusive. However, for much of corporate agribusiness the motivation to work sustainably requires some inducement from parties, including governments, which have environmental objectives, are resourced with non-commercial capital and help to reduce the commercial corporate sector's perception of the costs and risks involved. Moreover, governments should create a level playing field by strictly implementing and enforcing existing regulations and stimulating transparency and good practices (see Section 7.7).

Concrete actions which could be undertaken (or intensified) are:

- Develop, together with farmers, appropriate knowledge and techniques to actually implement sustainable intensification.
- Create clear and fair market conditions, and organise inputs and seeds, but also good transport and storage facilities.
- Seed companies could diversify their breeding programmes, and therefore pay more attention to agro-biodiversity.
- A further step might be to introduce biodiversity criteria in certification schemes. Most global food processing and producing companies will need carbon credits. By

combining climate mitigation measures with biodiversity-enhancing measures, synergies might be created. Another opportunity is for private actors to pay farmers in PES systems for carbon storage, water purification or biodiversity conservation.

- The design of innovative financial arrangements directed towards the 'missing middle' (between microfinance institutions and regional development banks) could stimulate the upscaling of local food processing industries.

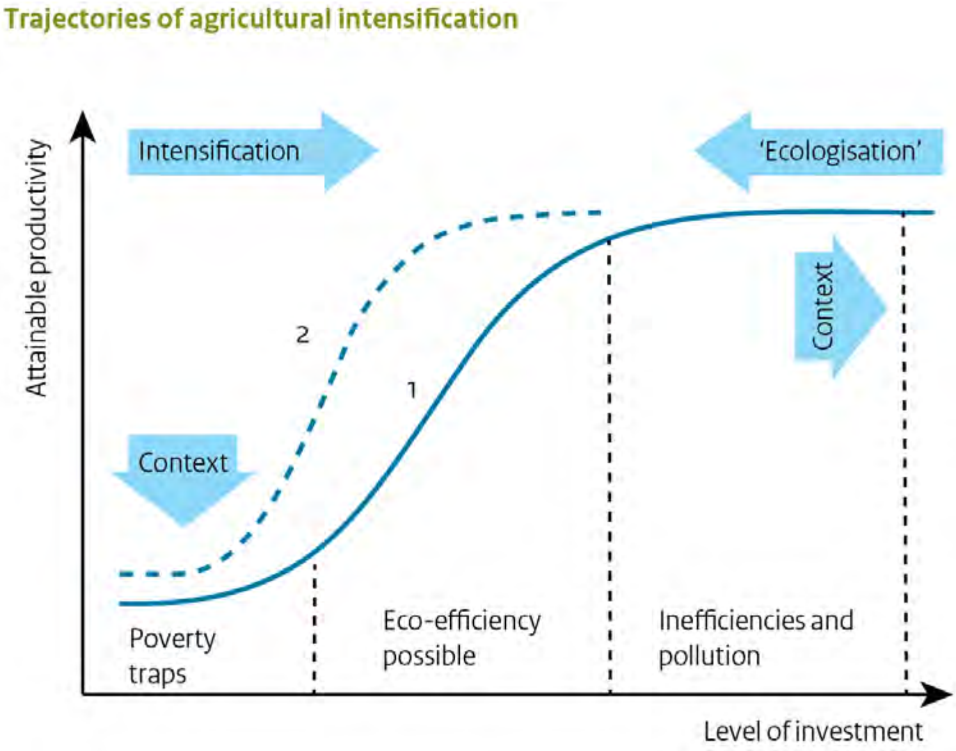


Figure 3.9. Attainable agricultural productivity per hectare of land or person as a function of the level of resource investment (capital, labour) (after Tittonell, 2013). Investments in research would allow a move from trajectory 1 to trajectory 2. The demographic and socio-political context in low-income countries makes it difficult for smallholders to escape from the poverty trap. In high income countries, farmers continue to invest in inputs in order to reduce production costs, pushing them further in the direction of inefficiency and pollution.

'Ecologisation' of intensively-farmed areas

Farmland biodiversity in intensively-farmed areas is currently low and still declining (EEA, 2010). In these regions, high productivity levels should be maintained without the associated emissions and pollution. 'Ecologisation' – decreasing inputs to an eco-efficient level – could be achieved in various ways. One approach is through a system change from monoculture farming towards alternative cropping rotations or cropping systems that combine different crops in one field (Figure 3.9; Tittonell, 2013). Another approach is to reduce inputs of fertilizers and pesticides to an eco-efficient level, as these inputs are currently often oversupplied, partly due to their relatively low costs and the risk-avoiding behaviour of farmers. Innovative techniques that combine the smart use of robotisation with remote sensing techniques and precision farming could replace most of the necessary labour and reduce inputs at the same time (Kohanbash *et al.*, 2013; Leenstra & van der Peet, 2009). In many regions, farmers are already being financially compensated to enhance farmland biodiversity and provide certain ecosystem services, as for example in the EU.

Governments can reduce the pressure caused by food production on biodiversity in intensively-farmed areas in many ways. The actual actions depend strongly on the context and on what has already been done. An important step is to better align agricultural and biodiversity policies. From a short-term perspective there might be tension between the two, but in the long term, good functioning ecosystems are essential for agriculture. Policy instruments to reduce emissions from agriculture include taxes, removal of subsidies and regulation. Lessons on how to combat environmental pollution could be shared between governments, while in certain regions cooperation between governments is needed to reduce cross-boundary pollution. Monitoring programmes will help to guide environmental policies. Governments could also create a level playing field by strictly implementing and enforcing existing regulations and stimulating transparency and good practices.

The food industry in general could do more (or go forward along the same track) by stimulating farmers to adopt biodiversity-friendly production techniques. Examples of these are pre-competitive cooperation to define and promote sustainable agricultural practises and certification schemes. As in regions with low yields, a further step might be to introduce biodiversity criteria in certification schemes.

Food waste reduction and dietary change

The third main strategy is to reduce food waste and change diets towards food commodities with lower environmental impacts (for example less animal- and more plant-based diets). This strategy is especially relevant for high-income countries, but certainly also for many emerging regions as diets change and food waste increases with increasing income.

The food industry as a whole has a key role to play, both in making healthy and sustainable food choices the logical choice, as well as in reducing food waste and losses. To reduce food waste, retail and food services could for example reduce portion sizes and improve packaging. Retail companies and food services (including restaurants and hotels) could make use of choice editing, for example by informing consumers about the impact of their food choices on biodiversity, but also by helping consumers make healthy and sustainable food choices. Food companies could support this by reformulating products, as well as by developing alternatives for meat. Governments have many policy instruments to reduce food waste and promote dietary shifts. Awareness-raising and taxing meat are often mentioned, but these are certainly not the only action governments could take. Other actions include paying more attention to healthy and sustainable diets in education, public procurement, and assessing the current policy mix to check whether there are currently policies that may, unintentionally, promote meat consumption.

Chapter 4. Wood production sector

4.1 Introduction

Wood is an important resource for humans. It is used for construction and to produce paper, as well as many domestic products such as furniture. Wood also provides energy for cooking and heating, and is the most important energy source in developing regions.

The wood production sector has a significant impact on global biodiversity, due to the large area that it uses to produce wood (a third of the global forest area; FAO, 2010), and the impact of wood production, extraction and processing on local ecosystem integrity. This is of special concern here, as forests harbour half to two thirds of global terrestrial biodiversity (Raven, 1988[3]). The sector's major direct impacts arise from the degradation of forests through the selective logging of trees, and through the way in which plantations are established and managed. Although the sector contributes to deforestation, particularly in indirect ways by opening up forest areas to other land uses, it is not considered the most important agent of deforestation (Kissinger et al., 2012). To reach the long-term biodiversity goals[4] of the CBD (as stated in the strategic plan for 2011-2020; CBD, 2010), the wood production sector is expected to reduce its impacts and promote sustainable use of the forest ecosystem.

The wood production sector is understood to include all activities and actors that are involved in, or have an influence on, the management of forests and the production and processing of wood for a variety of end uses. Actors include governments, private businesses, civil society and local communities, but the emphasis of this chapter is on the role of the private sector in reducing biodiversity loss. All aspects other than wood production that can be associated with forests, such as conservation, protection, regulation and socio-cultural functions (FAO, 2010), are beyond the scope of this chapter

In this chapter, we first explore the wood production sector in section 4.2, outlining how much wood is produced, by whom and from where, and how the sector is organised. Section 4.3 provides insight into the interrelationships between the wood production sector and biodiversity – how the sector depends on biodiversity and ecosystem services for the production of its raw materials, and conversely, how its operations affect forest biodiversity. In Section 4.4, the principal initiatives undertaken by the wood production sector to address biodiversity loss are discussed, specifically sustainable forest management (SFM), sustainable intensification of production by means of plantations, reducing illegal logging reducing the use of wood fuels and increasing processing efficiency. The effectiveness of these efforts and the main constraints to implementing them are briefly reviewed. Section 4.5 explores how three possible alternative future pathways consisting of different mixes of options (investment in technological solutions, regional solutions to meet demand for wood products, and reduced consumption) can help to meeting the Aichi targets. This scenario analysis shows which sectoral biodiversity loss mitigating options hold the most promise, and the scale and intensity of the required effort to meet the target. This is further elaborated in Section 4.6, with an emphasis on the most promising options for different actors that would be needed to intensify their implementation.

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[3] In fact, the proportion of global terrestrial species in forests is poorly-known.

[4] Aichi Target 5: by 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

4.2 Description of the wood sector

The wood production sector can be classified in several broad sub-sectors that produce wood for different purposes. The sector produces: 1) wood for construction and woodworking purposes such as furniture making: for these purposes the sector produces intermediary products such as sawnwood and wood panels (plywood, veneer, particle board and fibre board), 2) wood pulp for paper production, 3) wood for energy needs: traditional heating and cooking with fuelwood and charcoal, heat and power production in the forest industry (usually using processing wastes from pulp production) for own use or sale to others, and heat and power generation using wood-based biofuels in specifically-designed power plants (FAO, 2008b). A significant market has emerged for wood pellets in the past 20 years (FAO, 2010), mainly in response to the demand created by policies and bioenergy use targets in Europe (FAO, 2014c).

Table 4.1. Different types of actors in the wood production sector and their relevance for biodiversity mainstreaming. Note: categories overlap.

	Relation with biodiversity mainstreaming	Comments
Producers for international markets vs. local and subsistence producers.	Operators on international markets are more susceptible to national and international market-driven certification and regulatory instruments (FLEGT) for sustainability and biodiversity.	A large share of wood production is not traded on international markets.
Large-scale producers and high investment producers (e.g. paper processing industry) vs. small-scale, low investment producers and processors.	Biodiversity mainstreaming often requires investment and relatively advanced management skills.	The sector is highly fragmented; there are tens of millions of small forest owners, small- and medium-sized forest enterprises, community forests and artisans.
Producers in forest lands vs. operators from non-forests.	Much biodiversity and sustainability policy is directed to forests and formal forest lands rather than to multiple use landscapes.	In some countries a large proportion of wood is from trees on agricultural land, roadsides, and so on.
Producers in natural forests and semi-natural forests vs. producers in planted forests such as short rotation plantations.	Native biodiversity in natural forests is high and can remain high in sustainably-managed production forests; plantations totally replace native ecosystems.	Biodiversity conservation strategies are very different between these two classes (improved harvesting vs. better incorporation in landscapes) and address different spatial scales.
Producers in permanent forests vs. operators in conversion forests/non-forests.	In permanent forests there is often a legal requirement for sustainable forest management; in conversion forests there is not.	Wood sourcing from conversion processes cannot be directly influenced by market instruments like certification.
Legal producers vs. illegal producers.	Illegal logging often takes place in formally protected areas, and adds to forest degradation and deforestation. Obviously, there is no consideration about biodiversity conservation.	A high percentage of production in some countries (often developing and emerging countries) is not legal (either illegal or informal).

The wood, paper and energy sub-sectors each have specific features in terms of magnitude, sourcing and supply chains, wood quality, production and harvesting methods of raw materials, and impact on forests and their biodiversity. The sector is highly fragmented and escapes simple classification, but for addressing biodiversity concerns it is relevant to distinguish between different actors and operating modes with respect to wood production and trade (Table 4.1). The variety of wood products and actors is high, and supply chains vary in length and complexity. Large-scale, globally operating firms that extract wood from natural forests and plantations, process it and trade the products all over the world exist alongside small- and medium-sized enterprises that extract wood for mostly local use and domestic markets. The small-scale producers include community-based ones by indigenous peoples, individual producers and artisans. A range of intermediaries, traders and middlemen buy, process and/or sell wood-based products and indirectly influence production practices, and therefore biodiversity impacts, through their influence on producer's prices and margins.

Half of the registered wood production is for energy purposes

The total registered global wood production was estimated to be 3.53 billion m^3 roundwood equivalent (r.e.) in 2012, of which 1.66 billion m^3 (46%) was for *industrial roundwood* (the raw material for sawn wood, wood-based panels such as plywood and veneer, paper and paper board) and 1.87 billion m^3 r.e. (54%) for *woodfuel* (FAO, 2014c)[5]. Industrial roundwood production is slowly recovering after a dip caused by the global economic recession, starting in 2008. Woodfuel production has remained almost stable in this period, but the long-term trend has been an increasing one (Broadhead et al., 2001; FAO, 2008b).

Global roundwood production is dominated by large and forest-rich countries in the northern hemisphere and by populous developing countries with a high reliance on traditional energy sources. The US, Canada, Brazil, China and the Russian Federation jointly account for 54% of global industrial roundwood production, while India, China, Brazil, Ethiopia and DR Congo dominate woodfuel production (44% of the total woodfuel production; FAO, 2014c). Due to the omnipresence of forests and the versatility of wood as a material, many countries have a substantial wood production sector. As many as 54 countries (of which 45 tropical countries) have more than 50% forest cover and 77 countries report annual industrial roundwood removals of over 1 million m^3 (2005) (cf. FAO, 2010).

The three major climatic zones dominated by forests differ substantially both in terms of the way in which wood production takes place and in terms of forest biodiversity; boreal forests account for 31.5% of global roundwood production, temperate forests for 53.0% and tropical forests for 15.6% (Arets et al., 2011).

Only part of primary and secondary wood products internationally traded

At a value of 231 billion dollars in 2012 (FAO, 2014c), the international trade in pulp and paper, wood products and secondary processed wood products as a group ranks eighth among traded commodity categories (FAO, 2007a). Even though the legality of international traded wood products is the subject of intense public debate, it represents a minority of total global wood production. Of *manufactured* (processed) timber products, for example sawn wood, wood-based panels and veneer, pulp and paper, about 25–30% is traded globally (PBL estimate based on FAO, 2014c). In contrast, less than 1% of woodfuel is traded internationally. A major part of logs, wood products and residual fractions find their way to domestic markets for timber and wood-fuel, especially considering that much production for local purposes remains

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[5] FAO statistics distinguish wood for solid wood purposes and for fibre (paper) (together: industrial roundwood) from wood for woodfuel. Statistics on how wood is distributed over the three main uses (woodworking, energy and pulp) are not easily available, partly because different units are used. For Europe, the distribution of primary biomass flows is 45% (woodworking), 36% (energy) and 19% (pulp and paper) (CEPI, 2012).

outside the official statistics. These domestic and informal flows are barely influenced by international trade regimes or sustainability standards.

Historical trends show that international trade in wood products is rising (UNECE, 2014). Major international flows of wood are between developed nations, but the market has also begun to experience a significant increase in South-South trade (FAO, 2007a; Hudson, 2013). Countries such as Vietnam and especially China with their large domestic market and processing capacity have become major importers of wood from southern and tropical countries, while exporting processed products worldwide.

Economic importance of wood production

Roundwood production, wood processing and pulp and paper production employ approximately 0.4% of the world's formal workforce and contribute 1% to the global Gross Domestic Product (FAO, 2011). In most countries, the wood production sector is relatively small (its contribution to national GDP rarely exceeds 2.5%; FAO, 2008a) compared with natural resource-based industries, yet it provides an opportunity for millions of people living in rural areas and with limited access to other jobs. Worldwide more than 13 million people are employed in formal forest sector activities (FAO, 2014a) and another 40–60 million people may be employed in the informal sector of small- and medium-sized forest enterprises (Agrawal et al., 2013). The pulp and paper industry accounts for almost half of the total gross value-added in the wood production sector, followed by the wood industry (30%) and forestry activities (25%; FAO, 2008a). However, much of the local wood production – often a vital component of the local economy and of people's well-being – does not appear in the formal statistics and is not fully accounted for in the GDP. Agrawal et al. (2013) estimated that the non-cash economic contribution of forests to household and national economies ranges between three and five times the formally-recognised cash contributions. The economic contribution of forests to other sectors, in particular tourism, industry, health, water and agriculture are also not accounted for.

The sector is highly fragmented, especially in the tropics

The structure of the wood production sector in terms of size varies with the nature and accessibility of the primary resource, the product and the capital intensity of the sub-sector. Given the nature of the logging industry (relatively low yields distributed over large areas, especially in heterogeneous tropical forests and the need to keep hauling distances short), the industry tends to be fragmented in relatively small firms located close to the resource. The exceptions are in the boreal and temperate zones or where large-scale plantations have been established, and in the paper and pulp sub-sector, where high investment in processing facilities is required.

Fragmentation makes it difficult to achieve economies of scale and other production efficiency gains. There is less concentration in the supply chains, so unlike the "hourglass" structure of supply-chains in agro-commodities such as soya (WWF, 2012). It is also harder to implement environmentally- and socially-responsible practices that require advanced levels of skill and management. There is limited availability of and poor access to affordable and reliable finance; existing financing instruments are not tailored to the needs of different users (van Dijk & Savenije, 2009).

In the tropics, small and medium producers, that include indigenous peoples, local communities and private smallholders, constitute a major part of producers. They often operate in largely informal settings producing for subsistence and domestic needs. The number of people involved in these operations can be large, as is their importance in supplying local and domestic timber, woodfuel and charcoal markets (Wit & van Dam, 2010). Firms serving international markets tend to be larger and more sophisticated.

Illegal and informal logging widespread

In some countries, particularly in the South, a substantial proportion of total production remains outside the official statistics, because it is illegally produced and traded or informally harvested and used for subsistence and local consumption. Although the estimated illegal cut of timber worldwide of more than 100 million m^3 is low compared with total production, it can be regionally very significant, for example ranging from an estimated 25% in Malaysia to 70% of total production in the Brazilian Amazon. The trend in illegal logging is decreasing (Lawson & MacFaul, 2010). In the woodfuel and charcoal sub-sector too, a large (but unknown) proportion remains outside formal production systems (FAO, 2008b).

Illegal logging and associated trade impede the sustainable development of the sector as it can produce wood products at a reduced cost, discourage investment in sustainable logging and sustain a corrupt monitoring and enforcement environment from which the whole sector suffers (Goncalves, 2012). This is a major cause of informal and illegal activities in the sector. In many countries, forest ownership and tenure rights are unclear, not upheld or unfavourable for indigenous and local peoples. Poor governance works out badly for all bona fide actors: sometimes concessions or logging rights are awarded in an illegal or fraudulent manner in areas where indigenous and local people have long-standing tenure rights; sometimes legitimate wood producers suffer from encroachment.
Even when the markets for illegally- and legally-produced wood products are different (e.g. local versus export markets), it is hard to isolate a supply chain from the consequences of poor governance and illegality; achieving forest certification is severely hampered in such conditions. In the Congo Basin, widespread illegal activities are reported and forest certification are considered risky unless forest governance and law enforcement is improved first (Greenpeace, 2013).

Major trends: economic, technological and political developments affecting the wood production sector

Increases in global population and wealth will drive increased demand for wood products. To fulfill the increasing demand, wood will be sourced more and more from planted forests (FAO, 2010). New technologies stimulate the use of increasingly complex wood-based products, and this will lead to a shift from solid and hard woods to soft woods and wood particles. This will also be associated with a shift from natural forest-derived raw materials to plantation-derived materials. The wood production industry is expected to follow the resource towards areas where land is cheap and available for plantation development, wages are low and social and environmental regulation less stringent. This will lead to a global shift in production areas and associated trade.

The centre of economic growth may shift towards Asia, and this will be associated with different consumption patterns and different social, cultural and environmental norms in production and trade. China continues to increase in importance as a global intermediary for wood products and has already overtaken a number of other major countries in different product groups. China is also highly significant for international trade in forest products, being the world's largest importer of industrial roundwood, sawnwood and fibre furnish and the largest exporter of wood-based panels (FAO, 2014c).

The impacts on the sector of international policies and agreements (for instance on climate, energy, food security and biodiversity) may lead to more stringent enforcement of national legislation (reduction of illegal logging, informal and subsistence logging; protection of forests and biodiversity), replacement of fossil fuels by renewables (including wood), reforestation and afforestation efforts under a climate regime, and the replacement of (possibly degraded) natural forests by plantation forests or non-forest plantations such as oil palm.

International policies on trade (the EU Timber Regulation, Voluntary Partnership Agreements on forest governance and trade in legal timber, the Lacey Act and CITES) are increasingly used to impose environmental and social norms on production processes in other countries. The effect on the sector is expected to be a greater adherence to social and environmental legislation, reduced pressure on high-value timber species, a shift from unregulated to regulated forms of wood production and a shift in production away from high-risk countries (where legality is hard to assure) to low-risk countries (Brack & Bailey, 2013).

4.3 Benefits to the sector from ecosystem services and impacts on biodiversity

As forests hold a very large proportion of the Earth's terrestrial biodiversity (Gibson et al., 2011), the role of wood production operations is important and has been under intense scrutiny. This section reviews the relation between the wood production sector and forests and biodiversity – on the one hand its impact on forests and biodiversity and, on the other hand, its dependence.

There are many direct and indirect impacts from the wood production sector on biodiversity

Direct impacts of the wood production sector on biodiversity arise from deforestation (conversion into other land cover), degradation of forests through the selective extraction of trees, fragmentation of forests (isolation and edge effects) and the way in which plantations are established, managed and harvested. Forest degradation is defined here as a reduction in canopy cover and a loss of carbon and biodiversity, while the forest remains in place and is expected to regrow or be replanted (Kissinger et al., 2012). The main driver of deforestation is agricultural expansion, but part of the responsibility lies in the wood production sector as wood extraction makes forests prone to further degradation and eventual conversion (Honosuma et al., 2012; Kissinger et al., 2012). Indirect impacts are due to environmental effects outside the direct management area in which production takes place. Such effects are brought about by mechanisms such as displacement of production, infrastructure development, use of pesticides and water and energy use. Harvesting, management operations and wood processing also impact on the biodiversity of rivers and streams through the use and pollution of water and the modification of riparian and riverine habitats. The use of fuel, processing chemicals and pesticides impact biodiversity well beyond the immediate production areas; these indirect impacts are not discussed in detail here. All of these impacts are discussed in more detail below.

The wood production sector is highly dependent on forest biodiversity

The wood production sector depends on natural processes for the production of natural resources and for maintaining the productive capacity of forests. Forests also have an important economic and social function for national economies and forest-dependent local communities, by providing food, fibre, fuel, medicines and wild relatives of agricultural crop species (genetic resources, see also chapter 3) and other ecosystem services such as climate and water regulation and religious and spiritual values (CBD, 2009; Bozzano et al., 2014; FAO 2014a).

Where harvesting occurs in primary forests, especially in the tropics and in the boreal forests of Russia and Canada, forest operators directly reap the benefits of centuries of biomass accumulation in large trees provided as a service by nature. Even in semi-natural forests, regeneration and growth are largely governed by natural processes, with a minimal input of external resources. Only in intensely-managed plantations is there a high degree of human control over soil, water and nutrient conditions and stand management.

In some cases, the dependency of the sector on tree biodiversity is explicit, where the variation in timber properties and visible features are a direct technical or marketing argument. This is the case for veneers and other high-quality decorative timbers. The end use of timbers depends on their mechanical and sometimes visual properties – a manifestation of biodiversity. In the pulp and paper industry, long-fibred softwood conifers are generally used for newsprint and packaging, while short-fibred hardwoods are better for high-quality printing paper. About a third of the tree species mentioned in country reports to FAO are specifically managed for their products and/or services (mainly for timber, non-wood forest products and energy; FAO, 2014d).

On the other hand, biodiversity can also limit the development of the wood production industry. A high diversity of trees with strongly varying properties growing in mixed stands– a common situation in tropical forests – severely reduces the merchantable volume of wood, as timber markets are focused on just a few species. This leads to low-intensity and selective forest operations that have generally moderate impacts on forest biodiversity, but also to high per-tree investments in infrastructure and a high collateral impact on forest stands per unit harvested volume.

While there is little debate about the wider importance of forest ecosystems for the wood production sector, it is harder to establish the immediate value of species conservation for wood production. Many tree species depend on other species for their pollination or dispersal, and natural enemies of pests provide services to forest managers, but in general it is hard to quantify such benefits. The general lack of knowledge of species values limits mainstreaming of biodiversity in wood production operations. Reasons for nominating species as priorities include not only their economic value (timber, pulp, food, wood energy, and non-wood forest products), but also social and cultural value, conservation value (biodiversity, threatened species, endemic species, genetic conservation, scientific value), environmental value (e.g. soil and water protection, soil fertility and watershed management) and invasiveness (FAO, 2014d).

Trends in forest extent and deforestation

With an estimated 4.03 billion hectares, forests[6] currently occupy about one third of the Earth's land area and are estimated to contain more than half of all terrestrial species, mainly in the tropics (FAO, 2010). Moreover, forest ecosystems account for over two thirds of net primary production on land, making them a key component of the global carbon cycle and climate (TEEB, 2010). The world's forests store more than 650 billion tonnes of carbon. Legally-established protected areas account for an estimated 13% of the world's forests, so the conservation of forest biodiversity and the management of ecosystem services is for a large part in the hands of actors in the wood production sector (FAO, 2010).

Historically, about 50% of the global original forest cover[7] has been cleared or degraded (WRI, 2014). The FAO (2010) states that primary forests currently account for 36% of the global

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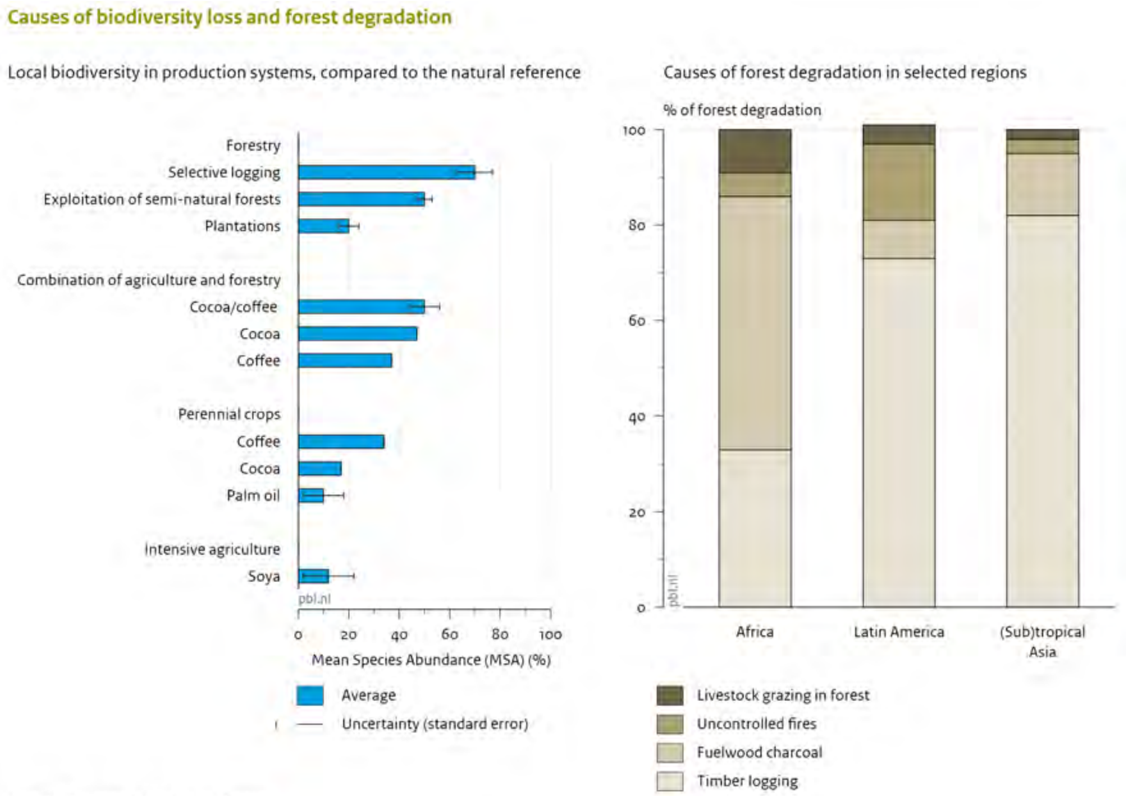
[6] Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10%, or trees able to reach these thresholds in situ (FAO, 2007b).

[7] Where climatic conditions support the development of forest ecosystems (based on analysis by WRI; GPFLR, 2011).

forest area. According to the Intact Forest Landscapes inventory, only about 15% of forests are still intact (Potapov 2008; Intact Forest Landscapes, 2014). Most of the rest of global forests has been fragmented or degraded. The deforestation rate has shown decreasing trends in several countries but continues at a high rate in others, overwhelmingly in the tropics (Hansen et al., 2013). Around 13 million hectares (net value) of forest were converted to other uses or lost through natural causes each year in the past decade, compared with 16 million hectares per year in the 1990s (FAO, 2010). While the extent of primary forest has decreased by 40 million hectares since 2000, planted forests increased by about 5 million hectares per year between 2005 and 2010. Deforestation and forest degradation (whether caused by the wood production sector or not) jointly account for about 12% of global anthropogenic carbon emissions (van der Werff et al., 2009).


Causes of biodiversity loss and forest degradation

Local biodiversity in production systems, compared to the natural reference

Causes of forest degradation in selected regions

Source: PBL, 2009, Kissinger et al. 2012

Figure 4.1. Forest degradation is attributed to logging for timber and woodfuel (right; Kissinger et al., 2012). Remaining biodiversity in forest ecosystems used for production purposes depends on the intensity of use and management (left). Biodiversity is expressed here as the degree of naturalness, indicated by the MSA indicator (Alkemade et al., 2009).

The major contribution of the wood production sector to biodiversity loss is through forest degradation

The largest impact of the wood production sector on biodiversity by far is through forest degradation. Kissinger et al. (2012) attribute 80–90% of forest degradation in the tropics to timber logging, fuelwood collection and charcoal production, with marked variations between the three tropical continents (Figure 4.1). Wood production is not considered a major direct driver of deforestation and associated biodiversity loss in the tropics (Hosonuma, 2012; Kissinger et al., 2012; Figure 4.2). Commercial and subsistence agriculture jointly account for a large part of deforestation and therefore forest biodiversity loss. Of 132 million hectares of forest conversion (1990–2008) that could be linked to the global production of agricultural and forestry products, just 4.5 million hectares was attributed to logging (Devriendt et al., 2013). This excludes a potentially significant proportion of deforestation that could not be linked to an identifiable driver and could partly be due to logging. Nevertheless, it shows that the direct impact of wood production on deforestation is limited compared with other sectors. It should be noted that the establishment of agro-commodity plantations in many parts of the tropics may be preceded by clearing of the forest for timber.

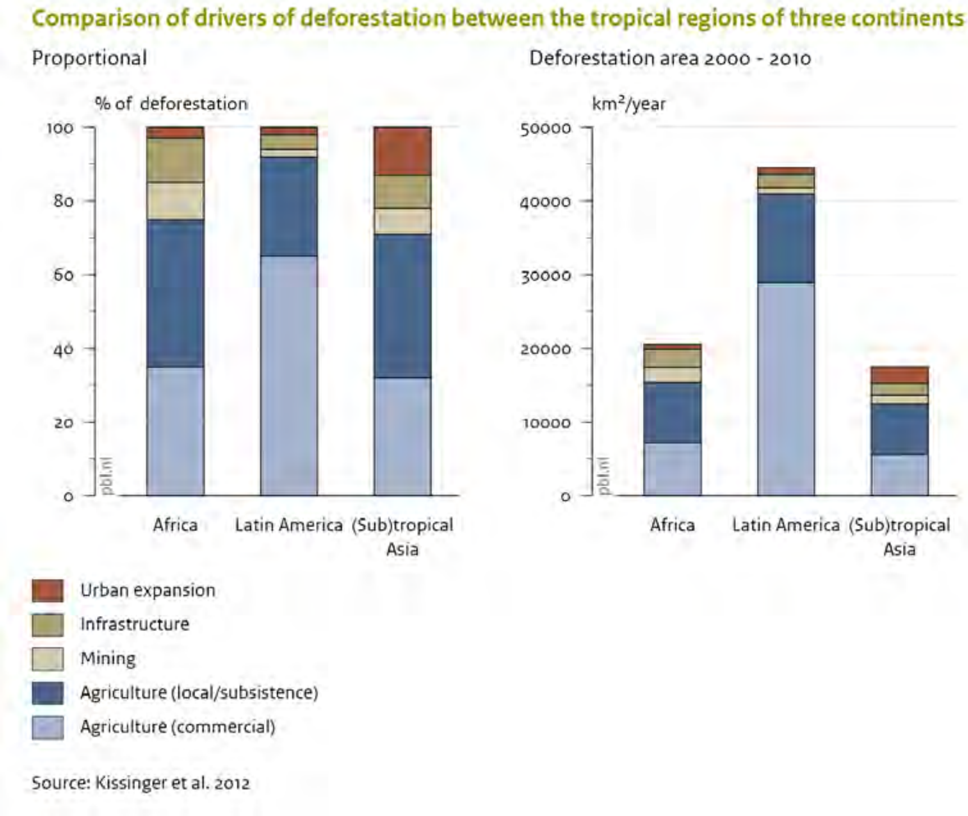


Figure 4.2. Continental-level comparison of drivers of deforestation in the three tropical regions (left: proportional; right: in terms of area) (source: Kissinger et al., 2012).

Wood comes from an array of sources, with planted forests becoming more important

Wood production takes place in forests in all states of naturalness, ranging from primary forests without significant human interventions to planted forests (Table 4.2). In many tropical countries and in countries such as the Russian Federation, substantial amounts of roundwood are harvested from primary forests. People and small enterprises without clear use or ownership rights, or with limited access to technology and equipment, usually derive wood from accessible, degraded forests (modified natural forests) and from trees on agricultural lands. This concerns products such as charcoal, woodfuel and timber for subsistence purposes and for the domestic market.

Planted forests only make up about 7% of the world's forests; forest plantations consisting of introduced species make up about a quarter of that area (FAO, 2010). These low-biodiversity forests are an increasingly important source of roundwood. China, the United States of America, the Russian Federation, Japan and India have the largest areas of planted forests, and their area increases globally by about five million ha per year.

High-value tropical hardwoods usually come from natural, often primary forests with a high biodiversity conservation value. This follows from the slow growth rate of high-quality hardwood trees, most of which cannot be grown in plantations, at least in economical terms.

Nevertheless, high-value natural forests are still used for the production of low-grade commodities like pulp.

Industrial wood supply is clearly shifting from natural forests to planted forests (FAO, 2010). This means that the importance of natural forests as a wood source is likely to diminish in the future (see Section 4.5). This is not necessarily favourable for biodiversity conservation as this may expose natural forests that do not contain an economic value to other uses, including full conversion (see Section 4.6).

Outside forests, locally significant volumes of timber are derived from non-forests: lands in agricultural use, for instance for agroforestry (shaded coffee, shaded cocoa, smallholder mixed agriculture). More than 1 billion hectares, or almost 50% of the agricultural land in the world, has tree cover of more than 10%; about 7% (167 million ha) of land classified as agricultural has more than 50% tree cover (Zomer et al., 2014). Wood plantations may be established on degraded forest lands (reforestation) and in non-forest ecosystems such as savannas (afforestation).

Table 4.2. Sources of raw material for the various wood sub-sectors, based on the FAO classification of naturally regenerating and planted forests and trees outside forests (FAO, 2004). Dark colours designate major sources of raw materials; lighter colours are less important sources.

Forest category			Definition	Timber and wood/ industrial scale	Timber and wood/ local scale	Pulp, paper and particles	Woodfuel	Biomass (biofuel/ biotechnology)
Natural forests		Primary	Forest of native species, where there are no clearly visible indications of human activity	■		░		
		Modified natural	Forest of naturally regenerated native species where there are clearly visible indications of human activity	■	■	░	■	
	Semi-natural	Assisted natural regeneration	Assisted natural regeneration through silvicultural practices for intensive management	■	■	■		
Planted forests		Planted	Planted component. Forest of native species, established through planting, seeding or coppice of planted trees	■	■	■	░	░
	Plantation	Productive	Forest of introduced species and in some cases native species, established mainly for production of wood or non-wood goods	■	■	■	░	■
		Protective	Forest of native or introduced species, established through planting or seeding mainly for provision of services like erosion control				░	
Non-forest		Trees outside forests	Stands smaller than 0.5 ha; trees on agricultural land (agroforestry systems, home gardens, orchards); short rotation tree crops; in cities and scattered in landscapes	░	■		■	■

Several direct and indirect effects of forest management

Direct impacts on forests and biodiversity occur when wood production operations physically affect forest ecosystems, such as when harvesting trees (or parts of them) or the whole stand, and from stand management such as thinning, weeding and other silvicultural treatments. Selective harvesting of high value species (timbers such as mahogany (*Swietenia spp*.) or non-timber forest products such as agar wood (*Aquilaria spp.*) may lead to the local disappearance of these species. Site preparation for initial establishment of a silvicultural system (e.g. drainage followed by plantation establishment) or as part of a silvicultural system (prior to reseeding or replanting) modifies soils and water courses, with direct and indirect impacts on biodiversity. The introduction of trees, whether native, exotic or genetically modified, and whether in the form of enrichment of existing stands or wholesale stand establishment or re-establishment, directly changes forest composition. The construction of roads or skid trails, the obstruction or deviation of waterways and other infrastructure such as sawmills also physically affect forest stands.

The indirect impacts of wood production operations may be more substantial than the direct ones. Indirect effects result from changes in habitat (soil conditions, hydrological conditions, microclimate) and species composition (biotic interactions with other trees, pollinators, dispersers, pests, diseases). Freshwater ecosystems in or near forests are particularly vulnerable to siltation resulting from erosion caused by wood production operations and roads. Fire risks are higher in disturbed forests, and may have a major impact on forest types in which fire is not a regular phenomenon (see for example Asner et al., 2006).

Logging can be the first step in a chain of events that leads to degradation and the total conversion of forest to other land-use types and the total elimination of biodiversity, especially when logging operations are associated with the opening of roads in previously inaccessible forests (Laurance & Balmford, 2013). Road building causes isolation of populations due to forest and habitat fragmentation, erosion and hydrological disturbance, and invasion of exogenous species. Hunting and fishing, establishment of settlements, fire, illegal logging and swidden agriculture may follow on the heels of forest operations.

Effects of logging depend on management practices

The impact of wood production operations on forest degradation and forest biodiversity depends on a number of management factors:

- Scale – ranging from very local in the case of subsistence use to interventions at the scale of 100 000s of hectares (forest concessions).

- Intensity – ranging from highly selective extraction of trees (or even parts of them) to total removal of all woody biomass in plantations and even-aged monoculture stands. (Alkemade et al., 2009; Figure 4.1).

- Frequency – some uses such as informal woodfuel gathering can be more or less continuous. Interventions in forest for industrial use range from frequent in some short rotation plantation systems (8-year rotations for *Acacia mangium* for pulp and woodfuel production) to very infrequent in forests used at rotations of 50 years or more.

The degree to which wood production interventions resemble natural disturbances determines the extent to which native forest biodiversity will be impacted. The closer the disturbance regime matches the natural disturbance regime, the greater the likelihood that the forest will retain its typical forest biodiversity. If this is not the case, non-forest species or species associated with secondary (disturbed) habitats will invade or increase in number. For instance, reduced impact logging (RIL) practices aim to match the fine-grained pattern of tree disturbance that is typical for tropical rainforests as much as possible (Putz, 2008), while patch-wise removal of whole forest stands may do the same in forest ecosystems that are subject to natural large-scale disturbances (wind throw, fire, pest outbreaks) (North & Keeton, 2008).

The conservation value of managed forests can be very high

The biodiversity and species composition of forests dedicated to the production of timber, pulp or other commodities are very different from those of primary forests originally occupying the site. Primary forests (both tropical and non-tropical) are recognised as the ecosystem type containing the most species, and even irreplaceable for sustaining biodiversity (Gibson et al., 2011), especially in the tropics. The importance of managed forests as a habitat for true forest species (representative of undisturbed conditions) decreases when interventions are more intense, more frequent and on a larger scale (Alkemade et al., 2009). However, this does not imply that managed or intervened forests have little value for biodiversity conservation. Natural tropical forests that area managed for selective logging may harbour high levels of biodiversity (Putz et al., 2012). Given the large extent of managed forests compared with strict conservation areas, they are quantitatively and qualitatively important reservoirs of biodiversity. Even poorly managed, degraded forests still hold higher levels of biodiversity than large-scale agricultural landscapes.

4.4 What is the sector already doing in favour of biodiversity?

This section focuses on initiatives already being undertaken by the private sector to mitigate its impacts on biodiversity and ecosystem services and to enhance biodiversity. Key strategies followed by the sector are summarised in Table 4.3. The main initiatives include promoting sustainable forest management, combating illegal logging practices and increasing processing efficiency of wood resources. Responsible corporate behaviour is cutting across these strategies and is an important driver for improved practices. While the sector has the ability to integrate biodiversity concerns into its own operations, the effectiveness of some interventions depends on the performance of other actors, including governments and civil society.

Sustainable forest management is the key sector option to reduce biodiversity loss

Implementing sustainable forest management (SFM) is the main approach taken by the wood production sector to reduce biodiversity impacts. It aims to maintain or increase long-term productivity while reducing the impact on biodiversity and other ecosystem services (e.g. carbon sequestration, water balance, etc.)[8]. Sustainable forest management is partly achieved through government regulation, and partly through adherence to voluntary production standards, often in the context of forest management certification. Because of different production environments, sustainable forest management can involve different activities in natural and semi-natural forests and forest plantations.

It is important to distinguish between the terms sustainable forest management and forest certification. 'Certification' is not equivalent to sustainable forest management, as not all sustainably managed forests are certified, but in practice the extent of sustainably managed forests is mostly measured using the area of certified forests. It is taken up in the CBD indicators framework for showing progress with sustainable ecosystem use (CBD, 2010). The independent verification of forest management practices against a standard (for example, the FSC or one of the PEFC standards) allows for the certification of sustainable forest

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[8] This refers to a narrow definition of sustainable forest management, emphasising the operational and silvicultural aspects. The UNFF adopted definition is broader: sustainable forest management as a dynamic and evolving concept aims to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations (UN, 2008).

management. For legal timber, a largely comparable system of verification and labeling exists (see for example EFI, 2007).

Table 4.3. Improvements in the wood production sector.

Main direction	Sustainable forest management		Reduce illegal logging and trade	Increase efficiency and re-use
General effect	Reduced forest degradation, long-term productivity.	Increased production and avoided deforestation.	Reduce illegal logging and trade. Level playing field for sustainable wood.	Reduce the need for raw inputs.
Mainly relevant for	Natural forests	Plantations	Developing and emerging countries	Paper and pulp industry; woodfuel sub-sector
Production and processing measures	Reduced impact logging (RIL), green tree retention, conservation areas, high conservation value forest management, planning of road networks, appropriate pesticide use. Forest management certification.	Responsible expansion of plantations in degraded areas. Retention and management of high conservation areas. Avoid the 'escape' of non-native species, conserve soil and water resources and appropriate use of fertilizers and pesticides.	Improved (forest) governance. Establishment of definitions of legal wood, removal of unfair and illegitimate policies and legislation. Wood tracking systems. Implement VPAs.	*Production*: Improved planning and apply RIL. *Processing*: Efficient processing technologies. Recovery of residual wood. Recycling. New uses for residual wood and soft woods.
Trade measures	Chain-of-Custody certification	Chain-of-Custody certification	Implement trade regulations, tracking & tracing	Marketing of lesser-known species and wood residues
Demand-side measures	Public and private procurement policies, green building codes. Raising consumer awareness, selective purchasing by consumers. Stimulate demand for sustainable/legal wood products.			Paper and wood recycling. Use fuel-efficient cooking stoves, use alternate fuel sources for cooking.

The labeling of wood products and chain-of-custody (CoC) certification are important market strategies for demonstrating sustainable forest management and the legal origin of wood products. These labels link supply of and demand for sustainably produced wood products: they help assure consumers of the legal and/or sustainable provenance of wood products, may help command a premium price or retain market share in environmentally-demanding markets, and allow consumers to exercise market demand for legal and/or sustainable wood products.

In the North, many companies achieve forest certification using their own resources, but in developing countries (and also for small producers in the North), cost and technical capacities are major impediments to successful certification. Many donors have programmes to support companies and community forestry groups in implementing sustainable forest management and achieving certification. Equally, many companies collaborate with NGOs (e.g. WWF GFTN – Global Forest and Trade Network, TFT – Tropical Forest Trust and IDH, the sustainable trade initiative in the Netherlands) to share experiences and jointly move towards sustainable forest management.

Good practices in natural forest management include RIL (mainly in the tropics), green tree retention (in clear cutting systems, mainly in boreal forests), creating biodiversity set-asides, corridors and riparian buffer zones, identifying and managing high conservation value (HCV) forests, properly designing and managing road networks and hard infrastructure and limiting the use of pesticides (van Kuijk et al., 2010).

Good management practices in plantations are broadly comparable to those in natural and semi-natural forests. Silvicultural practices (site preparation, tending, control of weeds and pests) tend to be more intense, and the species are often exotic to the region. Good practices therefore avoid the introduction of non-native species into surrounding ecosystems, conserve soil and water resources and use fertilizers and pesticides judiciously. In general, the biodiversity of plantations is lower than and different from that of naturally-occurring forests in the same region, especially where natural forests are mixed-species and of diverse age. Their potential positive impact on biodiversity depends on the adequate management of biodiversity set-asides, corridors and vulnerable areas.

Preventing forest conversion and reforestation is promoted by the sector

The key strategy for reducing the biodiversity impact of plantation establishment is to prevent the conversion of natural forests and avoid the degradation of HCV areas – primary forests, forests on peat land and valuable non-forest lands. Industry standards, including for forest management certification and for certification of (woody) biofuels consistent with the EU Renewable Energy Directive generally require HCV assessment and management; they exclude plantations from receiving certification if established by converting primary forests or peat lands prior to a certain date (e.g. 1995 in FSC). The purpose of these standards is to concentrate planting on degraded lands of lower ecological or social value, and to create landscapes consisting of mosaics of high production plantations, native vegetation and areas in use for other land uses. Under pressure from NGO action, companies operating forest plantations (mainly for the pulp and paper industry) in countries with high plantation expansion rates in environmentally-sensitive regions are increasingly pledging to stop converting high conservation value forests including forests on peat land (see for example APP, 2013).

Plantation establishment is often conducted in the context of forest and landscape restoration, thus to a certain extent reversing previous loss of biodiversity and ecosystem services. The establishment of commercial plantations for wood products can be combined with the re-establishment of environmental services (e.g. carbon storage, erosion protection, soil fertility), and sometimes with providing resources for woodfuel collection. Examples of large-scale rehabilitation include the restoration of the Löss Plateau in China (Feng et al., 2013) and the farmer-led rehabilitation of over five million hectares of Sahel woodlands in Burkina Faso and Niger (Reij et al., 2009). In contrast to these examples, the establishment of Eucalypt plantations on degraded lands (e.g. in Brazil) has a clear commercial forestry purpose. It should be noted that the contribution to reversing biodiversity loss can be very limited if restoration leads to large-scale and monotonous plantation establishment.

Certified forests cover 10% of global forest area, mainly in the North

The proportion of global forests under some form of sustainable management depends on the definition of sustainability used. In the tropics, the area of permanent production forest in ITTO producer countries considered to be under 'management consistent with sustainability' (ITTO, 2014) increased from 36.4 million hectares in 2005 to 53.3 million hectares in 2010

(Blaser et al., 2011). The area of FSC or PEFC certified tropical forests in 2010 was about half this area (17 million hectares).

The global area of FSC and PEFC certified forests was 417 million hectares in 2013 (UNECE, 2014)[9]. This total area is probably an overestimation, as a part is double certified (13%; Potts et al., 2013). This is close to 10% of the total global forest area, with some regions exceeding 50% (Western Europe: 60% in 2013). This is equivalent to about 25-30% of the global forests that are in use for *production* purposes (PWC, 2012; Potts 2013). The potential supply of industrial roundwood from certified forests was estimated at 500 million m^3 in 2013, equivalent to about 28% of global industrial roundwood production (UNECE, 2014).

The extent to which certified forest management is effective as a tool to enforce and enhance best practices for biodiversity conservation and management of ecosystem services is an issue that is open to debate. Certification is not designed specifically for biodiversity conservation, and inherent trade-offs exist between biodiversity objectives and other objectives of sustainable forest management. Also, there is variation in certification prescriptions between different certification schemes and certifying bodies, and there are uncertainties surrounding the long-term effects of forest management on biodiversity.

However, based on research and pooled expert opinion, there is evidence for a positive effect of applying sound management practices and certified forest management on biodiversity; however, a solid scientific basis to prove and quantify this is still lacking (Zagt et al., 2010; Blackman & Rivera, 2010). A distinction should be made between whether good practices are beneficial for biodiversity in an absolute sense (van Kuijk et al., 2009), or whether the process of undergoing certification leads to major improvements (additionality). The amount of CARs (corrective action requests, which must be followed up to receive and retain certification) provides relevant insights for this last aspect. Of all requests for corrective action issued by certifying bodies to FSC-certified forest operations, 4% were biodiversity related (n=3102). Such requests to improve performance involved 73% of forest management units studied and ranked sixth among all criteria (Peña-Claros, 2009). This can be interpreted as evidence that certification actually improves the biodiversity performance of certified forest operations. The audits conducted by independent certification bodies are a kind of soft law enforcement on activities within and conducted by the certified operation (Newsom, 2005).

The direct effect of certification (the proportion of production area that is certified) on a country's deforestation rate is weak, debated and subject to many uncertainties (Cashore & Auld, 2012). Certification, with its focus on forest management units, is limited in directly addressing higher landscape-level drivers of deforestation, forest degradation and biodiversity loss. It is acknowledged that certification raises stakeholder awareness and may improve the enabling conditions for sustainable forest management (Cashore & Auld, 2012).

Certification of all forests will be hard to achieve

While the area of certified forests continues to grow, the transition to responsible forest management practices will not happen quickly enough to reach all forests by 2050, in particular in the tropics (PWC, 2012). The area of certified forests in the tropics is growing steeply, but still represents just a small proportion of the production forest (about 4–6% of designated production forests; PWC, 2012; Blaser et al., 2011) and represents 7.3 million m^3 of annual production. An additional significant area can be considered as sustainably managed but is not certified (including community forests and producers who do not want or are not

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[9] This figure and all other certification statistics mentioned apply to natural and planted forests. About 10% of FSC certified forest is plantation forest and 28% semi-natural and mixed plantation-natural forest (FSC, 2014). Similar information is not available from PEFC.

willing to pay for certification[10]). The practices in the remainder of tropical forests are either unregulated and informal (subsistence use of timber and woodfuel), illegal or regulated by governments that barely have the political will and capacity to ensure compliance with sustainability standards. The high direct and indirect cost of certification, low levels of forest management capacity, limited demand for certified produce and high opportunity cost of forest management compared with other land uses further weaken the business case for certification in the tropics (Lammerts van Bueren et al., 2013; Cashore & Auld, 2012). In Europe and North America, barriers to mainstreaming the use of sustainably produced tropical timber are related to the high cost of certification and the low potential to achieve price premiums in the market (Chen et al., 2010).

Some examples of collaborative, landscape-wide approaches that stretch beyond the boundaries of individual forest holdings and embrace broader natural resource management concerns exist. The Canadian Boreal Forest Agreement (CBFA) was signed in May 2010 by 21 forest companies and 9 leading environmental organisations, aiming to conserve major areas of Canada's boreal region, protect threatened woodland caribou, and provide a stable timber supply for participating companies (Gunn, 2013). Landscape approaches exist elsewhere, where wood production companies collaborate with each other and with other partners (often a conservation NGO) to manage forest operations and whole landscapes in an integrated way. These efforts are often project-based – whether or not they can exist without external funding is not clear. Examples include landscapes managed in the USAID-funded CARPE programme in the Congo Basin involving two certified forest companies and several forest management units (CARPE, 2014).

Control of illegal logging by government regulation

Government-led policies have been developed for reducing illegal logging and promoting legal trade. These are accompanied by incentives to enable the wood production sector to integrate environmental and social concerns into its operations. Efforts to combat illegal trade are the EU Timber Regulation, (part of the Forest Law Enforcement, Governance and Trade - FLEGT - Action Plan), the US Lacey Act, and Australia's Illegal Logging Prohibition Act. These initiatives place legal barriers on the import of illegal timber on the home market. Voluntary Partnership Agreements (VPAs) – another component of FLEGT – are bilateral agreements with producer countries. VPAs aim to guarantee that any wood exported from a timber-producing country to the EU comes from legal sources, and help the partner country stop illegal logging by improving forest governance and regulation and establishing a legal assurance system (Pearce, 2012).

Government initiatives to combat illegal trade are complemented by industry initiatives to exclude illegal timber from their supply chain, develop codes of conduct for members of trade associations and support primary producers to comply with legal logging regulations. Some of these initiatives (such as TTAP and GFTN) overlap with those to promote forest certification, which is seen as a critical tool to avoid illegal logging.

The scope for reducing biodiversity loss through measures to combat illegal logging is not easy to estimate. Most of the effects will be indirect, by improving forest governance and improving the competitiveness of sustainable operators. Reductions in illegal logging in Brazil, Cameroon and Indonesia between 2000 and 2009, estimated at 345 million m^3, may have avoided the degradation of 17 million hectares of forest in these countries (Lawson & MacFaul, 2010).

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[10] Potentially 36 million ha, see above and Blaser et al. (2011).

Demand for certified and legal wood products is concentrated in the North

The demand for verified sustainable wood products is concentrated in countries with high environmental awareness and active NGOs and in certain product groups. For coniferous softwoods, the market is close to 100% verified sustainable in a range of countries, but for tropical and temperate hardwoods the sustainable market share lags behind, even in the most environmentally-conscious markets (de Boer & Hentschel, 2011). Outside Europe and North America, the demand for certified products is virtually absent. For instance, the consumption of timber of verifiable sustainable origin (FSC, PEFC) is high in several European countries (UK – over 85% of imports (2009; TTF 2011); Netherlands – 86% of imports (2013; VVNH, 2014a); Belgium – 41% (2012; de Groot et al., 2014).

Demand for certified wood products depends on the environmental awareness of consumers and is strongly determined by NGO action and reputational risk management by retailers and governments, leading to market requirements for FSC or PEFC certified wood products. In general, wood suppliers are very interested in trading with large retailers and environmentally-conscious markets, and the number of FSC and PEFC CoC certificates increased from fewer than 10 000 in 2007 to over 35 000 in 2013 (UNECE, 2014). Demand for legal wood products is also strongest in countries with high environmental and social awareness, mainly driven by legislation such as the EU Timber Regulation and the US Lacey Act.

High transaction costs limit further demand for certified timber, additional instruments needed

Within environmentally-conscious markets in Europe, increasing demand for certified wood products is constrained by a lack of urgency felt by suppliers, consumers and government, the high transaction cost (for administration, logistics and audits), confusion about the different certification systems, the higher price of certified timber and the poor image of tropical timber in general (Lammerts van Bueren et al., 2013).

The demand for verified sustainable wood products can be further stimulated by sustainable public procurement policies, green building codes requiring the sourcing of environmentally-responsibly produced materials and private purchasing policies of major retailers (such as Do-It-Yourself chains) and wood consuming businesses. The industry collaborates at national (e.g. the Green Deal on sustainable forest management in the Netherlands) and international level (European Sustainable Tropical Timber Coalition STTC initiative, TTAP Tropical Timber action plan) to stimulate demand, and with NGOs such as the WWF to promote the supply of legal and certified timber and increase the market for it (Global Forest and Trade Network). FSC and PEFC also have programmes to stimulate demand for certified wood products.

Possibilities exist for increasing resource use efficiency and reducing consumption

There are many possibilities for increased efficiency in the various wood product processing chains, as part of a trend towards a circular economy. They help to reduce the need for raw materials and thus contribute to reducing biodiversity loss. Recycling and increasing the life cycle of wood-based products also helps reduce the environmental footprint of the forest product industry.

Wood production

In particular in selective logging systems in developing countries, the efficiency of harvesting and processing can be very low. In unplanned selective logging systems, up to 10% of already harvested trees are left in the forest. Poor felling, cross-cutting, transportation and sawmilling techniques contribute to further loss of wood. Poor marketability of some species and sizes also increases inefficiencies. In charcoal production at small-scale facilities in rural areas, about 20% of the original weight of wood is converted to charcoal, while this is about 35% in modern facilities. Industries are actively engaged in programmes to find new uses for ‘waste’ wood, to market new (lesser-known) species and to improve efficiency through training and better equipment. Still, in some places the abundance of the resource, or its low price, does not stimulate investment in increased efficiency and, hence, technology.

Timber processing

Cascading wood through a range of products leads to a more efficient use of each m^3 harvested. This is accomplished by reusing, recycling and possibly incinerating wood products in a series from high-end uses to low-end uses. This requires sophisticated systems for the collection and recycling of residues, the integration of product chains and the development of innovative technologies to replace virgin resources or even non-wood resources with wood residues (bio-based economy). The industry is playing an important role in driving this innovation.

Apart from paper, opportunities are also emerging for enhancing wood recycling. Through innovative design, return and recycling programmes and expanded investment in recycling facilities, a full range of wood products, from pallets to railroad ties (sleepers) to flooring and construction debris are no longer discarded as waste. Recycled timber is promoted as an environmentally-friendly source of materials in green building codes. There is also a market for used timber as woodfuel.

Paper industry

The paper industry derives about 40% of its raw material inputs from recycled materials and this percentage is growing. In Europe, the corresponding figure is 72% (CEPI, 2014). The global recovered paper demand has grown by about 45% since 2000 and the energy used to recycle paper is about 70% less than when paper is made from virgin wood and raw materials.

Reduced consumption has mainly been an issue in the paper industry. Reduced paper use may save money for companies and lessen impacts related to forest loss, energy use, pollution and waste disposal (Sarantis, 2002). Electronic work processes may have diverted growth in paper consumption over the past decades, but the paperless office never materialized until now. The development of new technologies like tablets is expected to have an impact on paper consumption. Whether or not this has a positive effect on biodiversity depends on the environmental (and social) performance of the substitute products. Electronics manufacturing requires mineral mining that contributes to several environmental and social problems, such as deforestation, ecosystem degradation, poaching, soil and water contamination, land grabbing, slavery/forced labour and illegality. For North America, it is predicted that, by 2015, most publishing paper end uses (magazine, newspaper and book publishing) will fall by 12–21% compared to 2010 levels and will see another 40–50% fall over the next 15 years; market declines are also anticipated in Europe, especially for printed newspapers (RISI, 2014). However, it is less certain whether this also holds for other world regions.

Fuelwood use in developing countries

Programmes to increase cookstove efficiency or replace traditional woodfuel with alternative energy sources (biogas, electricity, fossil fuels, sun) reduce dependency on native forests for woodfuel, especially in Africa and Asia. More than 160 improved cookstove (ICS) programmes are currently running in the world, varying in size, scope, stove technology and financial mechanisms (Ruiz-Mercado et al., 2011). Although the main driver of ICS programmes is health concerns related to indoor air pollution, the potential for biodiversity loss reduction through reducing forest degradation is substantial. Most programmes pay particular attention to improving stove efficiency, stimulating large-scale manufacturing, marketing techniques and financial regulations to quicken adoption. The Global Alliance for Clean Cookstoves (UN Foundation) is a public-private partnership seeking to enable 100 million households to adopt clean cookstoves and fuels by 2020. The Global Alliance target has the potential to 'save' 3–6 million hectares of forest and reduce emissions equivalent to 100–400 million tonnes CO_2.

The technical potential of efficiency gains are not always realised. In the woodfuel and charcoal sub-sector, improved cookstoves could theoretically use 50% less woodfuel or more, but most tests report no more than 25–30% savings (Barnes et al., 1994). It is also more often observed that such stoves, if they are adopted at all, do not necessarily lead to decreased charcoal consumption as long as the charcoal price is not restricting.

Low wood prices are a barrier to implementing these possibilities

A key barrier to increasing efficiency in the supply chains of wood products is the low cost and wide availability of wood. Increasing efficiency – whether this is during harvesting, in sawmills and processing facilities or in recycling programmes – requires technical capacity, planning, infrastructure and investment in equipment and technology. These investments only pay off if the price of wood or secondary products is high. Some government policies, such as log export bans in many tropical countries, depress local prices of roundwood and discourage investment in efficient sawmilling.

Sectoral initiatives to promote responsible corporate behaviour and standards

An increasing number of businesses and their representative bodies adopt principles and standards with the purpose to integrate environmental and social considerations in all aspects of their operations. This goes beyond the adoption of biodiversity-friendly forest management, but entails an explicit consideration of environmental-, social- or biodiversity-related responsibilities in planning, sourcing of raw materials and supplies, process and area management, communication, and so on. This is partly in the context of corporate social responsibility and partly driven by intrinsic strategic considerations about the importance of the social and natural environment for business sustainability. Biodiversity is sometimes an explicit, but more often an implicit component of these policies. For instance, many industry associations and private companies have charters, principles and policies aimed at reducing carbon emissions and deforestation. Examples are the 2020 zero net deforestation commitment by the Consumer Goods Forum (TCGF, 2010); efforts to avoid the entry of illegal wood in product chains; the sourcing of responsibly-produced raw materials or certifying forest areas under control of members (e.g. by the Forest Solutions group - WBCSD, 2012; or the Netherlands' Timber Trade Association's code for good conduct and commitment to sourcing wood from sustainably-managed forests - VVNH, 2014b). In other cases, specific guidance is provided by sector associations to members on instruments and tools to address biodiversity concerns in the business process. For instance, the Confederation of European Paper Industries (CEPI; no date) has issued an overview of best practices related to biodiversity management in order to promote voluntary action.

The financial sector presents a specific case, as it has the potential to influence corporate practices by making environmental or social performance a criterion for lending or investment. Preventing and limiting the negative impact of wood production sector activities on forests reduces financial risk, both in terms of sustainability of the investment and reputational risk. The financial sector is involved in several initiatives geared at promoting responsible investment in resource extraction industries, including the wood production sector. Examples are the UN's Principles of Responsible Investment (PRI), Principles for Sustainable Insurance (PSI), and the Natural Capital Declaration (NCD). Biodiversity is generally one of the components considered in the associated principles or guidelines.

Monitoring programmes for activities and progress are needed

Corporate or sectoral commitments to improved environmental performance must be accompanied by means to report and verify the extent to which companies actually comply. Lack of transparency about stated environmental principles can bear high reputational risks for the companies involved, as shown, for example in the case of Indonesian pulp and paper industries involved in deforestation activities contrary to stated company policies. Forest management certification is used as a tool by the corporate sector for risk management.

The Forests Program of the Carbon Disclosure Project (CDP) provides a system for companies to measure, disclose, manage and share vital information on their operational, reputational and regulatory risks and opportunities resulting from their exposure to deforestation. Timber production is one of the deforestation causes covered, along with palm oil, cattle, soy and biofuels. Some Scandinavian producers and a larger number of processing industries participated in the 2013 survey (CDP, 2013). Global Forest Watch is a forest monitoring and alert system that provides stakeholders with almost real-time open access spatial information about forests through a web-based platform (GFW, 2014).

The ISO 14001 international standards deal with environmental management systems (EMS) for the continual improvement of environmental performance. Most large forestry companies have such a system in place. Although ISO 14001 is not based on a universal outcome-based standard, it is independently audited, and provides a mechanism to set and achieve continuously evolving comprehensive environmental objectives at company level.

Underlying drivers of biodiversity loss are mostly beyond the control of the formal wood production sector

Current wood production sector initiatives to reduce biodiversity loss (e.g. logging practices and processing efficiencies) can be effective where there is direct control over the factors that cause biodiversity loss and when there is good alignment between biodiversity objectives and commercial objectives. However, in addition to the direct drivers of biodiversity loss, their underlying factors should also be considered (IFF, 2000). Table 4.4 summarises some of the underlying drivers of deforestation, how these impact biodiversity, and to what extent the wood production sector is able to influence these drivers. Policy and economic failure and poor governance are the key underlying factors that explain some of the impacts of the wood production sector on biodiversity. Although several are beyond the control of the wood production sector, there are options available either to directly influence some of these drivers, or to work pragmatically around the constraints imposed by, for example, poor governance or inadequate recognition of land tenure.

Table 4.4. Indirect and underlying causes of deforestation and how they lead to biodiversity loss. Substantial is interpreted as: sector has a practical ability to address this driver on a case by case basis. Drivers from IFF (2000).

Underlying drivers of deforestation	How this impacts biodiversity	Possible influence of wood production sector
Poverty	Drives unsustainable or inefficient forest management, illegal harvesting, hunting, lack of investment in forest management	Limited
Lack of secure land tenure patterns	Promotes short-term and unplanned maximisation of production rather than long-term sustainable management	Substantial
Inadequate legal recognition of the rights and needs of forest-dependent indigenous and local communities	Enables alienation of customary (forest) lands for commercial forestry and agriculture	Substantial
Lack of participation	Leads to underestimation of the role of	Substantial

	forests in local people's lives	
Lack of capacity and knowledge	Leads to inappropriate forestry practices	Substantial
Lack of good governance	Leads to inability to develop and uphold agreements and rules and enforce regulations that promote sustainable forest management	Substantial
Inadequate cross-sectoral policies	Leads to overlapping allocation of use rights, including forestry-incompatible land uses such as mining, agriculture	Limited (through advocacy)
Lack of an enabling policy and economic environment, at both the national and international levels	Obstructs the uptake and implementation of sustainable forest management practices	Limited
National policies that distort markets and encourage forest conversion	Reduces the value of standing forest and promotes the financial case for deforestation	Limited
Undervaluation of forest products and ecosystem services	Reduces the value of standing forest and promotes the financial case for deforestation	Limited
Illegal logging and trade	Leads to unsustainable harvest levels and disregard for environmental capacity to sustain harvesting	Substantial

4.5 What are the long-term options in the wood production sector?

To show the potential effects of mitigation options for biodiversity loss, a baseline future pathway (called Trend) and alternative pathways were constructed using the IMAGE-GLOBIO global land-use and biodiversity model framework (Stehfest et al., 2014; Alkemade et al., 2009). The modelling exercise serves to identify the most important options for reducing biodiversity loss from a global perspective. The results provide a general idea of the global potential of solutions in the wood production sector, i.e. sustainable forest management, production intensification with plantations, increased processing efficiency within the wood supply chain and consumption reduction. These options were chosen as they can be modelled in the framework and because sufficient data and dose-response relations are available (e.g. effects of forestry types on biodiversity in terms of MSA). The Trend scenario does not provide an exact description of the trends discussed in the previous paragraphs; its purpose is to provide a benchmark for comparison.

Modelled trend development for wood production and forest use

The main assumptions under the Trend scenario that serves as a reference for comparing effects of options are as follows (for more details see Chapter 2):

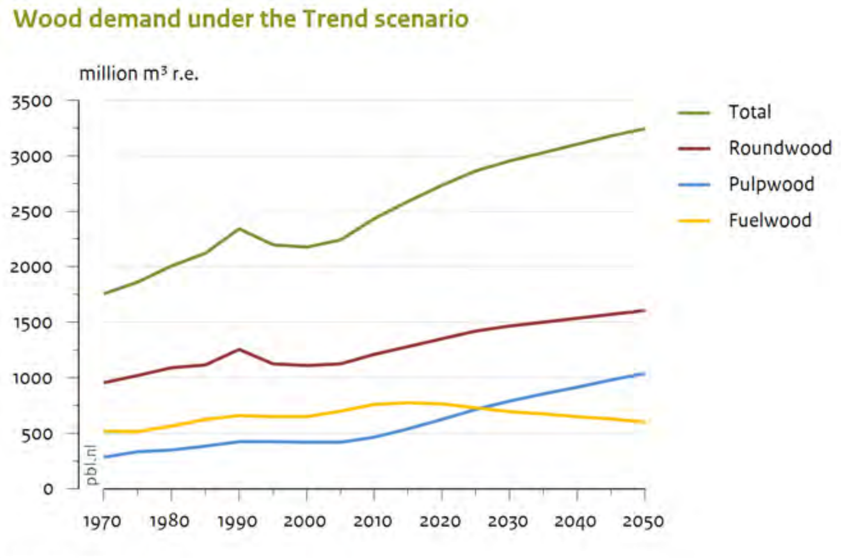
- A 30% increase in the world population between 2010 and 2050;
- A fourfold increase in GDP, causing growth in the demand for food, wood and energy;
- Increased use of land for production purposes as a consequence of these higher demands:
    - agricultural land use (for crops, feed and grazing) is projected to expand by 10% (about 4 million km^2);
    - the total forested area will decrease by 1.5 million km^2 due to conversion for crop production;
    - the area of forest managed for wood production will increase by 70% (about 3 million km^2);
    - insufficient investment available for plantation establishment will limit wood plantation expansion to 25% of the current area.

These assumptions on population and economic growth are identical for the Trend and pathway scenarios.

The following elements of the Trend scenario will be varied in the pathways :

- World food production between 2010 and 2050 is projected to increase significantly (see Figure 2.3), and this will lead to further deforestation. Growth will be driven primarily by an increasing demand for food products in current low-income countries, and especially by the increasing use of animal products in diets.
- World energy consumption is projected to increase by 65%, also mostly in current low-income countries. Under the Trend, energy supply continues to be dominated by fossil fuels, which will contribute to ongoing climate change and related biodiversity loss.
- Global wood demand is projected to increase by a third (Figure 4.3). This will be driven by population and welfare growth. Most of the increase in wood demand will come from growth in paper use (more than doubles), and to a lesser extent to increased demand for roundwood for construction purposes (increases by a third). Under the Trend, the global demand for traditional woodfuel in 2050 decreases by 80% of the 2010 values. This is caused by substitution with more modern fossil energy sources.
- The use of bio-energy is stimulated in present day policies to combat climate change (with positive knock-on effects on future biodiversity). This option requires additional land and other resources with immediate negative impacts on forest biodiversity (van Oorschot et al., 2010). Therefore, the use of bio-energy from woody sources was kept low in all pathways and other technological options were used to mitigate climate change.

The wood demand and production projections are based on projections on timber and pulp from EFI using their Global Trade Model (Kallio et al., 2004). These were slightly adjusted to match the global GDP projections used in the GBO4 scenario. The projected demand for domestic woodfuel is based on output from the IMAGE-TIMER model (Stehfest et al., 2014).



Source: PBL

Figure 4.3. Wood demand under the Trend scenario. Under the Trend scenario, the global wood demand increases by a factor of 1.3 between 2010 and 2050. This is mostly due to increased use of timber and pulp; woodfuel use for cooking and heating will be gradually replaced by other energy sources.

Forest biodiversity loss under the Trend scenario

Total global biodiversity (expressed in MSA) is projected to decrease from 69% in 2010 to 60% in 2050 (see Figure 2.11 and chapter 2) under the Trend scenario. The share of the wood production sector in this future global loss is about 16%; the agricultural sector about a third and the energy sector about half. This contribution of the wood production sector to future loss is mostly on forest degradation; it excludes the biodiversity loss associated with deforestation, as this is largely driven by agricultural expansion in the IMAGE model and is therefore attributed to that sector only (although this is a simplification of reality).

The biodiversity in managed forests is, for a large part, determined by the management intensity (Alkemade et al., 2009). In the IMAGE/GLOBIO model framework, some simplified wood production and management types are distinguished (Arets et al., 2010) and used to calculate trends in used forest areas, and the impact of the wood production sector on forest biodiversity (Stehfest et al., 2014). The MSA values of different forest management types are based on a large number of peer-reviewed studies. In the forest management type 'Selective logging', about 75% of original species abundance can still be found on average. This biodiversity value can be enhanced by applying RIL techniques that result in less forest degradation and leave more trees intact, mitigating the biodiversity loss associated with selective logging (Putz et al., 2012). It was assumed that this will increase the mean MSA by 10%. In forests where clear-cutting and cyclic rotation forms the management practice, the MSA is about 65%. The MSA of plantations using mostly introduced species is 45% (see Figure 4.1).

The area of forest plantations shows a modest increase of 25% between 2010 and 2050. The area where selective logging is practiced grows by about 50%, while the forest area where wood is produced by clear-cutting doubles. Under the Trend scenario, most of the future biodiversity loss of the wood production sector is accounted for by the expansion of the area required and managed for wood production; this grows by 70% (see Figure 2.6).

Effects of alternative future pathways

The alternative pathways address long-term changes in the wood production sector to explore opportunities for a more sustainable future. The CBD goals and long-term targets for 2050 that are relevant here are Target 5: reduce degradation of forest ecosystems; Target 7: areas under forestry are managed sustainably; and Target 11: 17% of terrestrial areas of interest to biodiversity are protected (CBD, 2010). The different pathways fulfil these targets in different ways, with different options for the wood production sector (Table 4.5).

Table 4.5. Main characteristics of alternative pathways in the wood production sector to achieve the 2050 goals.

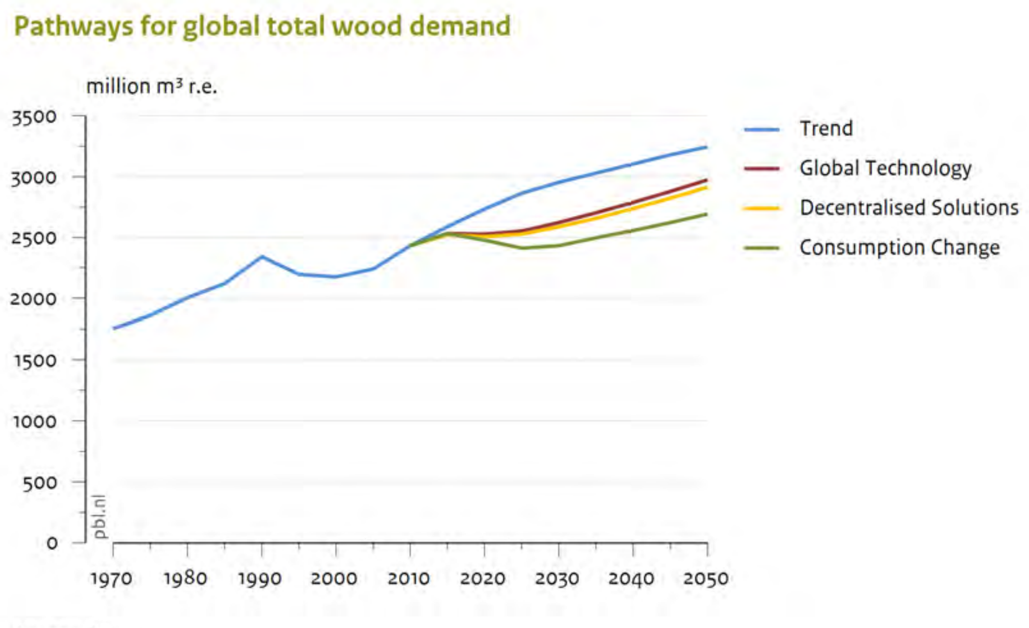
Pathway	Main assumption
Global Technology (GT)	Focus on large-scale, technologically optimal solutions, such as intensive agriculture and wood plantations with high yearly yields.
Decentralised Solutions (DS)	Focus on decentralised solutions, such as sustainable use of natural and semi-natural forests agriculture that is interwoven with natural landscape elements, and local sustainable energy production.
Consumption Change (CC)	Focus on changing human consumption patterns, most notably by limiting wood demand for paper and construction. Includes ambitious efforts to increase resource use efficiency and waste reduction (less material-intensive lifestyle).

Developments in other sectors, most relevantly in agriculture, take place simultaneously and result in both synergetic and counteracting effects as they both affect forest ecosystems and forest management. The most important cross-sectoral issue is increasing food production. More agricultural production is required to feed a growing and increasingly affluent population, and this leads to enhanced deforestation. The conversion process also provides a source of wood, although this is unsustainable as it reduced the forest resource.

In line with these narratives, specific assumptions were made to assess the quantitative outcome of the three pathways (Table 4.6).

Global wood demand is lower in all pathways compared to the Trend scenario (see Figure 4.4), due to different underlying causes:

- Lower demand for woodfuel in all pathways (about half), mainly due to the introduction of modern (fossil-based) energy sources for cooking in developing regions, which is a separate 2050 target ('modern energy for all').
- In the Consumption Change (CC) pathway, roundwood demand for purposes such as construction, paper and packaging is lower due to substitution from other resources, and due to lower wood consumption. Wood and paper waste are increasingly re-used, recycled or used for generating bio-energy. The GT and DS pathways do not contain strong incentives for reduced consumption.
- Less climate change mostly due to low-carbon energy systems. This will benefit future forest biodiversity. The assumed technology mix needed to achieve greenhouse gas reductions differs between the pathways.



Source: PBL

Figure 4.4. The future demand for wood (timber, paper and woodfuel) in the alternative pathways is lower than under the Trend. The growth in demand between 2010 and 2050 is almost 70% lower in the Consumption Change scenario.

Changes in wood production and forestry

There are several options for reducing the impacts of wood production by applying different forest management methods. In summary, wood is produced more efficiently in the pathways by expanding high productive wood plantations, and forest degradation is reduced by applying less damaging harvesting techniques:

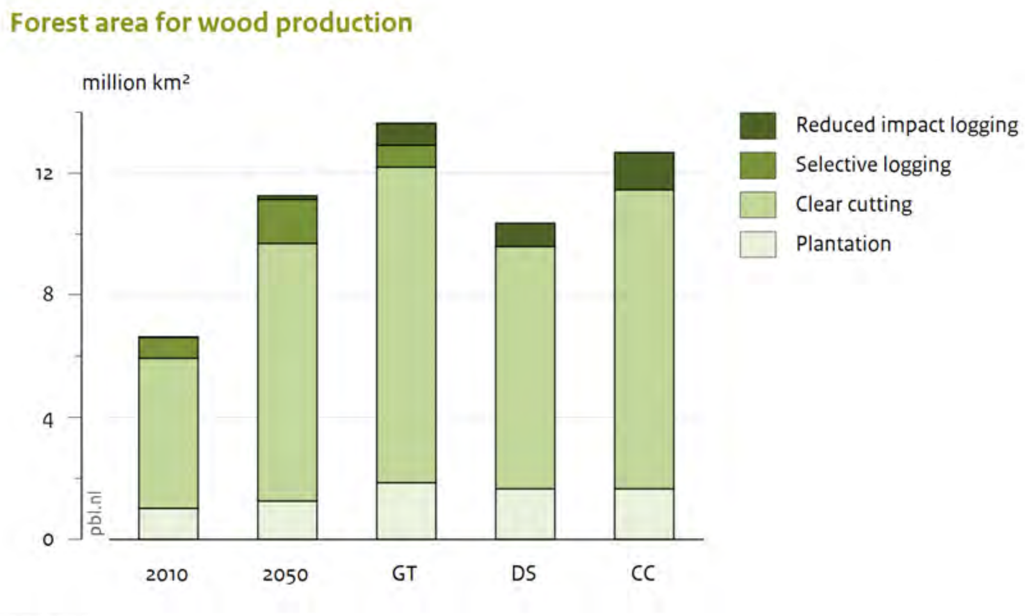
- An increase in production from plantations is assumed in all pathways. Up to 50% of the total wood demand will be supplied by these highly productive systems by 2050. The area dedicated to plantation forestry will increase by 80% in GT, compared with 25% under the Trend. In the other pathways, the plantation area will increase by 65%. The large-scale establishment of plantations is required for this option. Planting is preferred on degraded lands (abandoned from agricultural use), to limit adverse biodiversity impacts from this increase. Options for additional plantations are mostly found in regions with widespread recent deforestation where the land is abandoned or used for extensive cattle ranching (Southeast Asia, Central and South America).
- The selective logging of commercially valuable trees is a common practice in tropical forests and an important cause of forest degradation. The damage can be reduced using better planning and logging methods, commonly referred to as reduced impact logging (RIL). In the CC and DS pathways, forest management of nearly all selectively-logged forests will shift towards RIL; in GT this is partly applied as most investment goes to establishing plantations. Possibilities for applying RIL are concentrated in sub-Saharan Africa, Southeast Asia and parts of South America.
- Reduced deforestation is also necessary to reduce forest biodiversity loss. In the GT pathway, less agricultural expansion is required as agricultural yields increase importantly. As a result, deforestation almost comes to a halt after 2020. In the CC pathway, deforestation is also reduced, but here mostly due to lower demands for food, feed and wood. In the DS pathway, deforestation still exists after 2020, as the agricultural developments follow a different route. The focus in this pathway lies on local biodiversity-friendly agriculture, with a lower increase in productivity than in GT.

Table 4.6. Scenario elements of the wood production sector in the different pathways.

	Trend (baseline)	Global Technology (GT)	Consumption Change (CC)	Decentralised Solutions (DS)
Demand-side options	Consumption increase following demographic and economic growth. Part of the wood fuel demand is replaced by more modern fuels.	Increased replacement of traditional wood fuel by non-wood fuels (50% of Trend).	Like GT. Additionally, reduced consumption of roundwood (timber) and pulp (paper).	Like GT.
Waste and resource recovery	No strong incentives for increased waste recovery or recycling.	Like Trend.	Global increase in recovered paper. Waste reduction.	Like Trend.
Supply-side options	Modest increase in forest plantations. Selection systems in intact forests.	Strong increase in wood supply from plantations (50% of demand), mostly on abandoned agricultural lands. Partial adoption of RIL in selective logging.	Increase of wood supply from plantations, preferably on abandoned land. Full adoption of RIL in selectively-logged forests.	Increase of wood supply from plantations, preferably on abandoned land. Full adoption of RIL in selectively-logged forests.
Spatial differences	Standard distribution of supply and demand, and wood trade.	Similar to Trend.	Similar to Trend.	Regions move towards maximum self-sufficiency.

Changes in total forest area in use for wood production

A larger area for permanent forestry will be required to satisfy global wood demand in the GT and CC pathways compared with the Trend. In the GT pathway, the total area of forest managed for wood production by 2050 will be 30% higher (see Figure 4.5). The additional area with permanent forest management is needed to compensate for the amount of wood that is no longer obtained from deforestation processes, while the newly-established plantations still need maturing to become productive (30 to 40 years). In the CC pathway, reduced consumer demand is important for reaching the targets, and there is less investment in plantations than in GT. Here, the area needed for wood production in 2050 is about 25% higher than under the Trend. In the DS pathway, deforestation still occurs as increases in agricultural productivity are lower than in the other pathways. The forest area that is managed for wood production can be lower than in the other pathways as there is a continuing supply of conversion wood. So in this scenario, part of the wood production sector still operates in an unsustainable way, that cannot be maintained on the long run.



Source: PBL

Figure 4.5. The future global forest area needed for wood production is higher in the GT and CC scenarios than under the Trend. This is the consequence of interactions with the agricultural sector: in GT and CC deforestation is partly avoided and more permanent forest area is required to compensate for wood that is no longer produced during forest conversion.

Changes in forest biodiversity under different pathways

Net biodiversity loss resulting from changes in forest management systems is projected in two of the three pathways (Figure 4.6). Only in the Decentralised Solutions pathway, there is a net biodiversity gain of the combined options in the wood production sector (positive value for prevented MSA loss, compared with the Trend). The most important drivers of the additional loss are the additional areas for plantations and the increased area with clear-cutting practices.

In a previous scenario study, a similar set of options in the wood production sector were taken, in the absence of developments in other sectors. In that partial analysis, there was a clear long-term positive benefit for biodiversity (ten Brink et al., 2010). In the present study, the potential effects of all the options taken in the wood production sector are obscured here by interacting effects from the agricultural sector, that are simultaneously affecting the forest biome. Increases in forest areas with clear-cut practices (GT and CC pathways) are the consequence of reduced forest conversion, as explained above. Only in the DS pathway, this effect does not take place, as in this pathway part of the forest conversion continues up to or even beyond 2050. Establishing plantations leads to additional loss in forest biodiversity in all pathways as plantations contain low biodiversity values. When plantations can be established on low-biodiversity areas (reforestation), part of this loss can be prevented. Improving selective logging practices using RIL leads to biodiversity gains in all scenarios, but this change is relatively small compared to the increase in plantation and clear-cut areas.

Reduced deforestation also affect forest biodiversity. In the pathways with substantial agricultural productivity increase (GT and CC pathways), there is a biodiversity gain from avoided forest conversion. This effect can only be partly attributed to the wood sector, as it is mostly the consequence of lower expansion in the agricultural sector. And then there is the effect of reduced climate change, that is also positive for the future biodiversity of the forest biome. Improvements in forest management may also help improve the carbon storage function of managed forests, such as reducing forest degradation by implementing RIL practices and establishing high production plantations on degraded lands. As far as these positive biodiversity effects of global greenhouse gas mitigation are linked to forests, they can be attributed to the wood production sector.

These scenario analyses show that there are crucial interactions between the agriculture and forestry sector that must be taken into account when designing robust and integrated sustainable future pathways that meet the biodiversity targets in different ways. Is also points at the importance of increasing and promoting sustainable forest management practices, as the area of permanent forest that will be used for wood production will increase in response to reduced deforestation.

Source: PBL

Figure 4.6. Biodiversity loss in the different pathways as a consequence changes in the wood production sector and changes in deforestation that are driven by changes in agricultural yields. The modelled options have both positive and negative effects on total biodiversity loss. Only in the Decentralised Solutions pathway there is a net biodiversity gain.

4.6 Priority actions to promote the options that can reduce biodiversity loss

Many option are available for different actors along the wood supply chain

As forests harbour a large percentage of the world's terrestrial biodiversity, the wood production sector has a large responsibility for the conservation and sustainable use of the world's biodiversity. Several options exist for different actors along the supply chain to contribute add to this challenge. Some options lie outside the influence sphere of the wood productions sector. Rising consumption and stopping deforestation lead to several necessary actions for improvements in the wood production sector.
In short, the key necessary actions are:

- intensify efforts to implement sustainable forest management, especially in the tropics;
- strengthen the business case for responsible wood production;
- the sustainable expansion and intensification of plantations;
- improved land-use planning to balance the different claims on forests;
- increase resource use efficiency;
- address informal and small-scale production.

In the following, the options are first briefly described and then the actions needed to promote them are elaborated upon.

At the beginning of the supply chain, responsible management of forests is essential. This means that production practices must avoid deforestation, reduce forest degradation and utilise wood and wood products as efficiently as possible. Better management of existing forests should go hand-in-hand with an increased focus on the planting of forests and agro-forests on set-aside lands and restoring degraded forest lands. For woodfuel production and other local wood uses, the integration of plantations and tree planting and management within agricultural landscapes may help to reduce the effects of wood-gathering from natural areas.

At the consumption side of the supply-chain, the use of certification systems for sustainable production such as FSC and PEFC and private procurement policies help to stimulate the responsible forest management and wood production. Other options along the supply chain include the reduction of wood consumption, processing efficiency improvements, the improved recycling of wood products and the substitution of wood by alternatives.

To a greater or lesser extent, the sector has been making progress with respect to all these options – the challenge is to make better use of existing opportunities and to engage those who currently stay behind in adopting biodiversity-'friendly' practices. An increasing number of businesses see responsible forest management as a fundamental component of a long-term business strategy. For these businesses , the dependency of the sector on biodiversity and ecosystem services provides an important rationale for mainstreaming biodiversity into business decision-making. Another part of the wood production sector sees biodiversity and other social and environmental concerns primarily as a cost rather than an investment in sustainable business and corporate responsible operations. This can be simply because of short-term financial interest at the expense of public goods. Building a better business case for biodiversity conservation in the wood production sector remains one of the more fundamental challenges for the next decade.

Measures by the wood sector alone are not sufficient to address all drivers of biodiversity loss and especially causes of deforestation, some of them are simply not within reach of the sector (see Table 4.4). It must be realized that several of the underlying causes listed in Table 4.4 are out of reach of improvement sin the wood sector alone. Some drivers require concerted action with government, civil society and consumers. For instance, integrated land-use planning by means of zoning (including setting aside high conservation value areas, identifying areas for intensive or extensive use, and avoiding vulnerable areas) and the establishment of biodiversity corridors is important to complement responsible management of production forest.

More complex is the situation of the majority of small producers in developing countries. A clear dichotomy is present in the wood production sector. On the one hand, a part of the wood production sector is well-integrated into the market economy, more or less capital-intensive, uses the resource as a long-term asset, and is sensitive to public and civil scrutiny. And on the other hand, the part that operates informally, is focused on satisfying subsistence and local demands for wood products. This part of the sector is driven by a large local demand for low cost and low quality produce, an abundantly available resource and the availability of a large pool of labourers with few alternative livelihood opportunities.

Changes in practices of informal and local actors, who are involuntarily locked into unsustainable business practices will require a high degree of involvement of the government and civil society. Building capacity for sustainable forest management is crucial here, and improving policies and compliance mechanisms to reducing illegal practices.

Stimulate the implementation of sustainable forest management

Stimulating sustainable management of natural and semi-natural forests remains an important strategy, especially in the biodiversity-rich tropical forests. Concerted action between the private sector, governments and civil society is needed to take actions such as: increase trade in responsibly-produced forest products through the certification of sustainable forest management, and stimulating demand for certified products through measures like green procurement policies, green building codes, and consumer-oriented actions. It is also important to reduce the cost of certification; to simplify certification requirements without compromising on its objectives; making standards more locally tailored; and supporting producers in adjusting management practices towards sustainable forest management.

The performance of certification in terms of reducing biodiversity loss can be improved by continuously monitoring the performance on biodiversity-relevant criteria and indicators in assessments, and disclosing the information publicly to help and improving certification standards in revision procedures, and by supporting this process through research on the effects of forest management and certification on biodiversity.

In the boreal and temperate zones, a substantial proportion of production and trade is already certified. However, there are a number of possible ways in which standards relating to biodiversity and ecosystem services could be improved. Standards should include clear and consistently- understood terms, definitions, and approaches, and should ensure that all safeguards that address the key pressures on biodiversity and ecosystem services are included (CBD and UNEP-WCMC, 2012; p. 5).

In the tropical zone, the situation is less advanced than in temperate and boreal zones, with only a minor part of the forest area under sustainable management. To further mainstream certification in the tropics requires concerted private and government action to close the door to trade in illegal wood products, not only in the North-South trade but also in the domestic and South-South trade, and to increase the demand for sustainable wood products.

Government and NGO efforts are needed to raise environmental and social awareness and standards in markets where this is currently not a concern (specifically the large markets in Asia). Governance and market failures in production countries should be addressed, for example by implementing Voluntary Partnership Agreements and investing in local technical and managerial capacity required for sustainable forest management, and by implementing national Codes of Forest Practices. These are efforts that will not pay off in the short term but will have a large effect on reducing biodiversity loss.

Within the spectrum of forest management actions, two options stand out that directly contribute to reducing biodiversity loss. Primary and old growth forests harbour the highest and most specific forest-dependent biodiversity and are increasingly rare, especially in accessible and commercially-attractive forest types. Forest operations should avoid these areas and concentrate on the management of already intervened forests. Secondly, forest road networks, especially in previously inaccessible forest areas, facilitate the human invasion of forests and lead to stepwise forest degradation, loss of wildlife and deforestation. Good road network planning and management of access is a critical contribution to reducing this biodiversity loss.

Responsible expansion and intensification of plantations

The low cost for land and labour, good production conditions and the shift of markets and demand to the East and the South make the global South the favoured area in which to establish new plantations and associated processing plants. These are often areas with a high native biodiversity. Most plantations – those consisting of exotic species more so than those of native species – have a low significance for biodiversity. Plantations will only contribute to reducing biodiversity loss when their establishment is not associated with replacing native vegetation with plantations. This works if plantations are efficient and productive, if avoided forest loss is not undone by other expanding land-use demands, and if plantations are well integrated into wider landscapes that continue to conserve biodiversity and other ecosystem services. High value natural forests, local socio-economically important forests and plantations should be treated as integrated components of the landscape.

The main option available to the private sector to achieve this is to steer plantation development towards degraded or abandoned areas using the High Conservation Area approach or other approaches that integrate environmental and social criteria into land- use planning. Explicit and spatially-coupled biodiversity offsetting mechanisms (whereby areas within the region are conserved in compensation for the conversion of land into plantations) and payments for environmental services systems may be needed to fully achieve the biodiversity benefit.

An unintended consequence of investment in highly productive plantations may be a reduction in the economic and financial value of natural and semi-natural forests to many stakeholders, increasing the likelihood of its conversion to alternative land uses. The net effect on biodiversity will be negative. It is important to make sustainable forest management generally more attractive by increasing the financial value of standing forests (see below).

Increased efficiency and recycling in pulp and paper industries

The main options for reducing biodiversity impacts available to processing industries such as pulp and paper plants are well-aligned with their primary business interests: to reduce the inputs of raw materials and increase the efficiency of water, energy and wood fibre use, to increase the use of recycled fibre as a raw material and to promote wood cascading in general. This requires investments in research and development and human resources, as well as in processing technologies. The increased use of residual materials requires investment in recycling technology and collection systems.

The responsible siting of new processing plants is a very important determinant of sustainable resource use. Large-capacity paper and pulp mills create their own demand, and unless this can be satisfied by sustained production from plantations and other well-managed wood sources, there is a high risk that high-biodiversity natural forests will be used to feed the mill.

Strengthening the business case for responsible wood production

Measures to reduce biodiversity loss beyond the legal minimum will generally be seen as an operational cost that must be balanced by some form of financial, marketing or reputational compensation. In developing countries in particular, the sustainable management of natural tropical forests needs to cope with competing land uses. Sustainable forestry is less profitable than some forms of agriculture, and also urban development and mining (Blaser et al., 2011). It is also less profitable than unsustainable or illegal logging and trade. The business case for responsible forest stewardship in developing countries further suffers from lack of clarity about tenure, corruption and unclear and dynamic land-use policies. Biodiversity and other forest functions are served by a sustainable and profitable wood production sector with a long-term involvement.

Therefore, a key action is to increase the value of standing forests and strengthen the business case for sustainable forest management. This requires that the costs of negative impacts of harvesting and processing are internalised in the price of wood products (giving sustainable operators an advantage), and that the costs of social and environmental impacts are factored into the price of agricultural products. Responsible management of forests should be rewarded by preferential access to markets, investment in forest resources and by adequate prices. Governments and investors could stimulate the development of markets for non-timber ecosystem goods and services provided by forests (e.g. REDD+ and payments for environmental services), and create the conditions that allow responsible producers to sell these good and services. Increasing the social and economic value and competitiveness of standing forests will contribute to their long-term viability.

A further option to weaken the business case for unsustainable logging is to halt illegal logging and trade. This can be achieved by enacting proper legislation, tightening rules and enforcing them (taking account of the effects of stricter regulation on the informal sector and poor forest-dependent people), governance reform and closing markets for illegal produce.

Address informal and small-scale producers for domestic markets

In many countries, natural resource policies and regulation are export-oriented and disregard the existence of a local and growing demand that must be satisfied in a well-regulated way. The established sector benefits from inequities in regulation, fiscal policies and allocation of resources and is associated with vested political and economic interests. There is little interest in improving the position of the small-scale sector. Especially if export markets are more lucrative, this requires active policies to regulate the availability of wood products in places where local demand exists. Allocation of forest resources to local operators and quotas for the local market (as in Ghana; Wit & van Dam, 2010) may be needed to satisfy local demand.

A key challenge is to reduce the biodiversity impact associated with the vast quantity of wood produced for local and domestic wood and energy consumption by millions of small, more or less informally operating businesses (individuals, smallholders, communities and locally controlled forest enterprises), mostly in developing countries. Inadequate access to resources, technology, finance, and markets, poor organisation and representation, lack of power in an unfavourable political and economic environment, competition with illegal loggers, unfair and unnecessarily complex rules and regulations are just a few of the impediments to businesses operating in this field. The main options to address these issues must address the underlying governance and market failures.

A common response to informal and illegal operators is regulation and stricter enforcement; however this does not address the problem if illegality is linked to poverty, unfair regulations that favour elites and lack of legal access to forest resources. Promising options include the design and implementation of positive regulatory and fiscal policies and incentives that reward good practices. Examples are the implementation of a proper system of fees and taxes that reflect the value of the resource and encourage efficient harvesting and processing, better sharing of fiscal revenues from wood products down to local administrative levels, reinvestment of tax revenues into the sector and transparency about resource allocation. One of the more important aspects of good governance is the clarification of land rights and forest use rights, fair allocation of harvesting rights and removal of inequitable and conflicting policies about land. Initiatives that increase the stake of local people in forests and wood production and stimulate their long-term participation in it are likely to reduce illegal and unsustainable behaviours by other forest users.

A promising currently-implemented option for local markets that relates to supply chain governance is provided by expanding the Voluntary Partnership Agreements between the EU and producer countries (or similar arrangements) to cover as many countries as possible, and to include the domestic market for timber and woodfuel in the scheme. VPAs are the result of an open and participatory process and provide incentives to the established exporting wood production sector and government to agree to forest policy reform. Through their focus on legality, VPAs lead to the better enforcement of local biodiversity-related legislation. The scope of VPAs is currently limited – they cover nine tropical countries, mainly focus on export markets and never include woodfuel, but where domestic markets are included (e.g. in Ghana and Cameroon) they have a high potential for the sector-wide improvement of forest governance. REDD arrangements, National Forest Programmes and other similar initiatives that focus on the development of good governance in the wood production sector may have a similar effect, but lack the binding nature of VPAs.

Chapter 5. Water management

5.1 Introduction

Freshwater is a key resource and medium for various economic sectors. The availability of freshwater is unequally distributed across the globe, both in space and in time. Water is used for a variety of domestic and productive purposes, often at the expense of natural ecosystems. The main sources of freshwater are precipitation, groundwater and, especially, freshwater ecosystems such as rivers, lakes and wetlands. Freshwater ecosystems often sustain a high biodiversity. The many competing claims on the freshwater systems, for cities, industry, agriculture, energy and transport, cause problems with both water quantity and water quality, leading to substantial stresses on water-related biodiversity and ecosystem services. As floods, either from the sea or from rivers, are one of the main weather-related disasters occurring worldwide, water safety (flood protection) is another important issue. It is stated that the 'Anthropocene' (the era of the global impact of man on the biosphere) started with the regulation of the world's water courses and water bodies (Steffen et al., 2011; GWSP, 2014). The combined impact of canalisation, damming and other infrastructures on the world's water systems is enormous; about 70% of the world's rivers are heavily impacted (MEA, 2005; Vörösmarty et al., 2010). Making biodiversity preservation part of the sustainable use of aquatic systems is a challenge for the agricultural, river basin and urban water management sector that is operating in a complex interaction with spatial developments and a wide variety of users. The question addressed here is to what extent mainstreaming biodiversity can help the water sector deal with the many competing claims on water systems while at the same time maintaining their natural quality and services as much as possible.

This chapter discusses the main relationships between biodiversity, ecosystem services and freshwater management. After a short description of the sector, its interactions with other sectors and the main challenges (Section 5.2), we describe benefits of and impacts on biodiversity and ecosystem services for the sector (Section 5.3), current water management activities in favour of biodiversity and factors hampering or stimulating their broader use (Section 5.4), and long-term options (Section 5.5) and possible actions (Section 5.6).

5.2 Description of the sector

Setting the scene: the context for water management

The water management sector has its roots in the need to regulate water systems, provide freshwater and protect people, assets and land from flood disasters. This is a need that emerged early on in our history. Water management is perhaps not so much a sector on its own, but rather a collection of sub-sectors serving other sectors by adapting and managing aquatic systems (rivers, lakes, wetlands, aquifers and coastal waters, also including the use of rainwater) in such a way that they meet the requirements of the different users. Often various separate organizations at different levels deal with water management in a country, from individuals, e.g. well owners, through cooperatives, dedicated government or private line agencies, to entire separate ministries, not always in a well-coordinated way. Together these can be regarded as a sector that strongly depends on and influences other sectors. The sector has greatly contributed to economic development, by regulating the world's water courses and water bodies, distributing water for economic needs and reducing flood risks. The sector is an important economic player, with the world market for water and wastewater projects amounting to about 300 billion euros in 2010 (WssTP, 2010).

Technological developments mean that the physical management capacities of the sector have increased enormously over the last 50 years, particularly in the developed parts of the world. Many rivers and other water bodies are regulated for abstraction and the distribution of water for agricultural production, navigation, flood protection, water storage, drainage or power generation. In addition to these activities dealing with water quantity, securing the quality of the water (drinking water as well as sanitation and wastewater treatment) has become an increasingly important task.

The main users of water are households (for drinking water, cleaning and sanitation), agriculture, forestry, industry, mining, energy, transport, recreation, fisheries and aquaculture. Increasingly, nature is recognized as a separate user in several countries. These users differ highly in their demands and in their effects on the quantity and quality of the water as well as on the shape (morphology, level of canalisation, disruptions) of the water bodies (Table 5.1). Of these, agriculture is the 'thirstiest' production sector, using about two thirds of the water that is mobilised globally from surface and groundwater (Figure 5.1; Molden, 2007).

Table 5.1. Groups of water users with an indication of their specific water demands and selected impacts. Source: PBL and Water Health.

	Relative requirements		Impacts on		
Users	**Quantity**	**Quality**	**Quantity**	**Quality**	**Morphology**
Households (drinking water)	Low	**high**	low	low	low
Cities (wastewater)	Low	low	low	**high**	low
Food production	**High**	moderate	**high**	moderate/ high	**high**
Industry	moderate	moderate	low	**high**	low
Transport / navigation	moderate	low	moderate	low	**high**
Energy	**High**	low	low	low	**high**
Nature (river flows)	moderate/ high	**high**	low	low	low
Flood protection	moderate	low	moderate	low	**high**

The increasing demands of most users challenge water management in many parts of the world as it is increasingly difficult to meet all water quantity and quality requirements simultaneously. Mainly as a result of water abstractions for agriculture (Rockström et al., 2009a), many areas in the world are faced with water stress (a situation where the water demand is higher than the amount of available water) and river basins are closing, which means that the remaining outflow from a basin is not sufficient to serve downstream purposes (Molle et al., 2010). The proportion of the world's population living in areas with a water shortage is expected to increase from 30% in 2010 to over 40% in 2050, with concurrent deteriorations in water quality, particularly in non-OECD countries (OECD, 2012). It is expected that, by 2050, some 4.3 billion people will live under severe water stress according to Trend scenario (see chapter 2), mainly in South Asia, the Middle East and North Africa, as well as large parts of China. Ongoing climate change will further aggravate most of these water quantity and quality issues, also compromising the ecological values of terrestrial and aquatic ecosystems (e.g. Bates et al., 2007; WWA, 2009). Urgent solutions are required in cases of competition between different uses, for instance where hydropower dams disrupt migration of important fish species; between upstream and downstream communities; and when pollution by one sector makes the water unsuitable for other uses (e.g. WWA, 2012).

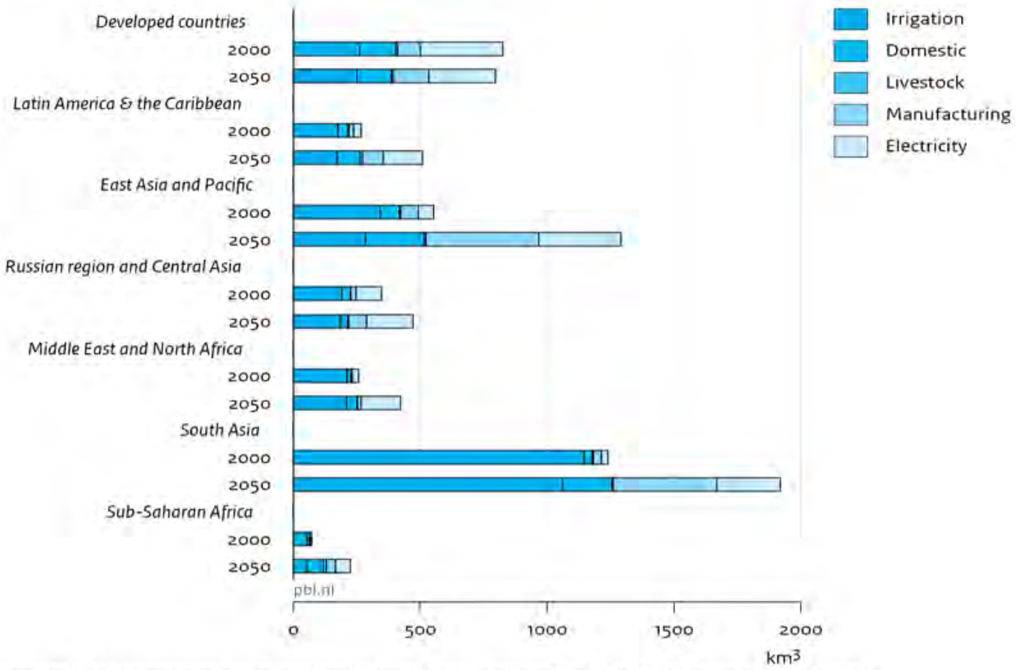


Figure 5.1. Freshwater demand (excluding nature) in 2000 and 2050 under the Trend scenario, with the various productive sectors using relatively more or less water in different parts of the world. Source: OECD, 2010.

In view of these competing claims, the general aim of the water management sector is then to regulate and manage water resources and water bodies to meet societal needs, in other words to ensure both human water needs (for households, cities, food production, fisheries, recreation, industry, energy and transport sectors) and water for nature (Falkenmark, 2003). Water management therefore needs to 1) secure the supply of sufficient freshwater, at the right times, to all of these users, 2) secure an acceptable water quality for all users, 3) provide adequate shipping routes and facilities, and 4) prevent damage by a surplus of water (flood protection). Fulfilling these goals depends on ecosystem services and biodiversity, but at the same time high water abstractions and canalisation may have detrimental impacts on biodiversity and ecosystems, thus threatening its own sustainability.

Organisationally, it is hard to delimit the freshwater sector, with responsibilities spread over many other sectors. For example, ministries of agriculture, energy, health and transport each have water-related strategies, are responsible for policy-oriented tasks and are politically driven. At an intermediate level there are public and semi-public actors such as river basin organisations (sometimes international, for transboundary rivers), water/drainage/sewerage boards and lake management authorities that generally operate under government rule, although with a varying degree of independence. At lower levels, the more technical implementation tasks are carried out by a range of formal and informal organisations, individuals and companies, either government-owned, privately-owned or mixed, such as engineering consultants, NGOs, constructors and equipment suppliers, water committees, contractors such as dredging or drilling companies, artisans, wastewater treatment facilities, farms and drinking water companies, organised in different ways in different countries. Integrated water resource management (IWRM), encompassing the entirety of water bodies in a basin and operating flows for all uses and users, dates from 1992 so is not new, but has always been a challenge to operationalize in practice. The question within the context of biodiversity preservation and the sustainable use of ecosystems and resources is whether, or how, the water management sector will be allowed to set out more sustainable pathways of ecosystem use and development. Its mandate for this will depend to a large extent on international and national goals and regulations and the willingness of international and national operating businesses to contribute to the sustainable and wise use of water systems (see for example Keys et al., 2012).

As a supporting sector, water management itself is organised in various sub-sectors that adapt and manage water systems to make them meet specific societal demands, while operating in a wider societal context. Both the state of the water systems and the water management demands depend on developments in other sectors, influenced by social, economic and political decision-making. The sub-sectors addressed in this chapter represent investment pathways as well as hotspots in terms of biodiversity dependencies and impacts.

From Table 5.1 it is clear that *water for food* not only requires the most water, but that its impacts are also highest, on both terrestrial and aquatic ecosystems and their biodiversity (see also Chapter 3). The energy sector, especially *hydropower* generation, is a strong economic force as well, with large-scale impacts on rivers. With population growth and increasing urbanisation, *cities* combine the high impacts on water quality of households and industry, releasing continuous flows of (in most countries) only partly treated wastewater into the environment, affecting aquatic biodiversity as well as downstream terrestrial ecosystems. Urban areas can thus be considered hotspots of water-biodiversity interactions. Finally, *flood protection* may lead to structural changes in the shape of rivers and wetlands, affecting their integrity. The navigation sector does have locally important impacts, especially on rivers and estuaries, without much impact on water quality and quantity. The main requirements for ship and harbour facilities include accessibility of water courses with sufficiently high water levels, without demands on water quality; the construction of inter-basin canals, however, can promote the distribution of non-native species Requirements and impacts of water and sanitation in rural areas are diffuse and less important at the global level compared with the investment pathways discussed here.

Challenges for cities, urban water management and biodiversity

An important worldwide trend is that more and more people are becoming concentrated in cities. In our Trend scenario, by 2050 nearly 70% of the world’s population is expected to live in cities, which implies an urban population increase of 2.8 billion compared with today. This concentration of the population creates both opportunities and challenges for the water sector (PBL, 2014). A focus on urban water management and biodiversity encompasses drinking water supply (demand for a continuous supply of good quality water), water for industries (higher quantities and impacts on water quality), as well as wastewater management (treatment requirements, downstream impacts). Worldwide, 748 million people (11% of the population) still lack access to safe drinking water, though most of these live in rural areas (WHO and UNICEF, 2014). The drinking water sector asks for water with a low level of microbial and toxic pollution and without algal blooms. This is often derived from groundwater and natural sources that depend on healthy terrestrial ecosystems, in some countries also from filtered surface water. Consumer water quality guidelines set by WHO (2011) are often translated into national standards for various water uses, while for instance UNEP strives to encompass water quality management strategies across sectors (UNEP, 2010b). Although water treatment technologies are improving, drinking water companies remain very keen on good quality intake water, as not all pollutants can easily be removed and to maintain a low price for consumers.

In urban areas, separate systems are required to collect and treat wastewater before it can be released to the environment. Many cities in the world, especially in low income countries, lack a central sewerage system (Figure 5.2). While urban water supplies and sewerage are often managed by public agencies, sewage collection from septic tanks is often carried out by private enterprises.

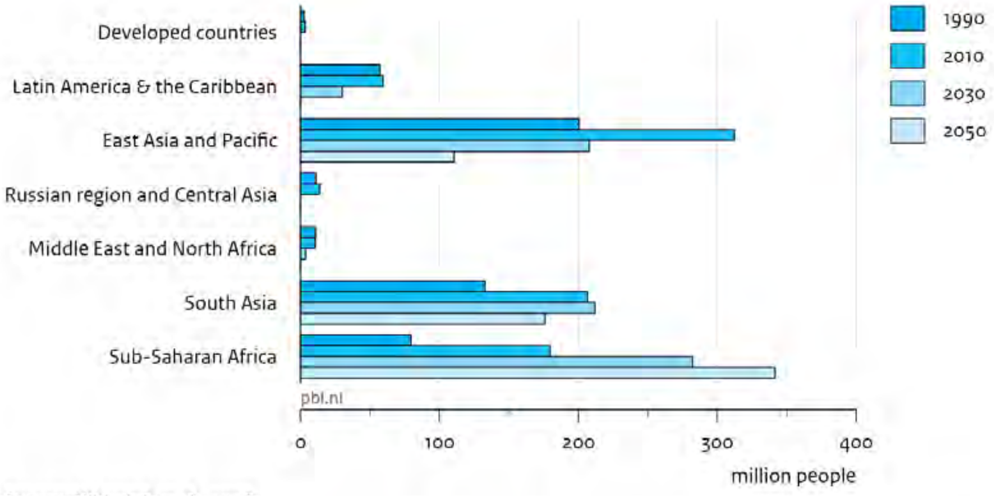


Figure 5.2. Population without improved sanitation in urban areas, 1990, 2010, 2030 and 2050 in Trend scenario. Source: PBL, 2014.

The water needs of industries depend highly on the type of industry. For example, mineral water bottlers, beer breweries, soft drinks factories and distilleries require high quality clean water. Many other industries, mining and energy companies mainly require water for cooling, with minimal requirements for its quality. Industries do impact freshwater systems through pollution and by increasing its temperature. Environmental laws may set limits on the water that industries can return to the system; sometimes in-house wastewater treatment is required before the water can be released, especially in high income countries.

Challenges for water for food

Water for food production (see chapter 3) includes the use of rainwater, irrigation of crops in cases of water shortage, drainage in cases of excess; the food processing industry; aquaculture; water for livestock; and inland fisheries. All these uses need sufficient water of the right quality but may impact water quality negatively by diffuse pollution from pesticides and nutrients (covered in Chapter 3). Wetlands deserve special attention as they are hotspots of biodiversity but threatened by reduced water inflow, pollution and conversion into agricultural land or habitation (e.g. MEA, 2005; Revenga et al., 2005; Junk et al., 2014).

For cropland and forest plantations, the main water issues are the quantity of the water supply during the growing season (sufficient but not too much), compliance with salinity standards and low toxicant levels. Water is an important production factor for farmers, over which they do not often have sufficient control. In regions with seasonal or annual precipitation surplus, agriculture requires drainage facilities during wet seasons and a water supply during dry seasons. Individual farmers or groups of farmers may have their own (informal) arrangements for irrigation and drainage at field level, though usually some sort (formal) organisation is required to mobilize water at a larger scale – be it for irrigation or drainage. These tasks are often carried out by government agencies such as irrigation or drainage boards residing under ministries of agriculture, though higher level management may fall under the authority of ministries of water resources.

Agriculture uses high quantities of water; in addition to rain it uses some 70% of the freshwater withdrawn from surface and groundwater globally; locally up to 90% (Molden, 2007; Cai & Rosegrant, 2002). In numbers total water use is around 5 000 km^3 for rain-fed agriculture and 1 800km^3 for irrigated agriculture (Molden, 2007). As other inputs are usually kept optimal in irrigated agriculture, this produces 40% of the world's food with 22% of the water consumption (de Fraiture et al., 2010). Water quality problems often arise in areas with irrigated agriculture and aquaculture (Beveridge et al., 1997). In irrigated areas as well as areas dominated by drainage, surface and groundwater are artificially managed with considerable upstream and downstream impacts on water flows, water quality and biodiversity. Livestock production consumes large quantities of water; almost a third of the global freshwater water is finally (through feed) dedicated to livestock (Peden et al., 2007). The main drivers of freshwater demand for food production are the growing population, urbanisation, changing diets with a higher demand for animal products, influences of food and energy prices and environmental degradation (de Fraiture et al., 2010). Without any changes in the way in which water is used, water demand for food production will need to increase by 80–90% to meet the demands of a growing population in 2050 (de Fraiture & Wichelns, 2010).

The freshwater fisheries sector also depends on optimal water quality and conservation of the natural habitat structure for fish, including spawning and nursery areas and migration routes (UNEP, 2010a). Aquaculture and livestock also demand a continuous supply of water that is at least non-toxic to the animals.

Challenges for hydropower

For hydropower generation, the main issues are an adequate discharge volume and river gradient and a suspended matter concentration that is not too high, as this reduces the lifespan of the reservoir. Thermal power plants need sufficient discharge as cooling water to stay within the temperature standards. The water that is released into the environment is usually very warm and sterile (Teixeira et al., 2009; Yi Li et al., 2009).

After a temporary levelling-off of new dam building, investments in this sector are again increasing, mainly in Asia and South America. Africa is expected to follow as there is much unexploited hydropower potential in the continent. The remaining potential for growth is estimated at about 70% worldwide (Fekete et al., 2010). Exploitation is stimulated not only by the low cost of hydropower, but also because it is considered a renewable energy source that fits in low-carbon emission scenarios.

Flood protection challenges

Flood risks will increase mainly because investments in flood-prone areas are increasing. Leaving aside the effects of climate change, under the Trend scenario the population living in flood-prone areas is estimated to be 1.3 billion by 2050, or 15% of the global population. This is an increase of 0.3 billion compared with the present situation (PBL, 2014). Population growth and economic development have been the dominant drivers of increases in the number of people affected and economic losses due to coastal and river floods (Visser et al., 2012). Up to 2050, the effects of climate change are expected to be small compared with the effects of the socio-economic drivers, even in high-end climate change scenarios (PBL, 2014).

As the concentration of people in cities increases (see above), the Trend scenario predicts 670 cities, each with 500 000 inhabitants or more, of which 88 with more than 5 million inhabitants, by 2050. Of these 88 cities, 50% will rank highest with respect to vulnerability to flooding, based on the size of the population exposed and GDP per capita (PBL, 2014). In these same areas with high population density, 'squeezing' rivers into narrow channels to facilitate navigation increases the risk of rivers overflowing during peak flows.

There is a wide range of measures available to reduce the flood risk from rivers or seas, ranging from technical measures (levees, storm barriers, dams and shelters), land use management and spatial development (no building in risky areas) to 'soft' measures like improving warning systems and evacuation plans and introducing insurance. The implementation of adequate flood risk strategies results in a high reduction in yearly exposed population and economic assets (PBL, 2014).

5.3 Benefits from ecosystem services and impacts on biodiversity

Benefits from biodiversity and ecosystem services for water management

Although water management and biodiversity often seem to be opposing interests (see next sub-section), it is worth defining possible synergies for the benefit of both. These will generally be mediated by ecosystem services – provided their use is kept within the ecological boundaries of the water systems themselves. Possible synergies are briefly mentioned here.

Well-functioning aquatic ecosystems – rivers, lakes, streams, wetlands, aquifers, estuaries and coastal waters – provide biodiversity and ecosystem services such as water storage, water flow, filtering and flood protection that serve the water sector. The biodiversity and ecosystem services are exploited to various extents for cities, food and hydropower and restrained for flood control (Figure 5.3). In practice, water management is often stretched to the limits, with all ecosystem services related to water management being maximally exploited (in two directions: the dependency of water management on ecosystem services and biodiversity, as well as impacts of water management on ecosystems and biodiversity). In addition, ecosystem services also 'compete' with each other, creating trade-offs. Optimising ecosystem services for instance for production or navigation functions may lead to reduced regulatory ecosystem services and a decline in biodiversity (Bennett et al., 2009).

For natural ecosystems such as forests, wetlands, rivers, lakes and coastal zones, important issues are water systems that retain their natural shape and connectivity, natural flow pattern and non-polluted water, to provide a wide variety of habitats for biota (Figure 5.3; see for example Finlayson & D'Cruz, 2005). Wetland zones connected to lakes may improve water quality and biodiversity in lakes and increase their resilience to climate change, as long as the natural water level fluctuations are maintained to ensure this functional connectivity. The future of global aquatic biodiversity depends on safeguarding water quality, conserving and restoring natural hydrology and flow patterns, preserving wetlands and aquatic habitat, and the 'wise use' of aquatic resources (see for example MEA, 2005; Dudgeon et al., 2006; Finlayson, 2011).

Cities

Protecting biodiversity and natural vegetation in catchment areas, as well as proper land-use management to prevent the pollution of water sources, reduce erosion and prevent floods, helps deliver cleaner water more reliably, both through groundwater systems and surface water systems. However, while forests can help increase groundwater recharge, they also consume water, which has to be taken into consideration (Jackson et al., 2005). Moreover, the use of ecosystems for 'services' such as water purification has clear limits, as 'over-use' will cause damage to the ecosystem and its biota. As a rule of thumb, wetlands can handle nutrient loads of up to 1 g P and 10 g N per m^2 wetland per year without being damaged; limits that are easily exceeded in practice (Verhoeven et al.,, 2006).

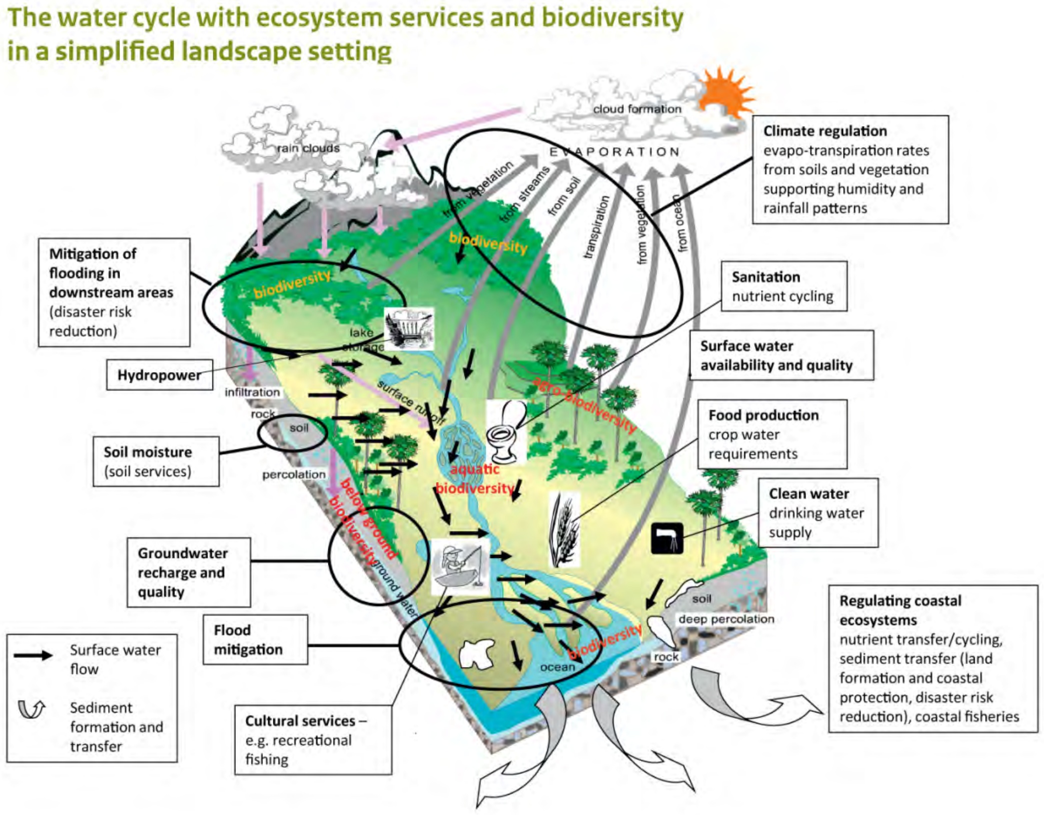


Figure 5.3. Illustration of the water cycle with ecosystem services and biodiversity in a simplified landscape setting (adapted by Boelee, from Coates et al., 2013).

Water for food

Undisturbed floodplains with intact wetlands that are rich in biodiversity contribute to the regulation of the seasonal water flow, securing water availability for agriculture and industries and improving water quality (Bullock & Acreman, 2003). They therefore deliver important ecosystem services, such as water retention and filtering (MEA, 2005; TEEB, 2010). The water sector may use these services for its benefit as, when well-managed, natural floodplains help increase water availability and reduce the need for the construction of artificial water reservoirs.

Hydropower

Hydropower plants benefit from intact vegetation upstream, as this prevents erosion and reduces the sediment load to the reservoirs. Upper watersheds with healthy ecosystems may deliver more reliable water flows as a higher variety in vegetation cover evens out water demand over space and time. Fisheries in water storage reservoirs for irrigation and electricity generation are emerging as an additional source of food and income in remote and highland areas, although the productivity is generally lower than that of natural lakes (Welcomme et al., 2010).

Flood protection

Wide river floodplains with connected biodiversity-rich wetlands can help reduce flood risks, or the impacts. This reduces the cost involved in dykes and other safety constructions. For coastal protection too, intact coastal ecosystems such as estuaries, mangroves and salt marshes can help protect shorelines and coastal communities from the effects of disasters such as flooding and high waves (Batker et al., 2010). Economic analyses have shown that, in some cases such as the Hadejia-Nguru wetlands in northern Nigeria, the value of the original floodplain in terms of averted costs of flooding was much higher than the economic returns irrigation system that replaced it (Barbier & Thompson, 1998). This is because irrigation systems are generally protected from overflowing and have a limited water storage capacity.

Impacts of water management on biodiversity

Major losses of aquatic habitats occurred due to conversions and water works, flow modification and loss of connectivity (Revenga et al., 2005). Combined with the impacts of pollution, over-fishing, climate change and suppression by invasive species, freshwater ecosystems have, relatively, the highest amount of species under threat of extinction (MEA, 2005). All water infrastructure, be it for cities, food production, hydropower or flood protection, is designed to change hydrology, impacting on the species that depend on these flows. This infrastructure leads to ecologically devastating seasonal flow reversals in many rivers (Postel & Richter 2003; Grafton et al., 2012; Pittock et al., 2014), although in lowlands the impact on biodiversity may be less significant (Feld et al., 2014).

Eutrophication and other kinds of pollution from both point and diffuse sources have led to the degradation of many lakes, rivers, wetlands and coastal waters (Finlayson et al., 1999). For instance, both the biodiversity and the retention and purification capacities of the Kis-Balaton wetland in Hungary were seriously affected by degradation of the catchment and high inflows of polluted wastewater (Somlyodi et al., 1997). The combined impact of high water abstractions, flow modification, flood protection measures, increased nutrient loads and pollution have altered rivers to such an extent that aquatic ecology is threatened, possibly irreversibly, worldwide (Xenopoulos et al., 2005; Vörösmarty et al., 2010; Janse et al., 2014). This is particularly urgent in closed and closing basins (Falkenmark & Molden, 2008; Molle et al., 2010) and in areas of over-exploited groundwater (Giordano & Villholth, 2007). Wetlands in particular are threatened by dams, poor water quality and land-use practices upstream, as well as by encroachment (Rebelo et al., 2010).

The combined impact of some major anthropogenic drivers – land-use changes, eutrophication, conversion and hydrological disturbance by river dams – on the biodiversity of freshwater systems (lakes, rivers and wetlands) has been modelled using IMAGE/GLOBIO scenario calculations (Janse et al., 2014), as shown already in Chapter 2 (Figure 2.10; see also Table 3.1). The impacts of these factors on biodiversity are highly different in various biomes (Figure 5.4). The average biodiversity intactness (MSA) is projected to drop to 30% in the water bodies in the scrubland biome in 2050 under the Trend scenario (already as low as 38% in 2000) and to less than 50% in those in the Mediterranean shrub, savannah and temperate deciduous forest biomes. The waters in the boreal and tundra biomes are generally less affected. These figures should be regarded as conservative estimates, as pressure factors such as water abstraction, climate change, toxic stress and overfishing are not taken into account and only a subset of the river dams (those in the GRanD database; Lehner et al., 2011) is included in the simulations.

Impacts from cities

Under the Trend scenario, nutrient effluents from wastewater are projected to increase rapidly: N effluents increase from about 6 to 15 million tonnes per year between 2000 and 2050 globally; P effluents increase from 1.3 to over 3 million tonnes per year in the same period (OECD, 2012; van Drecht et al., 2009). Most of this increase will take place in developing countries, primarily due to population growth, rapid urbanisation, increasing numbers of households with improved sanitation and a connection to sewage systems, and lagging nutrient removal in wastewater treatment systems. The nutrient removal in wastewater treatment systems is expected to improve rapidly, but not fast enough to keep up with wastewater generation; neither is the treatment efficiency high enough to counterbalance the enormous increase in nutrient inflows.

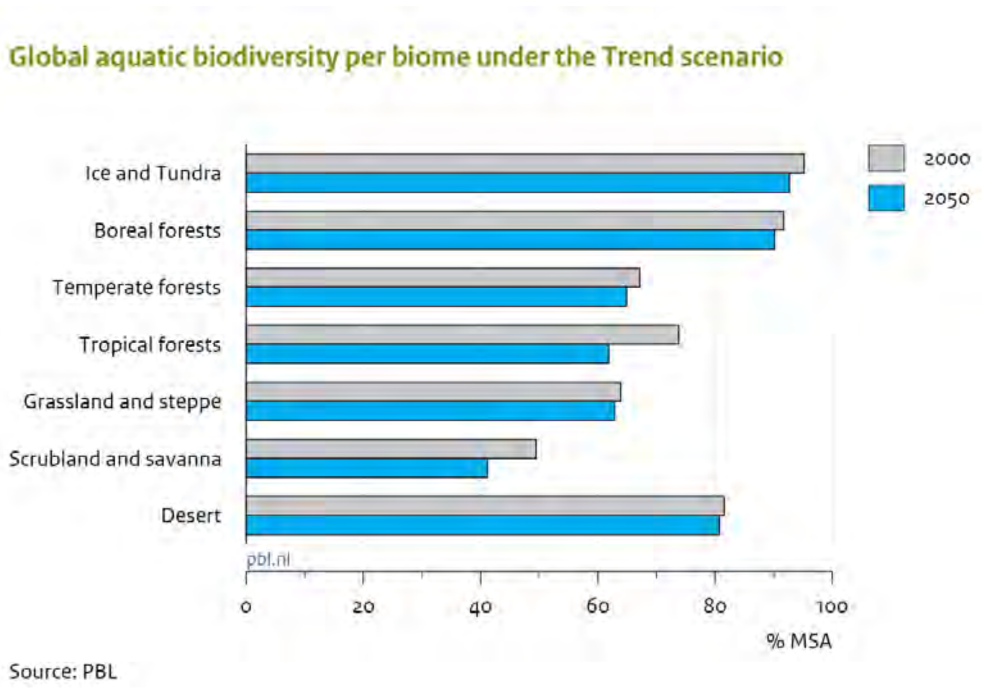


Figure 5.4. Global aquatic biodiversity per biome in 2000 and 2050.

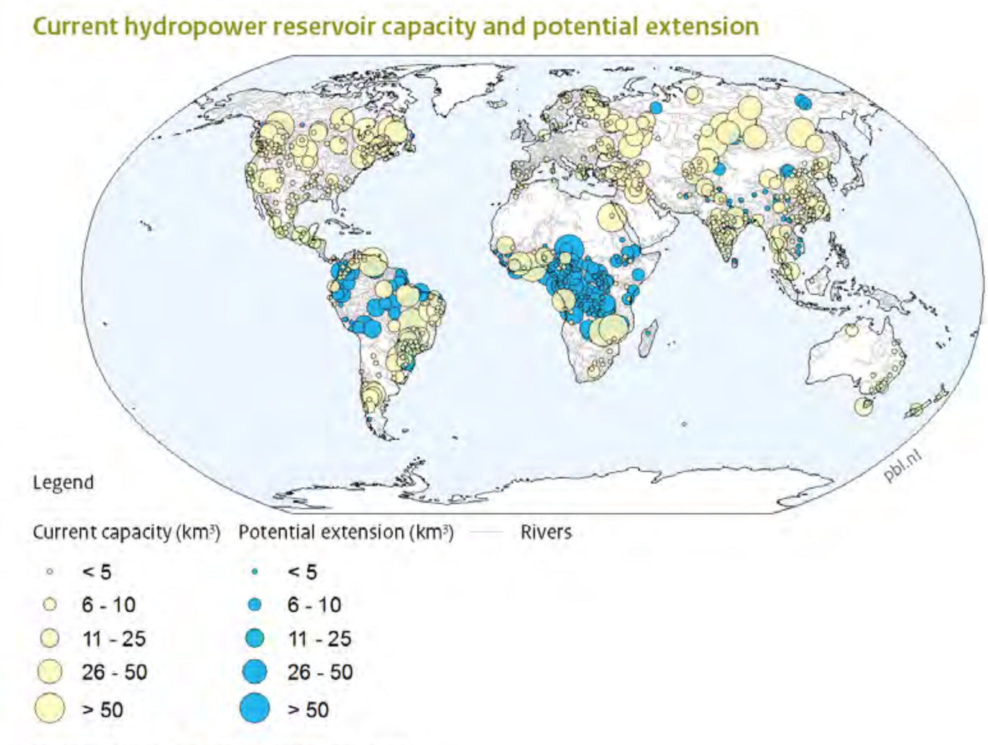
Impacts from food production

The production of food for an increasing population has caused biodiversity-rich nature to be replaced with large areas of monocultures, leading to pollution with agrochemicals such as nutrients and pesticides, land-use impacts and atmospheric interactions (Gordon et al., 2007; see also Chapter 3). For instance, rice fields have a much less diverse bird population than the original wetland (Elphick et al., 2010). At present, over 80% of the global nutrient load to freshwater that causes eutrophication is from diffuse sources, mainly agriculture (Bouwman et al., 2011). Nutrient outflows are expected to increase further, from both urban and agricultural emissions. These projections are included in the GLOBIO model used in the scenario analysis (see also Chapter 2; OECD, 2012; Janse et al., 2014).

Most of the world's aquaculture occurs in inland waters, primarily in Asia, with a production of about 50 million tonnes of fish in 2010 (FAO, 2012). While aquaculture also depends on the availability of clean water systems, they also pose a threat to these same systems through eutrophication and other pollution, the spreading of diseases and genetic pollution in wild populations, depending on the culture system used (Beveridge et al., 1997; Hall et al., 2011).

Impacts from hydropower and other dams

In 2010, there were about 50 000 large river dams (with a dam height of 15 metres or more) for hydropower generation, agriculture and other uses (WCD, 2000; Lehner et al., 2011). Nearly 7 000 of these (together representing over 75% of the storage capacity) are included in the GRanD database (Lehner et al., 2011). River dams alter and obstruct flows, and create serious barriers for migrating species. The disturbance of the natural flow pattern has major consequences for the biodiversity in the rivers (Poff et al., 2010) and floodplain wetlands (Kuiper et al., 2014). Dams also have negative impacts on water quality and on sediment transport in the river systems. In the filling phase of reservoirs, they can even be a net emitter of greenhouse gases such as methane. In total, almost 500 million people are directly affected by large dams (Richter et al., 2010). According to the simulations, the construction of large river dams (those included in the GranD database) is responsible for an average 19% loss in aquatic biodiversity intactness (MSA) in rivers and 15% in floodplain wetlands. In 2050, these figures will have increased to 23% and 20% due to a projected increase in hydropower capacity (Fekete et al., 2010). The hydrological potential (Figure 5.5) shows that even more dams could be constructed. The construction of dams results in the formation of reservoirs that also affect large areas of terrestrial ecosystems, including agricultural and natural land. The total area of artificial reservoirs already amounts to 0.3 million km^2 (Lehner et al., 2011).



Source: Lehner et al. 2011, Fekete et al. 2010

Figure 5.5. Current hydropower reservoir capacity and future potential. The 2050 projection is based on physical potential only. Map by PBL, based on Lehner et al., 2011; Fekete et al., 2010.

The fish production from inland water bodies amounts to about 11 million tonnes a year, representing around 12% of total global catches (FAO, 2012). The significance of inland fisheries for the livelihood and protein supply of local communities, mainly in developing countries, is often underestimated. Inland fisheries depend on the preservation of water bodies, restoration of natural connectivity for fish migration and good water quality. Dams often have negative environmental effects, including the disruption of migratory fish production (see for example Dugan et al., 2010).

On the other hand, by stocking commercial fish species at the expense of native species and overfishing, freshwater fisheries may also contribute to deterioration in water systems.

Flood protection

Levees and embankments for flood protection have eliminated many biodiversity-rich floodplains and connectivity between river, side-channels and wetlands has been lost. The channelisation of smaller streams and embankments around lakes has the same effect, leading to loss of habitat diversity, riparian vegetation and fish spawning grounds.

5.4 What is the sector already doing in favour of biodiversity?

Due to the extensive environmental impacts of water abstraction, regulation and pollution, the water management sector has a responsibility to mitigate the negative effects on water systems. In this section, some examples are given of measures that are being taken in the water sector to help preserve biodiversity and reduce negative environmental impacts. Many of these are of an integrated nature, spanning various sectors and investment pathways as multiple benefits are strived for. However, the success of such interventions often depends on other sectors that have their own drivers, such as agriculture.

Ecological practices in water management for cities

Obviously, reducing water pollution benefits aquatic life, though it will take substantial measures to reverse the degradation of aquatic ecosystems and restore aquatic biodiversity. At the same time, pollution reduction is also beneficial to the water management sector downstream of cities as it improves the quality of their resource, reduces treatment costs and helps secure the supply and meet the demands of multiple users. Wastewater treatment plants can be improved to recycle and re-use nutrients. However, although about 60% of the world's population was connected to a sewerage system in 2010, in lower income countries this is only 8% (Sato et al., 2013). In developing countries in particular, cheaper alternatives for wastewater treatment have to be found. The use of wastewater in urban and peri-urban agriculture turns the nutrients into fruit, vegetables and fish, thus contributing to more diversified diets in cities, while diminishing the downstream nutrient load (Scott et al., 2004; Qadir et al., 2007). For example, the productive use of wastewater to culture fish and irrigate rice and vegetables in 3 900 hectares of the East Kolkata wetlands (India) is an interesting example of how urban wastewater has been turned into an asset (Bunting et al., 2011). However, industrial pollution and faecal matter may increase health risks that in turn require mitigating measures (Drechsel et al., 2010). Combinations of treatment and aquifer recharge are also applied, where after initial treatment the soil acts as a secondary filter and the groundwater can be used for various purposes (Qadir et al., in press). Another option is to use the wastewater for greening of the city itself, in parks, forests, wetlands and urban agriculture. Such green areas can provide high biodiversity as well as multiple ecosystem services, such as flood and temperature regulation (CBD, 2012). Water-consuming industries are under economic and public pressure to use less water in the production of their goods. Environmental protection agencies require adequate wastewater treatment before the water is released into the sewerage system (or directly into the environment). In several countries or at regional level, regulatory frameworks are in place for water quality and monitoring procedures are functioning (e.g. the European Water Framework Directive; Brils et al., 2014). Such regulations or standards are sometimes too uniform and not adaptable to local situations and there are seldom implementing agencies that have the power to coordinate water pollution and regulate quality improvement measures. Still, these regulations can serve as accelerators for data collection and use the momentum to promote the ecological values of water bodies and the integrated management of water bodies and river basins.

Measures in the catchment areas of lakes and aquifers that serve as sources of drinking water for the cities are very important to safeguard the quality of this resource and to reduce treatment costs. Enhancing biodiversity in these terrestrial ecosystems can be an important part of this. Water boards and drinking water companies can thus help protect watersheds by actively stimulating land-use practices that cause less pollution, or by preserving natural elements in the landscape, which may also reduce erosion and prevent floods. For instance, good management of Mount Kenya, which hosts two important watersheds, is estimated to save USD 20 million a year by ensuring a regular water supply (CBD, 2012). The Munich Water Board in Germany, for instance, succeeded in transforming agriculture in the watershed of the springs of the Bavarian Alps into organic farming. The city organised information campaigns, offered the farmers compensation for the implementation costs of 'good practices' and the costs of certification, and increased the market for organic products. The project has led to significant improvements in water quality (Grolleau & McCann, 2012). The drinking water company in New York City invested in conservation of the biodiversity-rich forests and wetlands in the Catskill, Delaware and Croton watersheds, saving the costs of a new water filtration plant (Smith et al., 2006). Similarly, the Nakivubo Swamps near Kampala (Uganda) were maintained, rather than converted into agricultural lands, when the local government discovered that this wetland effectively filtered the urban wastewater. It was much cheaper to manage the wetland than to construct and maintain a water treatment facility (CBD, 2012). Comparable projects are being undertaken in Ecuador and other Latin American countries (Krchnak et al., 2011).

Private industries are taking these kinds of steps as well. In Contrexéville (France), for example, Nestlé initiated integrated pest management using predator insects in combination with other measures, such as payments for ecosystem services (PES) to farmers in the catchment area, all to protect the water sources from pollution and ensure a good quality resource in the future. Other economic instruments include water markets (e.g. in Australia), credits for water allocation or contamination (e.g. Ontario), and PES, often used to make downstream water users pay for protective measures in the upstream watershed (Smith et al., 2006). Such measures are also implemented in hydropower investments (see below).

Ecological practices in water for food

Faced with increasing water scarcity coupled with ever-rising demands for food, agricultural investments are targeted at increasing water productivity for crops, livestock and fish (Rockström et al., 2009b; Descheemaeker et al., 2013). Developments are continuing in the field of technology (e.g. improved food and fodder crops that require less water or can be cultivated in marginal land, re-circulating aquaculture systems) and farming practices (e.g. conservation tillage, improving efficiency in irrigation and aquaculture, fertigation - irrigation with dissolved fertiliser). Diversity in fields and landscapes also helps increase ecosystem health and biodiversity and contribute to increased resilience (Jarvis et al., 2007; Mulumba et al., 2012; Chateil et al., 2013).

Parallel efforts are being undertaken towards integration in multi-purpose agro-ecosystems (e.g. agroforestry, integrating crops with trees to preserve soil water, cultivating fish in rice fields or using water harvesting for livestock) and integrated landscape management, driven by opposite lifestyle trends (e.g. increasing consumption of animal products in the emerging economies and reversing trends in Western Europe; see Descheemaeker et al., 2013 for more details and references). Land-use planning can also be optimised (Bossio et al., 2010), for instance by restricting certain crops that lead to erosion or nutrient leaching to those parts of a catchment where water flow and water retention are safeguarded and pollutants are naturally caught (Swallow et al., 2008). Landscape elements can play a crucial role in the preservation of biodiversity; for example canals and productive hedgerows can also serve as corridors for fish and other wildlife respectively and provide habitat for predators of crop pests (Vohland & Boubacar, 2009).

In rural areas, integrated water supply plans consider multiple sources for multiple water uses: domestic, livestock, small-scale irrigation and other water-dependent productive activities. These increasingly include for instance rainwater harvesting as an ecological alternative to irrigation and drinking water supply in rural areas in low income countries (see for example Boelee et al., 2013b), as well as ecological sanitation to increase re-use and reduce pollution. Some highly efficient traditional irrigation methods are being re-invented. These could be especially effective in currently extensive forms of agriculture, such as rain-fed crop production, ranging and traditional aquaculture, where yields and profits are far below potential, both in absolute terms and in terms of inputs such as water. At the same time, increasing water productivity does not necessarily mean that water is saved, as farmers may use the same water to produce more, rather than produce the same with less water (see for example Ward & Pulido-Velazquez, 2008). Moreover, water that is not used upstream cannot really be considered lost as it is often used elsewhere in the river basin, by natural ecosystems and to recharge ecosystems (see for example Barrios et al., 2009).

Technological developments can play an important role in this. Agrochemical companies are under pressure to produce pesticides that break down much more quickly than currently-applied formulas so that groundwater pollution is reduced, and soil stabilisers are being developed to fight erosion and contain land degradation (Council of Canadian Academies, 2013). Remote sensing technology continues to evolve and is used to determine the timing of crop watering or drainage (precision irrigation; see for example Sadler et al., 2005), but also to monitor pests such as locusts and vectors of animal disease (allowing for more environmentally-friendly control measures). Intensive aquaculture, in which water is recycled and treated with filters and disinfection technologies, has very high water use efficiencies (Bunting, 2013). Animal breeding could lead to the development of animals that are more food-efficient, while modern livestock management practices have the potential to reduce local water pollution and thus contain the eutrophication of water bodies.

Other strategies consider trade as a solution, by importing water-intensive products from water-rich countries, but these tend to have limited results (de Fraiture & Wichelns, 2010). Similarly, while in some parts of the world water pricing can help provide incentives for water-saving, in other countries such policies would threaten food security and thus cannot be applied. In aquaculture, certification could play a role. In 2012, the ASC (Aquaculture Stewardship Council) ecolabel for cultured fish was launched and this is expected to spread rapidly in the coming years (PBL, 2013).

Using the potential of natural infrastructure for water storage may lead to multiple benefits (Emerton & Bos, 2004). In the Komadugu Yobe Basin (northeast Nigeria), upstream of Lake Chad, water managers built dams and reservoirs for water storage for irrigation and drinking water in the 1960s and 1970s, trying to rely completely on grey infrastructure. The irrigation system failed, however, while the resulting alteration of stream flow patterns caused problems with invasive waterweeds, stopped the necessary annual flooding of the fields, and destroyed fisheries, leaving the local population poorer and at higher risk of hunger. In 2006, a USD 125 million plan was agreed on for the restoration of river flow and wetlands and sustainable basin management, for which funding is now sought (Krchnak et al., 2011). In addition to conservation efforts, the sustainable uses of wetlands are being explored (Wood & van Halsema, 2008; Verhoeven & Setter, 2010).

Ecological practices in hydropower

The ecologically-sound implementation of hydropower is a big challenge. Adaptations to existing infrastructure are often difficult, though retrofitting and re-operation of dams does occur, to make them serve multiple purposes (Krchnak et al., 2009). At some locations, old dams are being removed at the end of their lifetime. Restoration options may involve the removal of an existing dam and its placement at another location where it causes fewer disturbances to the river system. An example is the restoration of the Penobscot River (Maine, USA), where two dams in the lower river were replaced with new dams in side branches. This reduced the disturbance to river flow and fish migration while the same hydropower capacity was maintained (Opperman et al., 2011).

The Hydropower Sustainability Assessment Protocol supplies a useful guidance promoting ecological design (IHA, 2014). In this protocol, controlling the natural flow is a master variable, which can be promoted as far as possible in the reservoir filling phase and also during operational management. Creation of additional storage to restore natural floodplain areas is often beneficial for ecosystems downstream. Essential is infrastructure that allows the passage of aquatic species and sediments. Water quality in the reservoir could be managed to avoid temperature increases, gas super-saturation and algal blooms. The restoration of habitats in riparian areas, together with effective monitoring and barriers against invasive species, has shown positive results in cases where it has been implemented. As the HSAP was developed very recently (Locher et al., 2010), only nine cases have so far been evaluated. Most of these scored a 3–4 (on a 1–5 scale) for biodiversity issues, although some of the reports were criticised.

Table 5.2. The Hydropower Sustainability Assessment Protocol, covering technical, environmental, social, economic/financial and integrative sustainability (IHA, 2014).

TECHNICAL	ENVIRONMENTAL	SOCIAL	ECONOMIC AND FINANCIAL	INTEGRATIVE
Siting and design	Downstream flows	Project affected communities and livelihoods	Economic viability	Demonstrated need and strategic fit
Hydrological resource	Erosion and sedimentation	Resettlement	Financial viability	Communi-cations and consultation
Reservoir planning, filling and management	Water quality	Indigenous peoples	Project benefits	Governance
Infrastructure safety	Biodiversity and invasive species	Cultural heritage	Procurement	Integrated project management
Asset reliability and efficiency	Waste, noise and air quality	Public health		Environmental and social issues management

In general, there is little information available on the spread of ecological measures in hydropower plants. A survey by the International Energy Agency (IEA) in 2006 revealed 60 cases of existing dams where mitigation or compensation measures for ecological damage had been implemented (IEA, 2006). The cases came from 20 countries, mostly in Asia and North America and a few in Europe. Most of the described measures can be categorised as operational phase measures. The building of many new hydropower stations in Asia and South America allows for inclusion of sustainability concerns from the onset. On such new projects, there are fewer constraints to implement innovative measures and environmental damage can be avoided, mitigated and compensated during the different phases of a project: planning/location, construction and operation/management. A lot of scientific, but also traditional knowledge is now available to support this approach.

As in urban watersheds, PES schemes are applied in the energy sector to help prevent erosion upstream. This will reduce the siltation rate, avoid costs for dredging and increase the life span of reservoirs. For example, in the Sarapiqui watershed in Costa Rica, a hydropower company pays USD 48 per hectare per year to upstream landowners for forest management and restoration. The payment is based on the costs of reservoir dredging that the company avoids and the operational benefits of more reliable stream flow that can be used for hydropower (Hanson et al., 2008).

Ecological practices in flood protection

As the limits of conventional solutions to water regulation became apparent, 'green' solutions have increasingly played a role in flood control. After major flood events in 1998, an extensive floodplain restoration project was carried out along the River Yangtze (China), including removal of levees and the reconnection of large wetland areas to the river (Pittock & Xu, 2010). The project 'Room for the River' (the Netherlands) aims to create side channels and inundation areas along the lower courses of the River Rhine, by again increasing the floodplain area that had been restricted by narrow dykes in some river stretches to make use of natural habitats and hydrology for flood protection and serve biodiversity goals at the same time (V&W, 2006). Such solutions provide benefits such as a reduction in the number of victims and damage and reduced costs (see for example Krchnak et al., 2011; de Vriend & van Koningsveld, 2012), though this may not be the case in places where almost all land is allocated and rivers are regulated. In this case, nature-based infrastructure may be more expensive simply because it takes up more space.

Experiments are currently ongoing regarding the restoration of riparian wetlands to protect the shores of the Markermeer in the Netherlands (de Vriend & van Koningsveld, 2012). In New Zealand, formal protection of the Whangamarino wetland led to reduced costs for flood protection while conserving water for irrigation during the dry season (Department of Conservation, 2007). Multi-purpose trees could also play a role in reducing flood risks by preventing erosion, transpiring relatively high amounts of water and providing food or wood at the same time (Carroll et al., 2004). Other, more local, measures include shoreline restoration in lakes and the dredging of nutrient-rich sediments.

If dams, weirs and sluices in rivers and streams are considered inevitable for energy generation or water regulation purposes, they can be made passable for migratory fish and other organisms. Fish passages have been implemented in several places, for instance in Sweden (Calles & Greenberg, 2007) and in the USA (Williams, 2008). In the Netherlands too, water managers have built several fish passages in recent years, especially at weirs in small streams.

Integrated Water Resources Management (IWRM)

Generally speaking, ecologically-sound water management is still in its infancy. Some countries have adopted a water allocation policy for water-scarce areas, usually as part of Integrated Water Resources Management (IWRM) that includes environmental flows, but may also use political tools such as demand management (GWP, 2012). In countries under severe water stress, such as in the Middle East and North Africa, water demand management (Laamrani et al. 2011) has become an accepted strategy, particularly in irrigated agriculture and in cities. In Morocco for instance, a special water committee with representatives from all sectors decides on priority water allocations in dry years, for instance skipping water for annual crops, rationing irrigation of perennial trees, but maintaining flows for drinking water supply and industry. In the Murray-Darling basin (southeast Australia), for instance, a management scheme ensures a fair distribution of the scarce water resources among the different users, including the designation of water for natural ecosystems (Bunn & Arthington, 2002).

Such environmental flows aim to provide water of the right quality at the right time for downstream natural ecosystems, particularly in river basins where upstream water abstractions have reduced the natural dry season water flows (Baron et al., 2002; Acreman & Dunbar, 2004; Arthington et al., 2006, 2009; Korsgaard et al., 2008; Poff et al., 2010). For instance, in the Pangani River Basin in Tanzania, flows had been reduced from several hundred to less than 40 m^3/s, mainly due to over-abstraction for irrigation and urban water demand. The remaining water is seriously over-allocated, leading to conflicts between irrigators, electricity producers and downstream fishing communities. The multi-partner Pangani River

Basin Management Project developed various flow scenarios to raise awareness of the water issues in the basin, help select the best development path for the river, and facilitate the integration of the selected environmental flow scenario into an IWRM plan for the basin (King et al., 2010). Environmental flows, particularly in the dry season, often also serve the needs of recreation and tourism, now among the world's dominant economic sectors. Depending on the type of tourism, clean and safe drinking water is required, as well as surface waters lacking algal blooms, with boating facilities, scenic beauty and a high biodiversity.

Box 5.1. Integrated mangrove management in Southeast Asia (based on Cools & Boelee, 2014)

Mangroves typically provide high biodiversity and multiple ecosystem services, including coastal protection, breeding grounds, firewood and food (Macintosh & Ashton, 2002). Mangroves are also among the most vulnerable and threatened ecosystems in the world as they are increasingly being cut for firewood and to free up new land for high-income intensive aquaculture (mainly shrimp farming). In addition, both mangroves and shrimp productivity are often negatively impacted by external pressures such as high water use upstream for irrigation and hydropower, and downstream impacts from saline water intrusion due to sea-level rise or sea floods.

These various inter-linkages between impacts, uses and benefits in mangroves are insufficiently understood, but integrated coastal management seems to be the most promising approach for preserving mangroves for coastal protection and safeguarding local livelihoods in aquaculture (Godschalk, 2009). At the same time, certain livelihood strategies combine various production systems with adequate forest, water and land management, implicitly contributing to biodiversity conservation. Diversification into other fisheries products (e.g. fish and mud crabs in addition to shrimp) and cash crops (e.g. fruit trees on the banks of the ponds) are particular improvements to the long-term viability of mixed shrimp-mangrove forestry farms (Johnston et al., 2000; Bosma et al., 2012; Bunting et al., 2013). Implementation of this integrated management approach, both at farm and district level, requires the engagement and coordination of multiple stakeholders, including authorities at the local, provincial, national and international level. A pilot project in the Soc Trang province in Vietnam, based on agreement between local farmers and local authorities, has proven to be effective for mangrove management and income generation (Schmitt et al., 2013). The agreement was embedded in an integrated coastal management plan, supported by the Vietnamese government and the Mekong River Commission, and could be further supported by for instance certification for shrimp farmers (GIZ, 2013).

The co-management project in the Soc Trang province is a good example of a local structure that could be added to existing IWRM institutions. It has demonstrated the need to give responsibility and user rights to local users. In return, obligations regarding mangrove rehabilitation and sustainable use can be asked for. Mainstreaming biodiversity in water management requires – because of the cross-sector nature of biodiversity and its impacts – better exchange of information between sectors. Often, stakeholders and sectors are not aware of the impacts of their actions, or even of the information they need to decide on actions. Improved access to scientific information from other sectors will benefit public decision-making and thus result in better governance.

Theoretically, such water allocations are based on sound ecological data and regularly monitored, at least to some extent (Esselman & Opperman, 2010; Poff et al., 2010). In practice this does not always work out as planned as the allocations are not always based on the latest scientific insights (Koehn et al., 2014) and biodiversity impact assessments are not always carried out (Pittock & Finlayson, 2011; Pittock, 2013; Grafton et al., 2014; Olden et al., 2014).

Various planning tools and methods are available to help analyse and implement ecological practices. For instance, catchment planning tools can help define the wetlands or forests that are crucial for water retention or erosion protection and improve the design of a protected area network (Verhoeven & Setter, 2010). They also help balance or optimise the socio-economic values of the different elements in the landscape (Zsuffa et al., 2014). Specific tools are available to assess the combined impacts of several determinants such as fragmentation, reduced flows and climate change on wetland biodiversity, values, services and potential (see for example Springate-Baginski et al., 2009; Mantyka-Pringle et al., 2014; Yoshioka et al., 2014), which helps in the assessment and monitoring of environmental flows. New analytical frameworks are also available to increase understanding of various climate change and allocation scenarios on aquatic biodiversity, which can help develop management options (Barmuta et al., 2013). Rigorous cost-benefit analysis, from an ecological and societal point of view rather than company profit-driven, could be an efficient tool for decision-making and for supporting more equitable cost sharing. In this way, water aspects can be better included in discussions on competing claims on resources, be it land- or water-based.

Integrated Water Resources Management approaches have been successfully applied for the restoration of aquatic ecosystems, often combined with land management measures. Several smaller rivers are being partly restored, by re-meandering, restoration of the natural flow pattern, natural shoreline development and reconnection of wetlands. These projects mostly have multiple aims: to improve water retention and filtering, adapt to climate change, and re-create diverse habitats for biota. Good examples of these are the restoration of the Skjern River in Denmark and the Savannah River in Georgia and South Carolina (USA; TNC, 2010). There are also some examples in coastal areas (Box 5.1).

In the upstream parts of catchment areas in particular, an effective land management measure is the promotion of riparian buffer zones made up of trees along rivers and watercourses. Along small rivers, these may act as adaptation measures to global warming as shading leads to moderation of the water temperature. More generally, these zones may act as a trap for eroded material and nutrients. The effect depends, however, on regional and local soil properties and hydrology (Feld et al., 2011; Stutter et al., 2012), but a width of around 30-50 metres can often be effective along lower-order streams. In Brazil, a buffer zone of 30 metres along river courses is set by law (but poorly enforced).

However, many restoration projects fail to reach the intended goals because the scope and spatial extent of the project is too limited and does not cover all relevant aspects of the river or catchment area (Feld et al., 2011). For instance, riparian zones along a small part of the stream will have little effect if an adjacent stretch directly borders intensively-managed cropland. Limited possibilities for the re-colonisation of species also contribute to a lack of recovery. More examples of current river basin management plans, IWRM and executed projects can be found in the Global Water Partnership Toolbox[11], in the UN Water 'Water for Life Decade' focus on IWRM[12], in the WANI water and Nature Initiative[13], and in the IUCN/IWA[14] Nexus dialogue on water infrastructure. The Alliance for Water Stewardship (AWS) is working on a certification system for the proper management of freshwater systems.

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[11] www.gwp.org

[12] http://www.un.org/waterforlifedecade/iwrm.shtml

[13] http://www.waterandnature.org/

[14] www.iwa.org

Barriers and levers

The many interventions that serve dual purposes of improved water management and biodiversity conservation are applied by actors worldwide, but not at a sufficiently large scale to have enough of an impact. The main condition for the wider implementation and success of the ecological practices mentioned above is the systematic integration of biodiversity in all investment pathways, supported by policy and funding (Foley et al., 2011).

River basin organisations do usually have the scope to involve all sectors in IWRM and bridge the scattered nature of the water sector, but in reality these institutions are weak and lack a clear mandate, sufficient authority and enough funds to carry out their tasks. This is even more complicated in low income countries and within trans-boundary rivers (Schmeier, 2013). Water governance is complex and depends on the country, on the different actors involved and on spatial and temporal scales. Only 10% of countries have adopted IWRM in their policy plans, and another 40% have adopted some elements of it (GWP, 2014). Apart from sound knowledge on river basin systems and insight into the water management measures required to make alternative scenarios a reality, it is important that cultural, organisational and financial barriers that hinder cooperation on the development of optimal solutions are removed. The success of many measures depends on the actions of other sectors, such as agriculture. High prices for food production and a subsidised water and energy supply (Mukherji et al., 2009; Shah et al., 2012) may become major drivers of watershed destruction to create more cropland. Links between these actors are ill-understood and not captured in adaptive management processes.

Another main barrier is that measures for reducing biodiversity loss are complicated and appear as win-win solutions mainly in the long term. Integrated solutions require more knowledge of the basin and water system and take more time, also because heavy modifications to rivers or other water bodies are sometimes difficult to reverse, with present land use and land ownership limiting restoration possibilities. As these measures focus on the mitigation of long-term risks, immediate economic gains are less clear. Such solutions are also more difficult to implement because of multiple stakeholders, and because they are not always compatible with political cycles. The more widespread use of a cost-benefit analysis that considers the full valuation of ecosystem services (TEEB, 2010) could serve as a lever to demonstrate that green, nature-based solutions are in fact more cost-effective than traditional infrastructure. However, this will not be sufficient to include biodiversity concerns into water management, as the monetary values are generally low, except in densely-populated urban areas.

Innovative organisational arrangements will be needed to implement ecological approaches across sectors and investment pathways, which are sometimes unable to be communicated effectively because of cultural differences. An example of this is sewage treatment (focused on effluent standards) versus aquatic ecology (focused on quality of the receiving waters). The identification and promotion of synergies, for instance the joint recognition of the need for water quality management, could help overcome such differences. This would also contribute to finding creative solutions to overcome cost partitioning. Integrated solutions usually combine multiple goals, but the costs and benefits are not attributed accordingly. Thus some actors bear most of the costs, while others reap the benefits.

Fortunately, there are some levers that help up-scale ecological, biodiversity-friendly approaches. There is an increasing public desire for landscape interventions to serve multiple goals rather than just one (Landscapes for People, Food and Nature Initiative, 2012). The insight that ‘green’ or mixed solutions offer multiple ecosystem services (not just energy generation, food production or nature conservation, for example) helps to broaden this support. IWRM would be a good starting point, as environmental flows are part and parcel of the approach, and interest in water management for a broader range of ecosystem services is increasing (Keys et al., 2012).

Well-functioning ecosystems contribute to the secure provision of water, food and energy, the so-called 'nexus'. Natural ecosystems can therefore be regarded as part of the water infrastructure ('green' or 'natural' infrastructure) as opposed to the 'grey', constructed infrastructure, such as water treatment plants or dykes for flood protection (Krchnak et al., 2011). These parallel interests provide opportunities for win-win solutions. By adopting ecological solutions ('working with nature') instead of only technical solutions ('fighting against nature'), multiple interests may be combined (Nagabhatla et al., 2012).

In sub-Saharan Africa, investments in agricultural water management have been picked up and stimulated by initiatives from funding organisations such as IFAD, the African Development Bank and various foundations (e.g. AGRA[15], Grow Africa[16], AgWA[17] and the African Agricultural Capital Fund). These initiatives explicitly include environment-friendly technologies for irrigation, drainage, aquaculture and animal watering, often as part of broader agricultural support (e.g. improved seeds or veterinary care).

The implementation of ecology-based water management depends on a good understanding of the hydrological and ecological functioning of the catchment, and on commitment and cooperation from all stakeholders. The approach is typically multifunctional and multi-sectoral, broader even than IWRM. Ecological approaches involve coordinated measures at different scales, from local to catchment scale, such as conservation and land-use planning within catchment areas, land management within land-use types, restoration of lakes and wetlands, restoration of river courses and shorelines, and measures in estuaries. Eventually, water systems that have retained their natural shape and connectivity, natural flow pattern and non-polluted water, are the ones that provide the widest variety of habitats for biota. Tailor-made solutions have to be designed for each catchment area, first considering how to reach the goals using intact ecosystems, and only secondly by designing additional technical solutions if they cannot be avoided. In that case, mitigation measures exist that may reduce the negative effects of these structures on biota.

5.5 What are the long term options?

As described in Chapter 2, the three global pathways – Global Technology (GT), Decentralised Solutions (DS) and Consumption Change (CC) – were designed to all reach the terrestrial biodiversity target of halving the world-averaged biodiversity loss rate in 2050. The scenarios were not designed with aquatic objectives in mind, but the pathways can still be coupled to the main pressures on aquatic biodiversity and to the available options to tackle these. The general analyses have been described in Chapter 2; here we go into some more detail on the impact of the options on aquatic systems and on regional differences. As only a subset of the options has as yet been implemented in the model chain, it is only possible to quantify the effect of these. These are mainly land-use differences. Specific water options, such as water abstraction, hydropower investments and environmental flow implementation, have not been varied between scenarios.

The pathways have different impacts on aquatic ecosystems and their biodiversity (Figures 2.9 and 5.6–5.8). Under the *Global Technology* scenario the average loss of aquatic biodiversity is

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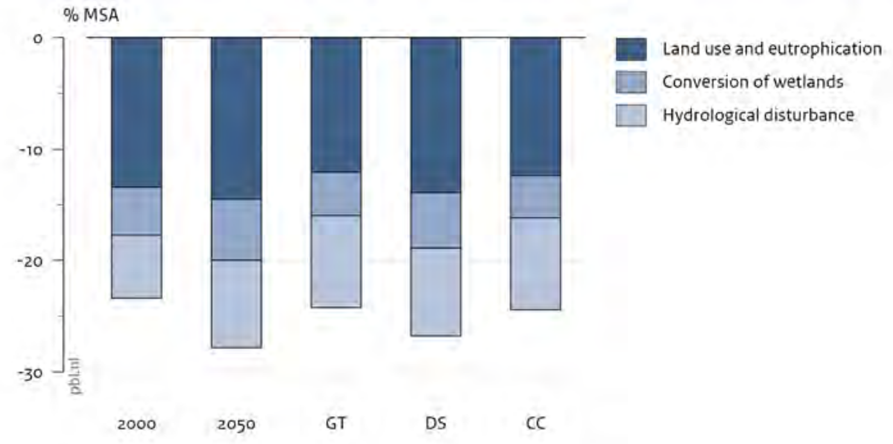
[15] http://agra-alliance.org
[16] http://growafrica.com/
[17] http://www.fao.org/nr/water/agwa/en/

lowest, mainly because agricultural intensification condenses land use, thus reducing the cropland area and the need to convert wetlands. This scenario also assumes the greatest improvements in urban wastewater treatment. Similar land-use impacts are shown in the *Consumption Change* scenario, mainly because of the changes in land use away from animal production and the reduction in food waste. The *Decentralised Solutions* scenario shows the smallest benefits on average with respect to the Trend. The benefits of lower nutrient losses from less intensively used cropland are apparently counteracted by the larger cropland area. However, the scenarios have different impacts across regions. For instance in Latin America and the Middle East, the *Consumption Change* pathway leads to the largest reduction in wetland conversion compared with the Trend, while in Africa the *Global Technology* scenario has the most to offer, and in China the *Decentralised Solutions* pathway (Figure 5.8). Similarly, specific indicators of a degraded water quality and biodiversity, such as algal blooms, are reduced in most regions with respect to the Trend; in Africa and China the largest decline is in the *Global Technology* pathway; in most other regions in the *Consumption Change* pathway (Figure 5.9). There appears to be no single solution that is beneficial in all regions of the world.

Pressures driving global fresh water biodiversity loss under the Trend scenario and pathways



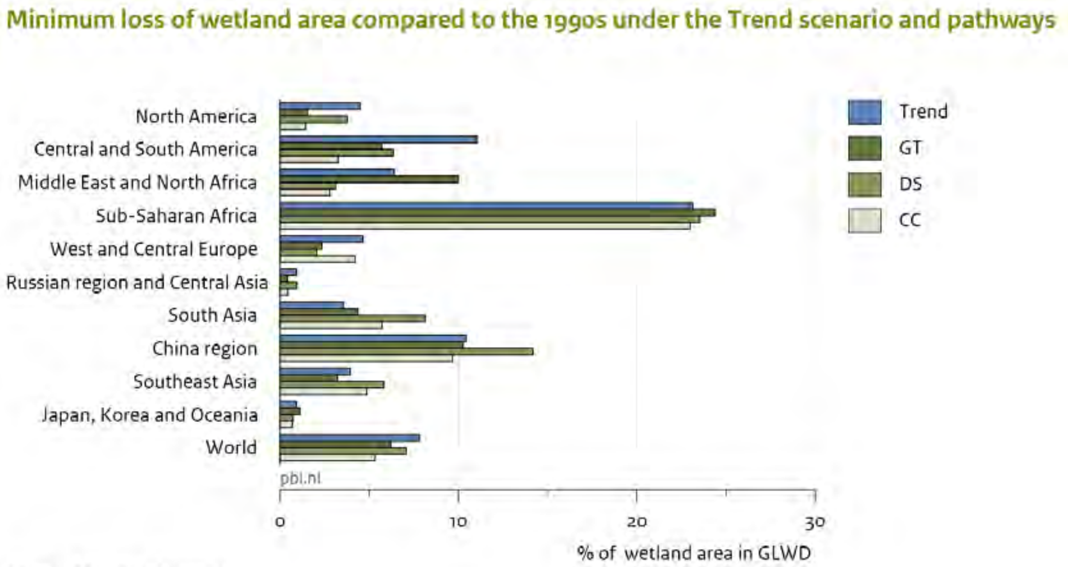
Source: PBL

Figure 5.6. Total reduction in aquatic biodiversity in 2000 and 2050 under the current Trend and three alternative Global Technology (GT), Decentralised Solutions (DS) and Consumption Change (CC) scenarios.

As these figures demonstrate, the various pathways towards reaching the Aichi targets for terrestrial biodiversity do not always result in equivalent benefits to aquatic ecosystems. However, numerous options to prevent biodiversity loss in the water sector have not been included in the scenarios but may have multiple benefits. Examples are measures that aim to reduce water consumption, either through increased water-use efficiency or reduced demand, or improve water quality, options for the use of hydropower or a combination of these in the implementation of IWRM, all of which were mentioned in the previous section.

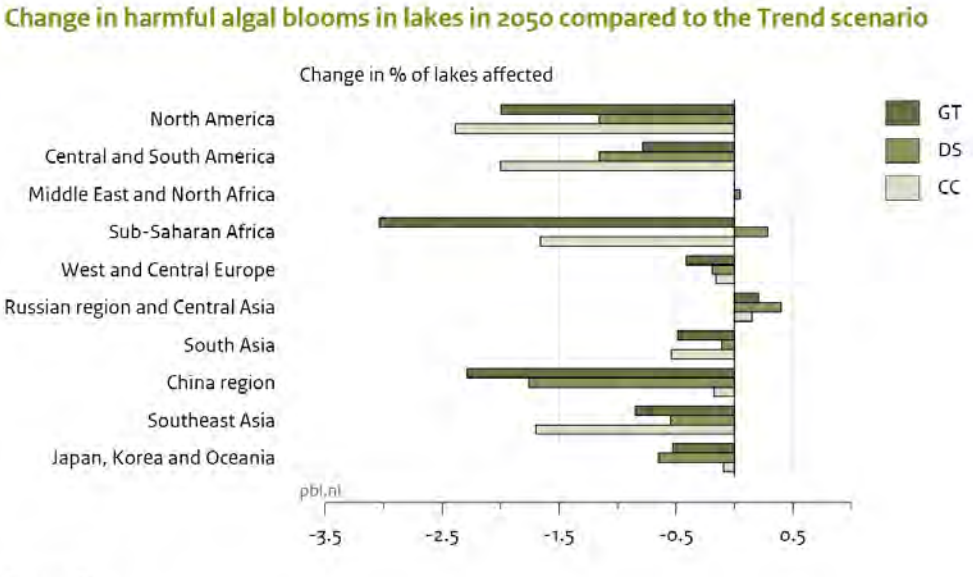
The sub-sectors might play different roles in the three global pathways. The *Global Technology* scenario will be largely driven by the private sector, for example seed companies, producers of agrochemicals and other actors involved in agricultural research and development. As food production is intensified and concentrated in high-intensity agricultural areas, local negative impacts on biodiversity may be high, as more infrastructure leads to increased hydrological disturbance and the fragmentation of nature (Nilsson et al., 2005). Concerning dams, one might focus on technical adaptations to reduce the negative impacts. The *Decentralised*

Solutions scenario follows a different pathway towards water pollution reduction, leading to more dispersed negative impacts over the landscape on biodiversity that may be harder to manage. This pathway might offer a smoother streambed for ecology-based water management solutions. The *Consumption Change* pathway might also stress the need for reduced water consumption, as well as a lower need for cropland and a reduced energy demand (including hydropower).



Source: PBL, GLWD (2005)

Figure 5.7. Minimum estimate for conversion of wetlands in 2050 (in km^2) based on land demands according to the current Trend and three alternative Global Technology (GT), Decentralised Solutions (DS) and Consumption Change (CC) scenarios.



Source: PBL

Figure 5.8. Changes in harmful algal blooms in lakes in 2050 according to three alternative scenarios (Global Technology (GT), Decentralised Solutions (DS), Consumption Change (CC)) compared with the Trend (= zero line).

There are limits to these ecological measures and their co-benefits in the shape of thresholds to the capacity of ecosystems to deliver water services (Barnosky et al., 2012). On the other hand, recognising that these ecosystem services have already been stretched to the maximum in many areas of the world (Figure 5.3), where water scarcity and pollution now seriously hamper development, ecological solutions are necessary to help balance biodiversity and a wide range of ecosystem services on the one side, with cities, water for food, hydropower and flood protection on the other. These solutions imply the use of ecosystem services or natural processes for water management goals. These services or natural processes often, but not necessarily, coincide with natural biodiversity values. With such measures, well-designed integrated river basin management can contribute a lot to biodiversity while at the same time serving water management goals (Falkenmark, 2003; Sadof & Muller, 2009; Krchnak et al., 2011; WWA, 2012). Taking an ecosystem perspective to water as well as land management, combined with protective measures and the regulation of emissions to water, as well as applying nature-based solutions, can contribute to the preservation of biodiversity and increase the chances of successful and sustainable freshwater management in the future.

This is in line with the principles of IWRM, now adopted in almost one hundred countries (UN Water, 2012; see Section 5.4). In IWRM, measures to improve the availability of water are complemented by attempts to reduce water consumption by clients (water demand management), to protect water quality, to stimulate efficiency measures and to spread information, all at different scales. This is a parallel interest with biodiversity, as a reduction in human water use and pollution would contribute to fewer disturbances of hydrological patterns, the restoration of environmental flows, reduced droughts in rivers and the maintenance of water levels in lakes, all of which are beneficial to aquatic life.

5.6 Priority actions to further reduce biodiversity loss

Mainstreaming biodiversity in water management could best be done by strengthening and expanding the potential for ecological approaches in IWRM, as this is the internationally-recommended planning mechanism in water management (WWA, 2009, 2012; Keys et al., 2012; Russi et al., 2013). In practice, the designated river basin organisations do not always have the political and financial support to implement even the basic principles of IWRM (Medema et al., 2008; Chéné, 2009). A combination of joint inter-sector analysis coupled with sector-wise application of IWRM that takes into account the actual investment pathways (and its managing institutions) might be more effective. The various strategies proposed below fit within this suggestion. Action to further reduce biodiversity loss and reverse the increasing pollution and degradation of the world's waterways can thus best be taken within the different investment pathways as outlined below. Where possible, the restoration of natural streams and the use of green infrastructure are preferred, to reverse current degradation of aquatic ecosystems, restore biodiversity and safeguard the ecosystem services that water management ultimately depends on.

Cities: protection and treatment

For cities, the major actors are municipal councils or comparable institutions, here referred to as 'municipalities'. Protecting biodiversity-rich watersheds and wetlands upstream can reduce the costs of drinking water treatment as well as prevent flooding. Municipalities are driven by the need to supply a growing urban population with safe water, via their water companies, and are usually so well-organised (and well-funded) that they can manage, or at least influence, their own watersheds. Legislation and coordination, under the umbrella of or at least in concordance with river basin organisations, might help support the implementation of biodiversity-friendly approaches to the drinking water supply. This would also strengthen the basin organisations. As a result, ideally policymakers can deal with the causes of water pollution before dealing with the consequences for good water quality. Strong coordination with agriculture is required to prevent eutrophication and pollution by agrochemicals. An approach based on the ecological integrity of upstream catchment areas would be essential to arrive at an encompassing water quality management plan.

Urban wastewater management strategies could be attuned to the integrated management plans of river basin organisations that incorporate all potential water users and polluters. The improved treatment and recycling of urban and industrial wastewater reduce the pollution to downstream aquatic ecosystems. Many water treatment technologies are available and could be deployed on a larger scale by the municipalities. Additionally, in low income countries, municipal policies need to move from restricting urban and peri-urban agriculture to the stimulation of the safe use of nutrient-rich wastewater for producing high-quality nutrition for growing cities, in turn supporting livelihoods (WHO, 2006; Winpenny et al., 2010). The establishment of water quality authorities or dedicated departments within basin organisations, supported by strong legislation, political will and sufficient funds, may be necessary to really improve water quality substantially.

Water for food: reduced abstraction and pollution

The agriculture sector as a whole urgently needs to deal with increasing degradation and natural resource scarcity, and targeted management for biodiversity preservation could be part of broad strategies towards environmentally-sustainable food security (Nellemann et al., 2009). Water for food can be used more efficiently by irrigation agencies, basin organizations and farmers, producing more crops, tree products, meat and fish with less water, land and other inputs, resulting in lower nutrient outflows and freeing water for natural ecosystems rich in biodiversity (see also Figure 3.3). Combined, many of the measures to increase water productivity also enhance ecosystem services (Gordon et al., 2010). Managing multi-purpose agriculture at the landscape level by the appropriate institutions such as district authorities, basin organisations or others, includes the mobilisation of multiple sources of water, using a wide range of water storage options, including natural infrastructure, as well as the integration of agricultural production systems. This leads to high water-use efficiency within agro-ecosystems as well as at the landscape level, reconnecting previously fragmented nature areas (Boelee et al., 2013a; Chester & Robson, 2013). The focus on ecosystem services thus enhances sustainable land use and reduces pollution. However, this requires dedicated institutions at the landscape and basin level, supported by strong legislation and reinforcement, all depending on the political will to preserve biodiversity and stimulate green growth.

A shift towards more vegetable and less animal-based food, as well as reduced waste of food will have important impacts. Water is among the inputs into animal food products that would be saved with a change in consumer’s diets, away from animal-based protein towards plant- and insect-based food sources (Section 3.5). Diversified and changed diets could be supplied by a mix of crops and livestock from local, biodiverse, farming systems and integrated in a water conservation strategy (see for example Chateil et al., 2013). Consumer-awareness of the ecological footprint and water consumption of food products may play a role in this. Likewise, any reduction in food losses and waste increases water productivity and thus reduces water consumption and pressures from land use and pollution.

The interests of sustainable food production and biodiversity loss reduction can be brought together in integrated water and river basin management plans, based on IWRM. Various stakeholders such as food producers (e.g. farmer organisations, pastoralists and shrimp farmers), irrigation managers and the food processing industry could use river basin organisations as a platform to help support more sustainable approaches that enhance ecosystem services and preserve biodiversity. A more integrated approach to water management in food production could encompass water quality and fisheries, as well as land planning; issues that are seldom included in agricultural or river basin management. Collaboration at the basin level could also be an opportunity for the agricultural sector to link with other water-dependent sectors, such as energy, transport, cities and industry, which would facilitate the gathering of information and promote long-term balanced solutions.

Hydropower: cost-benefit analyses and sustainable dam management

The hydropower sector (private companies in some countries, government in others) should also position itself as a part of integrated river basin management. For newly-designed plants, or in the case of renovation, a thorough analysis of costs and benefits of different ecosystem services should be carried out, and dam locations with the least impact should be preferred, for example in side branches instead of the main stem. Such assessments could be made obligatory by legislation. Furthermore, sustainable dam management offers the possibility to release environmental flows to downstream ecosystems, enhancing biodiversity and other services, while allowing for fish migration (Pittock, 2010; IHA, 2014). PES schemes, that can be run by basin organizations or as direct contracts, e.g. between hydropower companies and groups of farmers, have been demonstrated to help protect upstream watersheds and prevent the siltation of reservoirs (Wunder et al., 2008), as well as encourage carbon sequestration (Kelsey Jack et al., 2008) and increase biodiversity (Dunn, 2011). Hi-tech infrastructure and regulatory installations at large dams facilitate fine-tuning for multiple purposes including hydropower, irrigation and the urban water supply, as well as environmental flows and fisheries. Various alternatives to large dams are available that are both more sustainable and more cost-effective than conventional dams (Totten et al., 2010) and governments can help to promote these.

The current international dialogue on the ‘water-food-energy nexus’ offers a platform for the further streamlining of ecosystem-friendly approaches. This offers opportunities to also engage the hydropower sector in sustainable water management and planning and to promote the management of natural resources for a wider range of ecosystem services and biodiversity (GWSP, 2014). Environmental flows will continue to play an integrated role in such redefined IWRM (Sanderson et al., 2011).

Flood protection: green infrastructure and nature-based solutions

In many areas in the world, natural infrastructure can be a cost-effective alternative to artificial embankments for flood protection. High potential for implementation exists in countries where flood protection is still being implemented (e.g. sub-Saharan Africa and New Zealand). In those cases it may be more cost-effective to build on nature rather than replace it with grey infrastructure. Green infrastructure can be used in a landscape approach, most commonly run by district- or province-level authorities, in which natural resources are managed not only for food production, but for a wide range of ecosystem services including flood protection, biodiversity, natural pest management and reduced pesticide contamination (Figure 3.3).

As ecologically-based water management is generally more knowledge-intensive than traditional approaches, this offers numerous business opportunities for organisations and individuals that have more freedom to operate outside traditional disciplinary boundaries. Small and medium enterprises (SMEs), development organisations and consultants, together with scientific researchers, have enthusiastically started addressing the knowledge gap in the development of win-win solutions such as the combination of green and grey infrastructure for flood control and other benefits. Scientific approaches can help identify trade-offs and synergies.

Support for implementation

If we are to deviate from current trends towards the realisation of long-term ecological water management and biodiversity preservation goals, economic and political frameworks are required that help decision-makers change their way of thinking and acting. As water is used in almost all societal sectors, water issues should have a central place in planning across sectors (water-inclusive development) to establish priorities between agricultural production and other water uses on the one hand and the protection of freshwater sources on the other. A number of global organisations and initiatives are actively promoting sustainable and integrated water management: the Global Water System Project (GWSP), the World Water Assessment Plan (WWAP) that periodically issues a World Water Development Report (WWDR), the World Water Council, the World Water Forum, the OECD, the FAO, NGOs like the WWF, IUCN and TNC, universities and research organisations such as IWMI, the CGIAR research programme on Water, Land and Ecosystems, and others. Together they have firmly placed sustainable water management on the international agenda. Dedicated organisations such as the Ramsar Convention on Wetlands have a mandate to protect wetlands and have developed a joint work plan with CBD to specifically promote biodiversity.

An interesting opportunity is the on-going process to formulate the Sustainable Development Goals (SDGs) (see chapter 7). Building on the successful resource mobilisation for the Millennium Development Goals (MDGs), the SDGs explicitly strive for *long-term* human development and embrace green growth. The prevention of biodiversity loss through multipurpose water interventions fits well within this approach. The on-going dialogue on the 'water-energy-food nexus' is also progressively addressing the sustainability dimension (Hellegers et al., 2008; GWSP, 2014), as energy companies are under increasing economic (fossil fuels) and public (environmental damage) pressure to provide green energy.

Worldwide, as more governments endorse IWRM as a guiding framework for water management, river basin organisations are being established at national and regional levels (Schmeier, 2013), with international network organisations[18] for support, knowledge-exchange and capacity-building. The current international dialogue on the 'water-food-energy nexus', already mentioned, offers a high-level platform for the further streamlining of ecosystem-friendly approaches. The sustainability dimension of this 'nexus' is increasingly recognised. This offers opportunities to engage other sectors in sustainable water management and to promote the management of natural resources for a wider range of ecosystem services and biodiversity (GWSP, 2014). River basin organisations have been identified as potential change agents to push for an ecosystem approach and need strengthening to support this. Science can help determine the locally most effective mix of measures (see for example Carpenter et al., 2009), as has been done for water productivity scenarios (de Fraiture & Wichelns, 2010).

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[18] http://www.inbo-news.org

Chapter 6. Marine fisheries and aquaculture

6.1 Introduction

This chapter examines the relationship between capture fisheries and marine aquaculture, and biodiversity, as well as management options that can lead to the more sustainable use of marine resources and to biodiversity conservation. The world's seas and oceans are increasingly being exploited, and the growing pressures on the previously little-impacted Areas Beyond National Jurisdiction are of special concern (Merrie et al., 2014). Traditional uses such as fisheries and aquaculture, are growing and new activities are increasingly being developed, such as sustainable energy production, for example through wind-parks. A strategy of blue growth has been widely adopted; sustainable growth strategies in the marine sectors that unlock the potential of the marine environment.

In 2010, capture fisheries and aquaculture together produced 158 million tonnes of fish worldwide, of which 86% (136 million tonnes) was utilised as food for people. This , contributes to around 16.7% of all animal protein consumed globally (FAO, 2014). Up to 4.3 billion people, or around 60% of the global population, acquire more than 15% of their animal protein from fish (FAO, 2014). Fish and fishery products account for about 10% of global agricultural trade and the global fish supply grew at an average rate of 3.2% per year between 1961 and 2009 (FAO, 2014). Demand for fish is expected to grow (Garcia & Rosenberg, 2010) and fish and fishery products will continue to be highly traded. According to 2009 figures, Asia accounted for two thirds of global fish consumption (89.8 million tonnes), while Africa had the lowest regional consumption (9.9 million tonnes) (FAO, 2014). Not only do fisheries provide direct employment and income for local communities and an important source of food, but they also generate employment and income in processing and ancillary services and support subsistence-based activities. It is estimated that marine fisheries support 260 million jobs in the primary (capture production) and secondary (processing and ancillary services) sector worldwide (Teh et al., 2013).

Capture fisheries production has become relatively stable in recent years, whereas aquaculture – the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants – is the fastest-growing food production system globally, with an average annual growth rate of 8.6% between 1980 and 2012 (FAO, 2014). Global aquaculture production attained another all-time high in 2010: 60 million tonnes when excluding aquatic plants and non-food products, and 79 tonnes including macro-algae production. Aquaculture fulfils a major role in feeding people today, and its potential for doing so in the future is large.

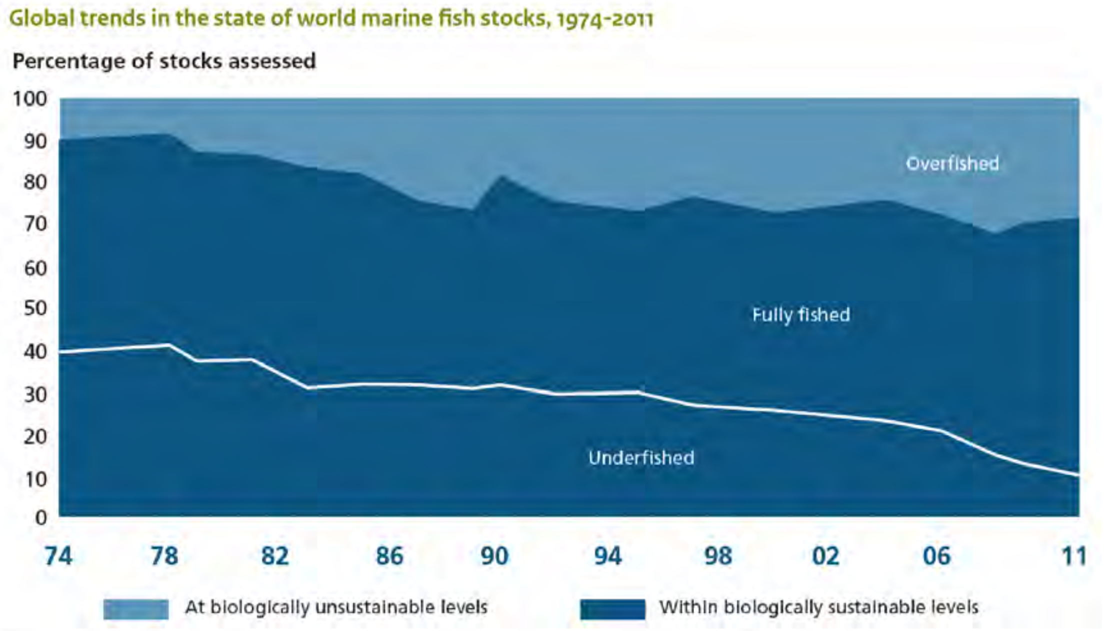
While the importance of inland fisheries (see Chapter 5) is recognised, the rest of this chapter focuses on marine capture fisheries and marine aquaculture (mariculture) only, and is split into the following sections: the fisheries sector (Section 6.2) and aquaculture (Section 6.3); a description of the fisheries and aquaculture sector (Sections 6.2.2 and 6.3.2); the benefits of and impact on biodiversity (Sections 6.2.3 and 6.3.3); current actions protecting marine biodiversity from fishing and aquaculture impacts (Sections 6.2.4 and 6.3.4); long-term options for reducing the biodiversity impact of fisheries and aquaculture (Sections 6.4); and priority actions for reducing fishing and aquaculture impacts on biodiversity (Sections 6.5).

6.2 Marine fisheries

6.2.1 Introduction

Capture fisheries are essential for humans, not only in terms of livelihoods, local economies and the wellbeing of coastal communities, but also in terms of food security and providing essential sources of protein. The CBD Strategic Plan 2011–2020 and the related Aichi Targets, especially Strategic Goal B (‘reduce the direct pressures on biodiversity and promote sustainable use’) and its related Target 6 (‘by 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits’) are of interest for fisheries management. Governments worldwide are committed to the implementation of this general sustainability framework for fisheries, maximum sustainable yield as a target for fisheries management is being widely introduced, and the ecosystem approach has become a more general starting point for fisheries management.

Globally, capture fisheries production appears to have reached a ceiling and produce is increasingly derived from aquaculture. The proportion of non-fully exploited fish stocks has declined, while overexploited stocks have increased (Figure 6.1; Froese et al., 2012; FAO, 2014).



Notes: Dark shading = within biologically sustainable levels; light shading = at biologically unsustainable levels.
The light line divides the stocks within biologically sustainable levels into two subcategories: fully fished (above the line) and underfished (below the line).

Source: FAO, SOFIA 2014

Figure 6.1. Global temporal trend showing the status of assessed world marine fish stocks. Source: FAO (2014).

6.2.2 Description of the fisheries sector

Characterising fisheries on a global scale is a somewhat arbitrary endeavour as classification is highly influenced by particular local circumstances. Some classical categorisations depend on the type of gear used: either active fishing gear such as trawls and seines, or passive gears such as trammel nets and long lines. However, information on the capacity of fishing fleets and different gears used worldwide is scarce. The FAO collects data, distinguishing between non-motorised vessels propelled by oars or sails and motorised vessels propelled by engines. The number of non-motorised vessels worldwide was 1.80 million in 1995 and 2.01 million in 2012, and the number of motorised vessels propelled by engines increased from 2.20 million to 2.71 million during the same period (FAO, 2012). Motorised vessels include both small-scale fisheries (with vessels < 15 m) and larger vessels. A study on fishing vessels > 100 GT (or longer than 24 m) in 1999 (FAO, 1999) suggests that such vessels represented approximately 1% of the motorised vessels. Over time, these vessels have fished an increasing percentage of the world’s oceans, with approximately 30% being fished in 1960, and approximately 65% being fished in the period since 2000 (Watson et al., 2012).

Another often used classification is that between pelagic fisheries, demersal fisheries and deep sea fisheries, often expressed as ‘métier’; this relates to the specific combination of fishing gears used, the species targeted and the area fished. In relation to this, an also frequently-applied classification is that of artisanal fisheries (small-scale, low-technology, subsistence fisheries of coastal communities), small-scale and large-scale fisheries, and industrial fisheries. This last is a particular point of confusion as some use the term industrial fisheries for any type of large-scale fisheries operation, whereas it is also a term reserved for a specific type of fisheries targeting species with no direct potential for human consumption but specifically fished for the production of fish meal and fish oil (in the North Sea, for example, represented by species such as sprat, Norway pout and sandeel).

Not only can a fishery be classified according to the production technology used, but also by the type of value chain the fishery is embedded in. As mentioned above, a prime distinction can be made between fisheries aimed at subsistence production and fisheries aimed at commercial production; however as even in most of the artisanal subsistence fisheries systems fish is usually exchanged between primary producers and consumers, almost all fishers are connected to consumers via a chain of traders (collecting trade, wholesale trade, long distance trade), processors and retailers. The length of the chain and the number of different actors involved varies by region and type of fishery. For instance, small-scale artisanal fisheries mainly involve a very short chain in which fishers sell fresh fish directly to local villagers or sell their catch to middlemen (traders) who then either sell it directly to customers or to hotels and restaurants (see for example Crona et al., 2010; Christensen et al., 2014). However, even in these more local production chains there are for instance many examples in West Africa where the produce of artisanal fishers is traded on an international scale. On the other hand, there are worldwide operating commercial fisheries with the vertical integration of all steps of the value chain within a single firm. Also, in some fisheries all catches are landed in the home port, whereas other fisheries operate on a global scale and land catches at specific targeted markets. Related to this is the discourse on the flag under which a vessel is operating and the nationality of the owners of the vessel.

6.2.3 Benefits from ecosystem services and impacts on biodiversity

Oceans and the biodiversity they support provide valuable goods and services to humans. For example, fish populations provide regulating services through their role in regulating food web dynamics and nutrient balances (Holmhund et al., 1999) and fisheries are an important provisioning service that supports the food security and welfare of millions worldwide. Fishing can also be considered a cultural service, as it plays an integral role in certain coastal cultures and traditions. In turn, fisheries are affected by the regulating (e.g. climate regulation) and supporting services (e.g. primary production) provided by ocean ecosystems.

Fishing directly impacts biodiversity through the removal of fish and the modification of marine habitats. It is widely acknowledged that fishing has already altered marine ecosystems (Pauly et al., 1998; Jackson et al., 2001) and that the persistence of overfishing will continue to negatively affect marine biodiversity and ecosystems. A global assessment of 207 marine fish population trends indicated that the assessed marine fish stocks declined by 38% between 1970 and 2007 (Hutchings et al., 2010), and an analysis based on more than 200 ecosystems showed a global decline of 52% between 1970 and 2010 for predatory fish biomass (i.e. fish with a trophic level (TL) of 3.5 or more; Christensen, in press). In certain cases, fishing has driven populations to such low levels that it results in the local extinction of marine species (Dulvy et al., 2014). Currently, over 550 species of marine fish and invertebrates are listed on the IUCN Red List as critically endangered, endangered or vulnerable.

The impact on a particular ecosystem varies according to the type of fishery. The impact of pelagic, demersal and deep sea fisheries is presented in Table 6.1 below.

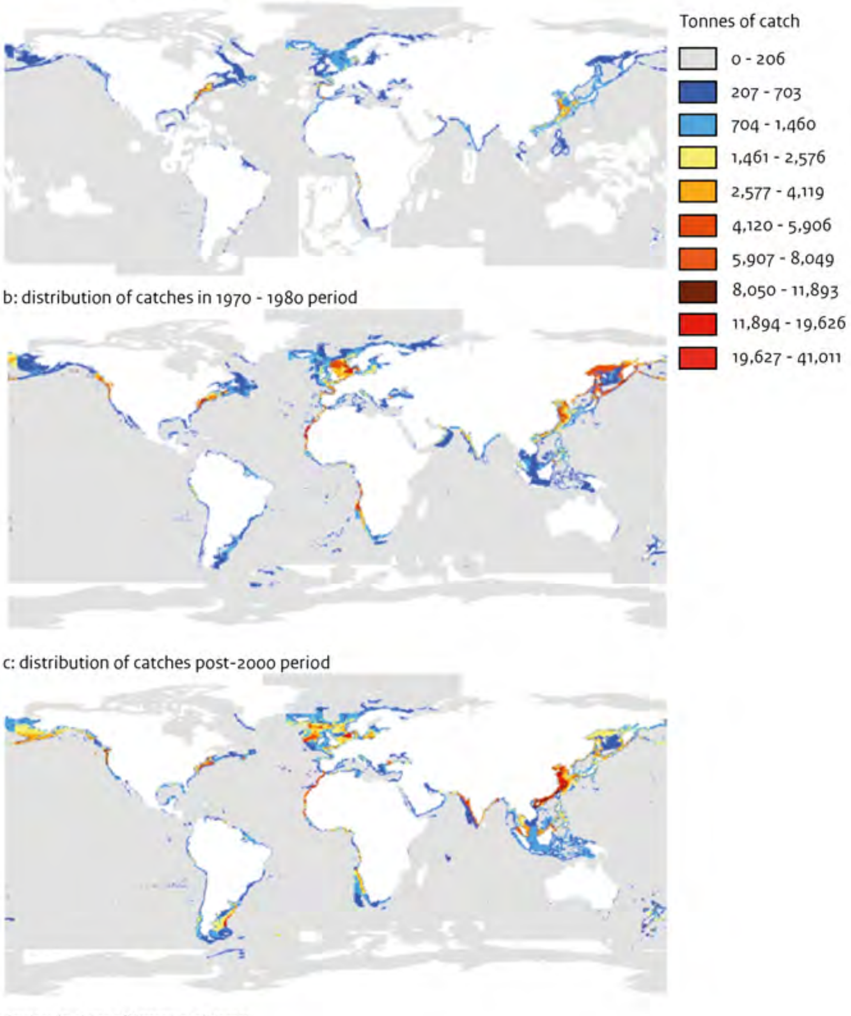
Table 6.1. Impact of pelagic, demersal and deep sea fisheries.

Fishery	Ecosystem impact	Impact on the provisioning of ecosystem services
Pelagic fisheries	Relatively 'clean' fisheries with little by-catch of other fish species. However, by-catch of large species (e.g. dolphins, sharks, turtles) may compromise biodiversity in some areas. No impact on seafloor habitats.	Overfishing may result in a reduced potential for food provisioning.
Demersal fisheries	Often mixed fisheries catching a wide array of fish species of which only part has commercial value. Discards are often an important food source for various scavenging species (birds, benthic invertebrates). These fisheries mostly use bottom trawls, which are known to damage seafloor habitats and reduce benthic diversity.	Overfishing may result in a reduced potential for food provisioning. By-catch of vulnerable species and the resulting loss of biodiversity may compromise the stability of food provisioning through predator-prey relationships, the provisioning of genetic material and resistance against invasions by non-indigenous species. Habitat destruction may compromise the mediation of waste, toxics and other nuisances as well as its capacity for bio-remediation or filtration/sequestration/storage/ accumulation by micro-organisms, algae, plants and animals. The loss of specific habitats that function as nursery areas will result in the reduced lifecycle maintenance of various populations, including those with commercial value. The seafloor is also known to be important for global climate regulation by greenhouse gas/carbon sequestration by sediments and their biota and the transport of carbon into oceans.
Deep sea fisheries	Often target fish populations that are vulnerable to fishing because of their life-history characteristics (i.e. slow growing).	See demersal fisheries.

In particular, many deep-sea fish and other large, slow-growing fish are especially vulnerable to over-exploitation (Cheung et al., 2005; Norse et al., 2012). This process is referred to as 'Fishing down marine food webs' (Christensen, 1996) and occurs when higher trophic level fish are progressively depleted and replaced with lower trophic fish – a process that has been documented in many ecosystems (Pauly et al., 1998; Pauly & Palomares, 2005; Stergiou & Christensen, 2011), albeit debated (Essington et al., 2006). In addition, some fishing practices directly damage or modify habitat structure and heterogeneity, with resulting impacts on both target and non-target species (Turner et al., 1999). The use of bottom trawls has increased globally in marine ecosystems (Watson et al., 2006; Figure 6.2), which directly impacts benthic habitats, can reduce overall biomass and shifts the benthic composition towards small opportunistic species. The use of destructive fishing gears is of particular concern in vulnerable habitats such as coral reefs, seagrasses, cold water corals and sponge grounds, which are declining at accelerating rates worldwide (Waycott et al., 2009; Burke et al., 2011). Destructive fishing such as dynamite and poison fishing threatens over 55% of coral reefs (Burke et al., 2011) and also contributes directly to seagrass loss, which has occurred at a rate of 7% a year since 1990 (Waycott et al., 2009). Gear selectivity can also directly affect biodiversity by capturing large quantities of by-catch, and is considered a primary driver of population decline in some species of marine megafauna (Wallace et al., 2010).

Global expansion of bottom trawling

a: distribution of catches in 1950 - 1960 period



b: distribution of catches in 1970 - 1980 period

c: distribution of catches post-2000 period

Source: database of Watson et al. (2012)

Figure 6.2. Global expansion of bottom trawling. Maps show global distribution of catches from trawling for different time periods (a) 1950–1960; (b) 1970–1980; (c) post-2000 (units are tonnes of catch). Based on the database of Watson et al. (2012).

Climate change will directly and indirectly impact fisheries through physiological and behavioural effects on fish and physical and chemical changes in the environment (Brander, 2010; Sumaila et al., 2011). Species distribution is projected to shift in the future, resulting in increased diversity and fisheries potential in high latitude regions, while the opposite will occur in the tropics (Cheung et al., 2010). It is expected that the northward movement of species will lead to more temperate species in northernmost European seas, while subtropical species will move northward to temperate regions (Philippart et al., 2011). This is expected to affect original species, whose niches may be filled by species originating from adjacent waters (Sherman et al., 2009). In certain areas such as the North Sea, distribution shifts are likely to increase the risk to critically-endangered species such as the common skate and angel shark (Jones et al., 2013). Endangered marine megafauna such as turtles are also deemed vulnerable to climate change; the combined pressures of human stressors and current rates of climate change are expected to have both positive and negative effects on turtle populations (Poloczanska et al., 2009).

6.2.4 What is the sector already doing in favour of biodiversity?

Numerous multilateral fisheries management conventions are in place at the international level for the conservation and sustainable use of marine biodiversity. These include the UN Law of the Sea Convention, the Convention on Biological Diversity, the FAO Code of Conduct for Responsible Fisheries, CITES (Convention on International Trade in Endangered Species) and the UN Agreement on straddling stocks and highly migratory fish stocks.

Rebuilding overfished stocks is crucial to achieve sustainable fisheries and to allow for the recovery of habitats and species. For this to happen, there is growing awareness that current excess fishing capacity has to be drastically reduced. This involves eliminating or diverting subsidies that contribute to overcapacity and overfishing and reducing illegal unregulated and unreported (IUU) fishing, which can be linked to excess fishing capacity that partly came about due to subsidies for fishing fleet development (Agnew et al., 2009; Sumaila et al., 2010a). Eliminating destructive fishing gears that damage marine habitat and/or have high by-catch is essential for minimising biodiversity and ecosystem impacts, as is adopting ‘greener’ technology that minimises greenhouse gas emissions.

A suite of management instruments is used to regulate exploitation rates, including gear restrictions, creating marine protected areas, and the use of economic incentives (e.g. vessel buybacks and individual transferable quotas (ITQs) to encourage reducing fishing effort (Worm et al., 2009)). Globally, national government fisheries management focuses on managing the deployment of the fishing fleet’s capacity (input regulation) and regulating the amount of fish landed (output regulation) and the way in which fish are caught (technical measures). Input regulation includes measures such as unitisation schemes, effort limits and temporal and spatial closures, license limits, technical limits such as the type and size of gear used, entry/exit schemes, vessel decommissioning/buyback and permits. Output control uses instruments such as Total Allowable Catch, Individual Quotas (IQs), fishing cooperatives, community quotas, area-based quota programmes, vessel quotas and Transferable Quotas (ITQs)/harvest rights. In some instances, access charges such as management cost recovery are being used as management instruments.

Whereas the previously dominant norm was the top-down governing of fisheries, new governance arrangements in fisheries management are increasingly seen worldwide. In these, the main focus is on developing management systems in which decisions on resource management are shared between governments and resource users. The term co-management covers a variety of such partnership arrangements. The fisheries management literature provides many examples of resource users’ participation in fisheries management. For example, Jentoft and McCay (1995) Raakjær and Vedsmand (1995) and Sen and Raakjær (1996 provide a plethora of cases in which user participation is applied, including African, Asian and European cases – the latter including some in the Netherlands, Denmark and Norway. Smith et al. (2008) provide the example of the Resource Assessment Groups that operate in Australia. Co-management of the sandeel fisheries in Ise Bay is a well-known case in Japan, where natural resource management is carried out through the interplay of fishing communities, science and government (Ashida, 2009).

Participatory arrangements in fisheries management can range from historical fishers' organisations, such as the Confradias de Pescadores in Spain and the Prudhomies in France to more modern arrangements (Galle and Weber, 1992; Jentoft and McCay, 1995; van Hoof et al., 2006). Safeguarding the user rights of native groups of fishers, such as in the Community Development Quota system of the US North Pacific Regional Fishery Council help bring economic and social development opportunities to native Alaskan villages along the coast of Western Alaska (May, 2008). Some are rather ancient local systems, such as found in Japan (Ashida, 2009) and the Customary Fishing Rights Areas in Fiji (Sen & Raakjær, 1996), but may also be of more recent signature, such as the management of the mechanised beach-seine fishery in Mozambique and the management of Lake Malombe in Malawi (Sen & Raakjær, 1996).

There is compelling evidence that such participatory governance is crucial for dealing with the complex problems of managing for multiple values and outcomes to achieve ecological sustainability and economic development (Kearney et al., 2007). Co-management arrangements involving fishers and government and/or NGOs have contributed to successful fisheries management outcomes (Gutiérrez et al., 2011), especially in small-scale fisheries in developing countries (Cinner et al., 2012). Given that the majority of the world's fishers are engaged in small-scale fishing, the use of shared governance and co-management arrangements is a promising action that can lead to sustainable fisheries.

An ecosystem approach that shifts away from conventional species-by-species management and moves towards holistic seascape management will provide the opportunity to maintain marine biodiversity. One example of ecosystem-based fisheries management (EBFM) being adopted on a regional basis is the Northwest Atlantic Fisheries Organization (NAFO) Roadmap for Developing Ecosystem Approach to Fisheries. The United States is also transitioning to EBFM, while large regional initiatives, such as the Coral Triangle Initiative of the Pacific in which six nations cooperate, have also adopted EBFM. The EU, through the Marines Strategy Framework Directive and the Common Fisheries Policy, has also made EBFM a cornerstone of policy.

Sustainability certification and labelling, such as that administered by the Marine Stewardship Council (MSC) and Seafood Watch, is another mechanism to meet sustainability concerns by providing incentives for fishermen. These are partnerships between actors along the fishery value chain, from fishers to retailers, restaurants and consumers. The MSC eco-label was the result of Unilever and WWF coming together in the early 1990s and creating, in 1997, the Marine Stewardship Council (Agnew et al., 2014). Unilever was primarily interested in maintaining the long-term supply of fish and, realising the need for healthy stocks, co-created the MSC (Agnew et al., 2014). Given that within MSC-certified fisheries improvements in environmental performance have taken place (Martin et al., 2012), the involvement of Unilever in the creation of MSC is a clear example of a positive activity at the wholesale/retail level in the fishery value chain.

In addition to incentives from government and the market in recent years, fuel prices have played an important role in the management of fishing effort. Fuel prices have increased considerably in the past decade. As a result, the economic performance of fisheries, especially active gear fisheries such as trawlers, has deteriorated, and fuel-intensive fisheries such as trawling have sought ways to reduce fuel use (Beare & Machiels, 2012). In addition, gear substitution is taking place, where the weight and drag of gears is reduced, for instance by reducing bottom contact (van Marlen et al., 2014).

Barriers and levers for change

Sustainable fisheries management efforts face several challenges arising from resource users, economies, institutions and the environment that permeate local, national and regional levels. Non-compliance and non-cooperation at local and international levels present barriers to achieving sustainable fisheries and are relevant to individual fishers (Kuperan & Sutinen, 1998) as well as to institutions. An example is non-cooperative behaviour between countries in the management of transboundary and migratory fish stocks (Munro, 2008). Prevailing socio-economic conditions that drive excessive fishing pressure also present a barrier to fisheries conservation (Cinner & McClanahan, 2006). Poverty and lack of alternative economic opportunities prevent fishers in many coastal communities from leaving the fishery or engaging in more sustainable fishing practices (Béné, 2003; Daw et al., 2012). In many cases, particularly in developing countries, reducing fishing effort conflicts with social employment objectives in the short run, providing a political challenge to balance the trade-offs of fisheries policies. A poor or lack of monitoring capacity, stemming from insufficient human or financial resources, allows the continuation of damaging and unsustainable fishing practices, such as IUU fishing and by-catch at local and international scales.

Levers to enable fisheries practice to become more sustainable can be found in incentives from the market, society and the general public and the management system. Public awareness of the effects of human activities on the marine ecosystem, and of fisheries in particular, is growing. On the one hand, this has led to the growing influence of labels, especially sustainability labels such as MSC, for both fish consumption and fish production, with larger retailers, supermarkets and food chains in particular increasingly demanding that their fish produce has obtained sustainability labelling. On the other hand, the ‘licence to produce’, i.e. the societal acceptance of current fishery practices, is being questioned. Increasingly, producers need to acquire this licence to produce, representing public consent to the industry to exploit the marine environment. This signifies a shift in the traditional governance of fisheries management: in the first instance the government licensed fisheries; fishermen were accountable to government and government was held accountable by society. Today, although fishing licences are still issued by the state, fishermen are increasingly held directly accountable by society for their actions; on the one hand through consumers wanting fish produce to be labelled with a recognised sustainability label, and on the other through society banning certain fishing practices, such as the current discard ban in Europe, the ban on electric fishing and bans on the finning of sharks.

In addition to this, a positive advance can also be found in the development of possibilities to involve resource users in the management of the resource. On one side, there is the continued development of rights-based fisheries management systems in which a major intended effect is the creation of economic incentives for owners of vessels to decrease their inputs of labour and capital on a fishery and to use the resource in an efficient, sustainable way (Committee to Review Individual Fishing Quotas, 1999). Transferable license and quota systems are the only recognised systems that effectively create exit strategies in the industry where the participants themselves adjust catch and processing costs to the potential income from the available quota (Trondsen, 2004). On the other side, there is a development towards co-management systems in which fishers become actively involved in the management of the resource use. Both systems create incentives for fishermen to become more actively involved in the sustainable use of the resource. Co-management or community-managed areas, combined with user rights give resource users a sense of secure user rights, which provides incentives for long-term stewardship of the resources.

6.3 Aquaculture

6.3.1 Introduction

Between 1980 and 2012, aquaculture grew on all continents (Figure 6.3), although the majority of production – 88.4% of all aquaculture harvest in 2012 – occurred in Asia, with China by far the largest producer. The rapid growth in this region has been driven by a variety of factors, including pre-existing aquaculture practices, population and economic growth, liberal regulatory frameworks and expanding export opportunities. North America, South America and Europe have also increased production levels, although their absolute yields, in comparison with Asia, indicate that further increases could occur (FAO, 2012). Aquaculture development in Europe and North America was rapid during the 1980s–1990s but has since stagnated, probably owing to competing claims on available spaces and resources, regulatory restrictions on sites, the lack of a level playing field and other competitive factors. Nevertheless, a steady increase in demand for fish, expressed in growing markets for fish and seafood, has been observed. This increase in demand can be attributed to a net effect of an increase in world population, but even more so to increased demand resulting from changing consumption patterns based on an increase in income in some parts of the world (World Bank, 2013)

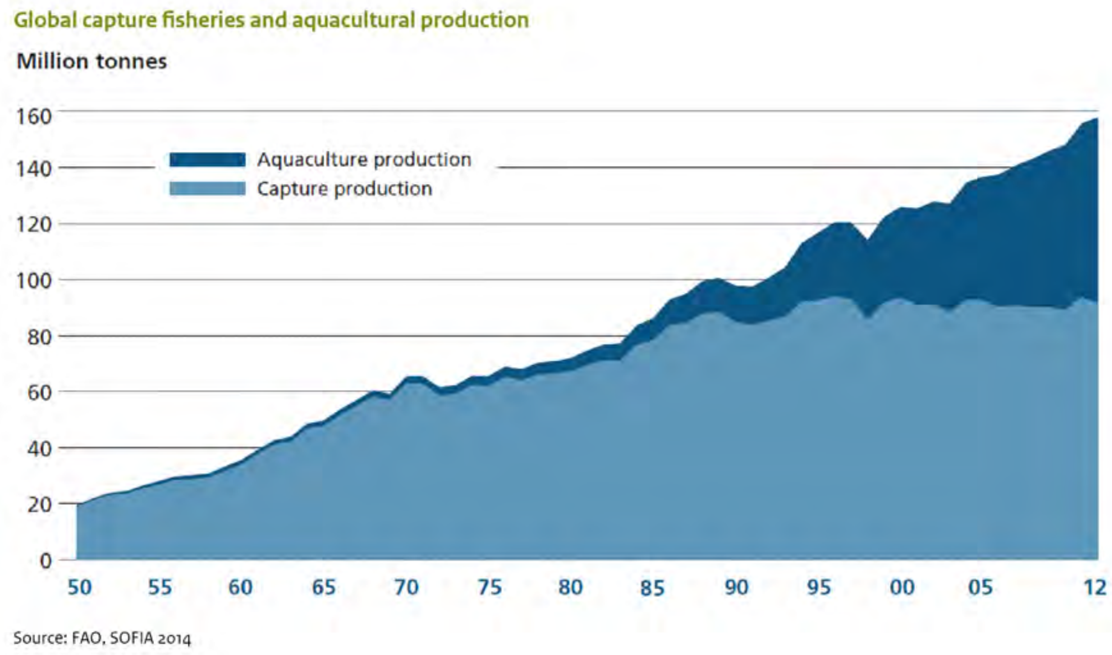


Figure 6.3. World capture fisheries and aquaculture production (FAO, 2014).

Aquaculture has both positive and negative impacts on biodiversity. Examples of positive aspects are the fact that cultured seafood can reduce pressure on overexploited wild stocks, stocked organisms may enhance depleted stocks, aquaculture often boosts natural production and species diversity, and employment in aquaculture may replace more destructive resource uses. On the negative side, species that escape from aquaculture can become invasive in areas where they are non-native, effluents from aquaculture can cause eutrophication, ecologically-sensitive land may be converted for aquaculture use, aquaculture species may consume increasingly scarce fish meal and oil, and aquaculture species may transmit diseases to wild fish (Diana, 2009). Defining and promoting conservation practices and thereby minimising potential negative impacts on biodiversity is an imperative for the sustainable future of the relatively young but rapidly-growing seafood production industry. This may lead to apparent tensions between *biodiversity* and *food security* objectives. For example, international initiatives to protect aquatic biodiversity typically call for local species to be produced in aquaculture; international initiatives to protect food security, on the other hand, call for the use of the most efficient aquaculture varieties (Pickering, 2011).

6.3.2 Description of the aquaculture sector

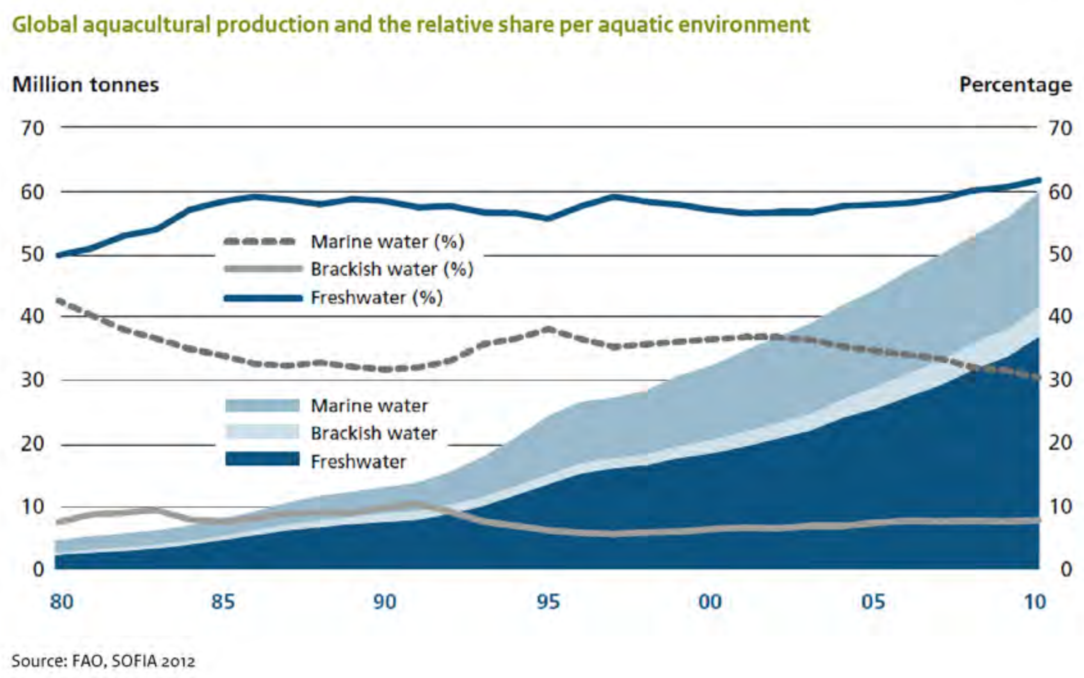
'Aquaculture is the controlled cultivation of some type of aquatic animal (e.g. invertebrates or fish) or plant, mainly for food. The crop can vary from aquatic plants to invertebrates or fish. The level of control over production can vary from managing only a portion of the life cycle to managing the complete life cycle by producing seed (e.g. fish fry) in a hatchery and using the fry to grow adults that can be harvested or used as brood stock. Extensive aquaculture is practiced when aquatic organisms are placed in an appropriate environment in which they can grow and be left unattended for a time before being harvested. In semi-intensive aquaculture, fertilizers may be added (Bostock et al., 2010).

Although a few hundred species are cultured worldwide, the top 5 species account for around 33% of the output and the top 20 species for 74% of production by volume (Bostock et al., 2010). Freshwater fish dominate global aquaculture production (57%), followed by molluscs (24%), crustaceans (10%), diadromous fish such as salmonids (6%), marine fish (3%) and other aquatic animals (1%) (FAO, 2012). Freshwater fish production is dominated by various species of carp, although tilapia and, more recently, pangasius catfish have become more significant.

Aquaculture can be categorised as fed and non-fed aquaculture. Fed aquaculture is relatively intensive as animals are cultured through the addition of feed in more or less controlled systems; this is predominantly the case for fish and shrimp cultures. This type of farming is done in recirculation aquaculture systems (RAS), ponds or open water cages. Most freshwater culture is performed in ponds using semi-intensive methods (water fertilization with inorganic and organic fertilizers and supplementary feeding with low-protein materials). Semi-intensive coastal ponds and lagoons have been exploited in simple ways for fish, mollusc, crustacean and seaweed production for centuries. For mid- to high-value marine fish species, floating cages have proved the most cost-effective production system across a range of farm sizes and environments (Bostock et al., 2010). Non-fed aquaculture is extensive and based on the natural supply of feed, carried out in the natural environment. This concerns shellfish and seaweed farming. Traditional shellfish farming is done on bottom culture plots, generally based on seed collected from wild beds. Suspended culture makes use of longlines or rafts. For oyster culture, tables are used, and in areas in France mussels are cultured on poles. Coastal aquaculture primarily comprises shrimp, oysters, scallops and mussels.

Aquaculture employs about 23.4 million full-time-equivalent workers worldwide, which includes 16.7 million direct and 6.8 million indirect jobs. Most (92%) of this employment is generated in Eastern Asia, which approximately matches its world aquaculture production share. Labour productivity is highest in North America and Europe; an indication that the aquaculture sector in these regions is highly industrialised, relying on machinery for production and, therefore, with a lower demand for manual labour. The direct employment in aquaculture represents 1.2% of the population employed in agriculture worldwide (about 1.35 billion in 2005). Moreover, assuming an average family size of five members, it can be inferred that, through employment, aquaculture contributed to the livelihoods of approximately 117 million people in 2005, or 1.8% of the world population (Valderrama et al., 2010).

Aquaculture makes a major contribution to global food security and more opportunities still exist to further expand its role. Aquaculture growth could be realised through improvements in technologies and resource use, intensification, the integration of aquaculture with other farming activities, and the development of additional areas for aquaculture. However, aquaculture will face significant challenges, including: (i) meeting a growing demand for seed, feed and fertilizers both in terms of quantity and quality, (ii) reducing production losses through improvements in fish health management, (iii) increasingly severe competition with other resource (land/water/feed) users, (iv) the deteriorating quality of water supplies resulting from aquatic pollution, (v) the successful integration of aquaculture with other farming activities, and in some regions the promotion of small-scale low-cost aquaculture in support of rural development, (vi) improvements in environmental management including the reduction of environmental impacts and avoidance of risks to biodiversity through better site selection, the appropriate use of technologies – including biotechnologies – and more efficient resource use and farm management, and (vii) food safety and product quality requirements (FAO, 1999; EFARO, 2013). Challenges may vary between regions. In many developing countries, for example, there is significant scope for enhancing the contribution of inland aquaculture to food supplies and poverty alleviation. However, most farmers are unable to access adequate technical information required to improve their practices, and training seems crucial for successful development. In more developed (marine) regions, reduced site availability resulting from competing claims in coastal zones might be a more profound example limiting further growth of the sector.


Global aquacultural production and the relative share per aquatic environment

Source: FAO, SOFIA 2012

Figure 6.4. World aquaculture production and relative share by culture environment (FAO, 2012).

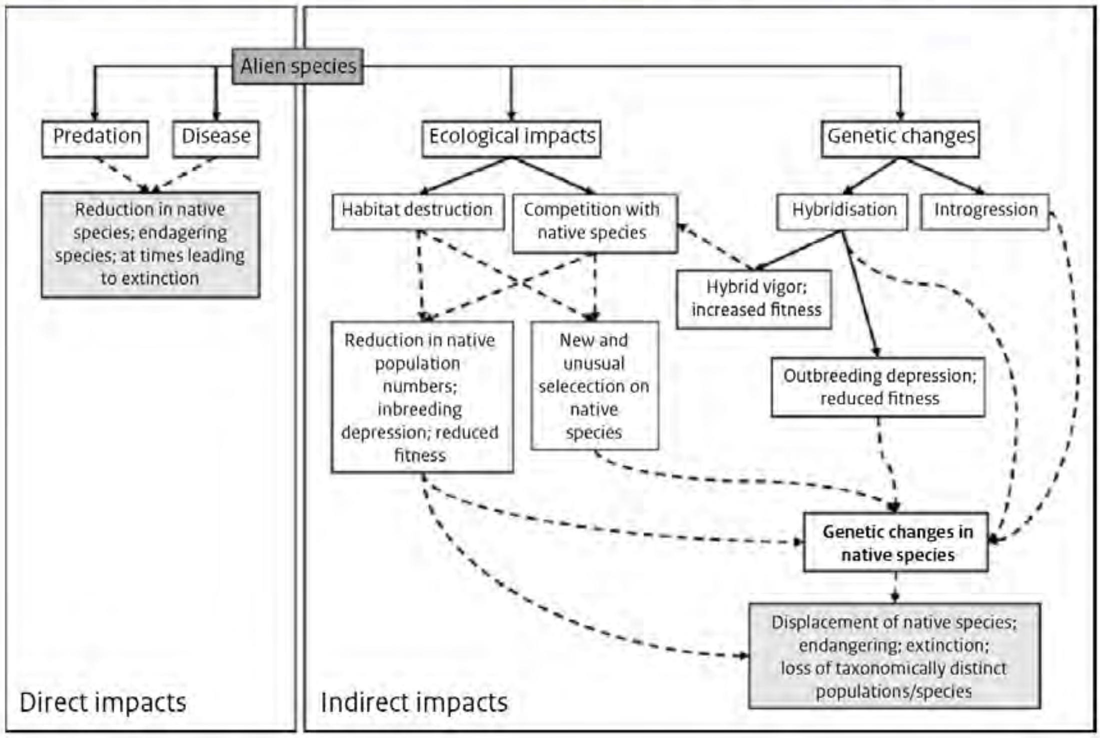
6.3.3 Benefits of ecosystem services and impact on biodiversity

The effects of each aquaculture practice (species, level of intensification, production area) on biodiversity conservation vary greatly (see Table 6.2 Aquaculture has various types of impacts on biodiversity but may also benefit to people and help reduce pressures on biodiversity. Given the need for seafood production and the risk of overfishing in many areas, sustainable aquaculture including hatchery/nursery systems may result in reduced pressure on wild stocks.

Biodiversity provides various services to aquaculture, these include the genetic resources from wild populations and wild relatives of the cultured species. Similar to agriculture it may reduce pests

An important impact of aquaculture on biodiversity is the introduction of new, possibly invasive, species or escapees of modified genotypes. Exotic aquatic species have been widely introduced and used for mass production in aquaculture, and their use is particularly common and important in Asian countries (FAO, 2012). Competition can occur between alien and resident species for food, habitat, mates or other essential resources. Particular concerns have been raised or observed regarding the introduction of cultured Atlantic salmon, the Pacific oyster, Grass carp and Mozambique tilapia (de Silva et al., 2009[19]). These species have been shown to interfere heavily with local stocks of the same species or to outcompete and displace other species. Genetic interactions between farmed and wild stocks may not only impact the species integrity due to mixing with alien genotypes but may also result in lowered reproductive efficiency or reduced fitness.

Effects on biodiversity from introduction of new species or modified genotypes



Source: De Silva et al., 2009

Figure 6.5. Schematic diagram of potential direct and indirect impacts on biodiversity due to introductions of new species or modified genotypes (de Silva et al., 2009).

The transmission of diseases or parasites from farmed animals to wild fish stocks and concerns about potential antibiotic resistance are a risk for natural stocks and thus for biodiversity. Built up of resistance is a side effect of frequently applying antibiotics in aquaculture. Of particular concern is the introduction of alien species, potentially hosting exotic pathogens with

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[19] http://www.fao.org/fishery/topic/14853/en

unknown effects on natural stocks. High densities of cultured stocks are prone to disease outbreaks, and in culture systems with direct interaction with the natural environment such as sea cages disease may easily be transmitted from cultured to wild stocks. A well-known example of this is increased sea lice infestations in wild salmon.

Aquaculture may also impact biodiversity conservation through the significant amounts of fish meal/oil used in intensive fish and shrimp cultures. Fishmeal commonly comes from small pelagic species of fish and is a limited resource. For these reasons, the use of fish meal in aquaculture must be considered a negative impact of the industry (Naylor et al., 2000). However, it is alleged that aquaculture, which accounts for only about 30% of global fish meal supply usage, has been unfairly singled out by critics of the industry (de Silva et al., 2009). Approximately 50% of all fish meal used in 2002 went to intensive livestock feeding, and the pet food industry is also a competitor for fish meal (about 7%; Tacon, 2004).

In non-fed aquaculture, feed is derived from the natural environment. This may raise questions about the carrying capacity of the ecosystem for aquaculture production. When culture stocks exceed a certain size, resource exploitation may exceed production capacity and overgrazing of the food source may occur (Smaal et al., 2013; Cranford et al., 2009). High grazing pressure may impact on the pelagic biodiversity, for example when phytoplankton composition shifts towards the dominance of very small sized organisms (picoplankton) (Cranford et al., 2009).

Organic and chemical effluents from aquaculture facilities have caused public concern about sustainability and the influence on the environment, including impacts on biodiversity. This has been a particular concern with regard to intensive open water fish culture, although many pond or tank systems – especially in developing countries – also still discharge untreated waste water to natural ecosystems. Clearly, high densities of cages and high numbers of fish in cages could produce situations in which the assimilative capacity of natural water bodies is exceeded by the demands of aquaculture, leading to environmental and biodiversity deterioration. This is particularly true for freshwater systems, which are often smaller in size and have high nutrient loadings (Diana, 2009). In marine cage cultures, low diversity is sometimes observed under cages with a relative high abundance of opportunistic species (Callier et al., 2011). When organic loading becomes excessive it may lead to ‘dead’ zones where very few organisms can survive. However, it should also be noted that opposite effects may be observed, for example increased local biodiversity was observed for fish culture in oligotrophic marine waters in Chile (Diana, 2009).

Land-use change associated with aquaculture is another risk for biodiversity conservation objectives. The perceived negative impact of shrimp aquaculture has received particular attention in this respect (Boyd & Clay, 1998). The major objection to shrimp culturing in this context is that mangroves are cleared to make way for pond facilities.

Open water aquaculture or fish farming in net pens or suspended shellfish culture may affect the benthic environment underneath the structures. The effects are different for fed and non-fed aquaculture, due to the differences in input. Impacts on the benthic environment consist of organic enrichment, and this typically occurs on a local scale. Impacts have also been demonstrated in a number of cases for suspended shellfish culture (Kaspar et al., 1985), while other studies show no impact (Archambault et al., 2010).

Processes linked to aquaculture can stimulate ecosystem productivity and enhance biodiversity. In oligotrophic systems, a dose-dependent positive impact can be expected from the input of nutrients from cage farms. For shellfish culture, the recycling of nutrients through filtration, biodeposition and mineralisation has been shown to stimulate phytoplankton turnover (Dame et al., 1991; Prins & Smaal, 1994; Jansen et al., 2011; Jansen et al., 2012).

Shellfish culture enhances the biomass of the cultured species and this acts as a food source for protected bird species. Extensive culture in the natural environment therefore increases food availability for various types of predators.

Open water cage aquaculture may attract many wild species and increase biomass stocks as a result of feed spills and faecal output as well as the introduction of surface area by the three dimensional culture structures. Over time, a complex community of species may emerge, representing different trophic levels that occupy the niche space offered by the aquaculture system. Culture systems may therefore act as artificial reefs and promote secondary production and biodiversity. It has been advocated that, through clever design, biodiversity can be engineered into farming practices (Chopin et al., 2012).

Table 6.2. Possible interactions between various modes of aquaculture and factors that influence biodiversity (• indicates a potential for significant impact; empty cells represent no/little potential for effect).

	Fish			**Crustaceans**	**Shellfish**		**Aquatic plants**
	Sea cages	**Pond: Marine & fresh water cultures**	**RAS: Marine & fresh water systems**	**Shrimp (pond)**	**Bottom (open water)**	**Suspended (open water)**	**Seaweed (open water)**
Impacts of aquaculture on biodiversity conservation							
Introductions							
Escapees	•	•					
Genetic alteration	•	•					
Disease transfer	•	•		•	•	•	
Invasive species	•	•			•	•	•
Resource exploitation							
Fish meal/oil use	•	•	•				
Overgrazing					•	•	
Waste							
Chemical use & medicines	•	•	•	•			
Organic loading & eutrophication	•	•		•		•	
Habitat use							
Loss of sensitive land (e.g. mangroves)		•		•			
Predator control	•	•		•		•	
Biodiversity conservation through aquaculture production							
Release pressure wild stocks	•	•	•		•	•	•
Natural production	•				•	•	•
Habitat formation	•	•			•	•	
Control of eutrophication					•	•	•

Various studies have shown that shellfish beds are hotspots for biodiversity (Saier, 2002). An extensive study in the Dutch Wadden Sea showed that a relatively high biodiversity was also observed on mussel culture in sub-littoral bottom plots (Drent & Dekker, 2013). Despite or due to the activities of the mussel farmers in terms of seeding juvenile mussels, mussel bed maintenance and eventual harvesting, the number of species on these beds was over 100, compared with 84 benthic species on wild beds.

In certain areas, the biofiltration capacity of shellfish is used to mitigate eutrophication impacts or the impacts of waste water discharges (Lindahl et al., 2005). Water quality improvement is relevant for enhancing biodiversity.

6.3.4 What is the sector already doing in favour of biodiversity?

There is a series of environmental best practices available for the industry (see for example Tucker & Hargreaves, 2008). In Europe, indicators have been developed for best practices in aquaculture (see Consensus, 2005[20]) and, at the global level, the global aquaculture alliance has launched a website on Best Aquaculture Practices (BAP). It should be noted, however, that this BAP pays no specific attention to biodiversity issues. Even so, mitigating environmental impacts can be considered an activity that favours biodiversity.

At the farm level, a number of mitigating measures with regard to environmental impacts are being practiced and can be further developed. These may also stimulate biodiversity conservation, for example through the following practices:

- Improved feeding efficiency to reduce organic waste fluxes.
- Improved feed formulation aiming for substitution of fishmeal and oil with alternative ingredients.
- Fallowing and rotation of cages and suspended shellfish culture systems to give benthic communities the opportunity to re-establish.
- The use of sterile triploids, which is especially important for species that are otherwise able to spawn during the production cycle. This is for example evident for cod, which may spawn in culture cages, and where gametes and juveniles may mix with natural stocks, whereas it plays no direct role in salmon aquaculture as salmon broodstocks spawn in fresh water environments while cages are in salt water.
- Reduced use of natural juveniles through improved hatchery performance.
- Careful use of chemicals such as ‘antifouling’ used to prevent colonisation of fish nets but toxic for non-target species. In some areas, such chemicals are not used and nets are cleaned using high pressure washing with seawater followed by natural drying on the seashore. Anti-fouling is not used on oyster and mussel structures.
- Systems that specifically aim for multi-species approaches by culturing different trophic niches are better known as Integrated Multi-Trophic Aquaculture (IMTA). These systems aim to reduce environmental impacts by benefiting from the improved use of nutrient loading, species interactions and diversified commercial products. The development of IMTA systems has received much attention in many areas worldwide (Soto, 2009), although current knowledge on marine IMTA systems has mostly been generated from experimental and small-scale operations as commercial-scale integrated cultures are still rare (Troell et al., 2003). In addition to integrated systems,

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[20] www.easonlie.org

technical and biological improvements have been implemented in RAS and pond systems for fish culture, aiming to reduce nutrient waste discharges.

At the level of culture areas, the industry together with water authorities is developing monitoring and assessment programmes, also because this is required for regulatory purposes. These include:

- implementing environmental monitoring programmes (e.g. for organic wastes or sea lice);
- performing carrying capacity studies to estimate the maximum production levels in certain regions and avoid overexploitation with negative effects on the environment;
- increasing awareness among farmers of the protected status of species;
- marine spatial planning to optimise areal use.

Barriers and levers for change

Introductions of non-native species require a global approach and a profound understanding. In this regard, the increasingly stringent legislation of major cultured aquatic food importing nations, demanding a strict adherence to codes of practice that minimise negative influences on biodiversity and assurance of maintenance of environmental integrity, is promising (de Silva, 2009. Many countries have already implemented guidelines for invasive species management. However, the paradox of food production and biodiversity conservation (including introductions of non-native species) is particularly evident for rural communities in developing regions where the socio-economic benefits of non-native aquaculture are significant and poverty, lack of alternative economic opportunities and limited training prevent farmers from implementing more sustainable practices.

Public awareness of the effects of human activities on the marine ecosystem is growing (see also Section 6.2.4). A lever to stimulate sustainable aquaculture is thereby the development of certification schemes, of which many have been implemented over the past decade aiming for economic, social and ecological improvements. An overall scheme for aquaculture is provided by the Aquaculture Stewardship Council (ASC). For extensive aquaculture, the Marine Stewardship Certification also applies as this is considered to be enhanced fishery. Most of the certification schemes include both fishing companies and NGO's as a key player in their creation and implementation (Holmer et al., 2008). Although no specific labels aim solely for biodiversity conservation, it is possible to say that improved environmental stewardship will benefit biodiversity conservation, either directly or indirectly.

In addition, we see initiatives arising in which governments actively involve the aquaculture sector in developing and implementing more sustainable production methods. The Norwegian government, for example, recently released a new licensing system (Green licenses), the primary aim of which is to stimulate the use of environmentally-friendly technology for commercial use. Companies that obtain such license are required to show how the main challenges of the industry, such as lice and escapees, will be tackled. This provides the industry with the opportunity to expand production while guaranteeing sustainable development.

6.4 What are the long-term options?

Three alternative pathways were designed to meet the same set of global sustainability objectives in line with the 2050 Vision for Biodiversity, including limiting and halting biodiversity loss and realising a global network of protected areas. See chapter 2 for more details. The three pathways are considered as plausible ways of reducing the long-term impact of fisheries on biodiversity. The pathways consider different mixes of production from marine fisheries and aquaculture, to fulfil the future demands. In all three pathways marine fisheries will be managed to rebuild over-exploited or depleted stocks to Maximum Sustainable Yield (MSY) levels by 2050. By 2050 marine aquaculture will be managed sustainably, using similar concepts as assumed for agriculture (see chapter 3) Further, stock rebuilding, phasing out of bottom-impacting fishing gears, and lowered fishing effort will lower the overall impact on marine biodiversity. The impact of fisheries on marine biodiversity is illustrated by estimating the proportion of fish stocks that still are at high risk of overexploitation if these pathways are being implemented. In addition to the general assumptions described in Section 2.5, the main assumptions are as follows (see also GBO4 scenario synthesis for fisheries; Leadley et al. 2014):

In the Global Technology pathway, the increased need for seafood leads to increasing intensive production in large-scale pond-based aquaculture of piscivores, with a subsequent rise in demand for forage fish in the short term. Increasingly this form of aquaculture will be replaced by new technologies of closed circulation systems, based on vegetable diets. Therefore it is assumed that coastal (i.e., within EEZ) pelagic fishing effort will increase by 2% per year until 2020 to meet the increased demand for fishmeal and fish oil. In addition, improved fishing technology will enable a shift to harder-to-reach resources, such as high seas fisheries and the arctic. Overall, global fisheries catches and exploitation rates by 2050 are assumed to remain at 95% MSY. Due to the larger scale operations involved (e.g., deep sea trawling) and further travelling distances, fishing costs will increase, while fish prices remain fairly constant. Increased fishing activity in the high seas may deter IUU fishing in some locations as monitoring and surveillance technology become more advanced.

In the Decentralised Solutions pathway fisheries management focuses on local and participatory, community based solutions. Seafood is caught and used locally, a shift towards targeting high value species and reduction in by-catch are assumed. An increase in fish prices can be expected due to increased targeting of high value species. Reductions of subsidies are expected leading to reduced overcapacity and a decrease of distant, high seas, fishing and an increase of coastal fisheries (Sumaila et al. 2010b). Aquaculture will also be more profitable, and will increasingly be managed in combination with other functions. Overall, it is assumed that fishing effort will be reduced to sustainable levels, such that global fisheries catches are at a maximum sustainable yield level (100% MSY).

In the Consumption Change pathway seafood demand is expected to increase as consumers change from a meat based to a more fish based diet. Aquaculture will play a significant role to meet the increased demand. Aquaculture will focus on more herbivores, and fishmeal and fish oil will be produced from recycling waste. Fishing effort of coastal pelagic fisheries is therefore assumed to decrease by 1% per year to 2020. ’Greener’ fishing technologies signals a reduction of by-catch and energy use by fishing vessels. Fishing costs are expected to decrease in the long run, although there may be high capital costs associated with switching technology. Therefore, it is assumed that populations of targeted high seas stocks are rebuilt by 2050. High sea catches will be at MSY, while coastal fisheries catch is maintained at the status quo (95% of MSY).

The indicator used to explore the reduction of impact on marine biodiversity resulting from the technical and behavioural options implemented in the three pathways is the proportion of overexploited fish stocks. This is estimated using a population dynamics model, using the Catch-MSY method developed by Martell and Froese (2012). Fish stocks were defined by species and FAO statistical area. In total 1343 stocks within Exclusive Economic Zones (EEZs) and 537 stocks in the high seas were included with catch data reported at the species level. The Catch-MSY method was applied to each fish stock to simulate changes in biomass and exploitation rate. For each stock, the number of runs was counted that were over-exploited and divided by the total number of runs, resulting in an estimate for the probability of overfishing. If that probability was more than 50% the stock was considered at high risk of over-exploitation. This was calculated for each stock in year 2006 and in year 2050. This analysis is derived from Leadley et al. (2014), and for more details see Martell and Froese (2012).

The proportion of over-exploited fish stocks (*pof*) was calculated for each FAO statistical region for both the coastal areas, indicated by the Exclusive Economic Zones (EEZs) and the high seas. Table 6.3 shows the *pof* values for each FAO region. In all three pathways overexploitation will be reduced both in the EEZs and in the high seas. Globally the *pof* decreases from the current 60% to between 24 and 31% in the EEZs and high seas, however large regional differences exist. In the baseline scenario *pof* would have been remained at about 60%.

Table 6.3. The proportion of stocks that are overexploited (stocks are over-exploited if probability of overfishing > 50%) in EEZs of each FAO region in 2006.

FAO Area	FAO Area name	Proportion of over-fished stocks (*pof* stocks) In EEZs			
		current / baseline*	Decentralised Solutions	Global Technology	Consumption Change
18	Arctic Sea	0.36	0.29	0.5	0.43
21	Atlantic NW	0.8	0.32	0.46	0.44
27	Atlantic NE	0.59	0.31	0.43	0.39
31	Atlantic WC	0.62	0.19	0.44	0.42
34	Atlantic EC	0.66	0.3	0.5	0.49
37	Mediterranean and Black Sea	0.49	0.24	0.41	0.39
41	Atlantic SW	0.55	0.26	0.48	0.46
47	Atlantic SE	0.78	0.33	0.51	0.49
51	Indian Ocean W	0.49	0.16	0.48	0.48
57	Indian Ocean E	0.4	0.14	0.55	0.5
61	Pacific NW	0.71	0.13	0.35	0.3
67	Pacific NE	0.68	0.27	0.49	0.37
71	Pacific WC	0.47	0.11	0.52	0.4
81	Pacific EC	0.62	0.29	0.47	0.43
87	Pacific SW	0.73	0.29	0.51	0.49
Global			0.24	0.31	0.28

*It is expected that the proportion of overfished stocks will not change under baseline scenario

The reduction in overexploitation in all scenarios Illustrate the assumption that exploitation rates were set at a sustainable level (required to achieve MSY). The *pof* stocks are higher in the Global Technology and Consumption Change scenarios because fishing for small pelagic species are assumed to be intensified in these two scenarios, in the short term. There are residual risks of over-exploitation even under the Decentralized Solution scenario because a small proportion of slow growth and low productivity stocks that are currently over-exploited may take more than 40 years to fully recover without a full fishing closure

One of the possible options to achieve fishing efforts at or below MSY levels is to make better use mixed fisheries. In mixed fisheries dozens of species are caught in one fishing operation, and the sustainable exploitation rate may differ greatly between species. The question remains how are fishers to harvest the most productive species and avoid the least productive ones? 'Old' conservation strategies would close the areas where the most vulnerable species are typically found, whereas 'new conservation' strategies provide incentives to fishing vessels to find areas where the target species can be caught and the vulnerable species can be avoided, or to develop and implement modified or alternative fishing gear that reduces by-catch and/or habitat destruction even if at the expense of a reduced catch of target species.

These latter approaches have been shown to be highly effective (Branch & Hilborn, 2008) and can be more effective at reducing the catch of vulnerable species than closed-area strategies. This is because the protected-area approach in marine conservation has two major disadvantages. The first problem is effort displacement; when an area is closed to fishing, the vessels move elsewhere, adding fishing pressure to accessible areas that potentially equals or outweighs the benefits seen in the protected areas (Pastoors et al., 2000). Hamilton et al. (2010) found that the abundance of target species declined outside reserves and increased inside reserves, yielding no net increase in abundance.

The second biodiversity problem is a reduction in the total sustainable yield of fish stocks when marine reserves are large. This loss will almost certainly be compensated for by some other form of food production with negative biodiversity consequences (Hilborn, 2013). Most likely an increase in fish production in controlled aquaculture systems is expected.

6.5 Priority actions to further reduce biodiversity loss

Globally there is an increasing demand for seafood and fish produce. In addition, other existing and new activities in the world's seas and oceans are growing rapidly, quite often fuelled by a blue growth strategy focusing on the sustainable use of marine resources to obtain economic growth. Our knowledge of the marine environment and its ecosystems is still rather limited. Applying the ecosystem approach and the precautionary approach in marine management could assist in utilising the seas, oceans and marine resources in a sustainable way. Noting the increase in the competing use of resources, especially space in the seascape, a solid marine integrated spatial planning is required.

As for fisheries and aquaculture, servicing an increasing demand will mainly have to depend on an increase in sustainable aquaculture production. A main challenge for fisheries and fishery management is to develop towards more sustainable practices and recover stocks and ecosystems. For aquaculture, the main challenges lie in embedding its cultures sustainably in the environment and reducing the overall environmental footprint.

Paired to the expected increasing demand for fish and fish produce, an expansion in incentives for producers is necessary to produce in a more sustainable and low-impact way. These incentives could come from the market, with an increased demand for sustainably-produced seafood carrying a food safety and sustainability label. It will also come from society at large, which is demanding that the producers obtain a societal license to produce. Incentives also need to be embedded in the marine management systems that pair ecosystem and biodiversity concerns with management measures and a governance system that allows producers to actively partake in the management of the resource.

As summarized in the previous sections many opportunities exist in the marine fisheries and aquaculture sector to reduce pressures on biodiversity. The key question is, how can the various actions be achieved? Within the context of this report, only general directions can be presented on what actions are possible, and it should be noted that many actions are site-specific, and that in many cases there are trade-offs which renders it impossible to give general recommendations.

Positive impacts on biodiversity can be achieved as a side effect of improving environmental good practices and policies in both the fisheries and the aquaculture sectors. The main directions are towards sustainable catch fisheries and sustainable aquaculture practices; changes in consumptions and reduce wastes; and multilevel regulation of fisheries. In general it is assumed that to reduce the pressure on wild fisheries, aquaculture products would need to replace wild fish in the market. However to date, it appears that much aquaculture is supplementing rather than replacing wild catch in the market.

Towards sustainable yield in fisheries combined with sustainable aquaculture

One way of mitigating biodiversity loss in fisheries is to reduce unwanted by-catch, especially of long-lived, late-maturing species that are particularly susceptible to fishing. Gilman (2011) described by-catch practice mitigation technology in global tuna fisheries by means of gear technology solutions, one successful case study for mitigating by-catch being the US fleet communication system that allows the reporting of near real-time observations of by-catch hotspots (Gilman et al., 2006). This enables a fishery to reduce the fleet-wide capture of protected by-catch species. However, Gilman (2011) notes that voluntary initiatives by the fishing industry relating to reducing unwanted by-catch have been limited.

To ensure that biodiversity losses (for example through by-catch) are mitigated, future management systems based on credit systems could provide an incentive for fishing operations with the lowest biodiversity loss (see for example Kraak et al., 2012). Technologies to increase aquaculture productivity and reduce pollution and other side effects are needed to achieve more sustainable oriented aquaculture. Aquaculture would need to move away from the use of wild juveniles in cases where wild populations are impacted and reduced its dependence on alien species. Introducing alien species is considered to impact biodiversity to the highest extent. Accordingly, there is a need to minimise both inter- and intra-continental translocations as well as translocations between watersheds. Particularly for shellfish culture restoration of habitats could be beneficial for both biodiversity and aquaculture, for example in mangrove ecosystems. The restoration of shellfish beds enhances shellfish stocks and provides a habitat for a large number of species. In a number of cases, exploitation and restoration are combined; this is a practice to enhance biodiversity through shellfish culture.

Increased attention on incentive based approaches such as ITQs may potentially decrease the tendency for non-compliant behaviour such as misreporting catches or illegal fishing , however transferable quota can come with social costs (Pinkerton 2013).. If sustainable fishing is to be achieved, the underlying drivers of overfishing must be addressed. MSC certification can stimulate fishers to adopt more sustainable exploitation patterns by market incentives. Other possible actions include providing incentives for fishing communities to engage in fisheries and marine conservation (Hilborn et al., 2005). The need for feasible alternative livelihoods or income options should be considered in conjunction with rebuilding measures.

Changes in consumption and reduce waste

The protection of marine biodiversity illustrates a range of ways in which working with industry groups can have far more benefit to biodiversity than traditional protected area approaches. A recent review of the implementation of by-catch reduction (Cox et al., 2007) emphasised the importance of collaboration with the fishing industry, 'Three common themes to successful implementation of by-catch reduction measures are long-standing collaborations among the fishing industry, scientists, and resource managers; pre- and post-implementation monitoring; and compliance via enforcement and incentives.'

It is preferable to produce and consume low food chain products such as molluscs, seaweed and omnivorous/herbivorous fish rather than species that use more fish meal/oil in their production. It should be noted that the industry is making strides towards reducing the percentage of fish meal/oil in feeds for carnivorous species. It should also be noted that the fraction of high trophic level products is increasingly being consumed in comparison with low food chain products (FAO, 2012).

Multilevel regulation of fisheries

Protected areas are traditionally the main measure to avoid further biodiversity loss. In marine environments it can also help to restore commercially exploited fish stocks. Countries have responsibility for their specific EEZ and are requested by the CBD to protect at least 10% of their marine ecosystems. Install protected areas in high seas outside the EEZs, however requires multilateral or international agreements.

Because of political pressures and legal requirements to reduce such by-catch, the fishing industry has reduced the by-catch of dolphins in the eastern tropical Pacific tuna fisheries by 99% (Hall et al., 2000), of sea birds in Antarctic long-line fisheries by 99% (Cox et al., 2007), of turtles in Hawaii longline fisheries by 95% (Moore et al., 2009), and of turtles in the shrimp trawl fisheries by 94% at the South Eastern coast of the USA (Finkbeiner et al., 2011).

Making the FAO Code of Conduct for Responsible Fisheries mandatory for countries, instead of voluntary, may be one way of achieving improved management at national levels. Furthermore, improving regional cooperation in fisheries management is essential for ensuring the sustainability and conservation of global fish stocks, especially those that occur in the high seas (Munro, 2008; White & Costello, 2014). Again, this involves understanding the trade-offs faced by each party and designing policies that incentivise cooperation. Lastly, rebuilding efforts will be hampered if actions are not taken to address global issues such as IUU fishing and the provision of fishery subsidies.

Chapter 7. Strategic directions for mainstreaming biodiversity in sectors

7.1. Introduction

Given the challenges to halt biodiversity loss and meet the 2050 Biodiversity Vision, the fundamental question is which governance approaches can be envisioned to ensure that sectors embed biodiversity concerns in their operations. The previous chapters have shown how sectors rely and impact on biodiversity, while also indicating a clear potential for more biodiversity-friendly production and nature-based solutions. The chapters ended with a number of priority actions and suggestions for implementation. Realising this potential will require a huge effort as it implies a considerable change away from business-as-usual, despite the increase in societal responses to biodiversity loss worldwide (sCBD, 2014). The challenge therefore becomes how to deepen, scale-up and speed-up existing sectoral efforts to move in a more biodiversity-friendly direction. This chapter suggests four strategic directions for public and private action to make this happen, based on priority actions identified at the end of previous chapters, and concludes with an analysis of the further role for governments in mainstreaming biodiversity.

This report suggests a pragmatic approach to enable and support sectors to integrate biodiversity concerns to free up the potential that exists in societies worldwide (GEF/STAP, 2013; Hajer, 2011; Karlsson-Vinkhuyzen et al., 2014; Kok et al., 2010; PBL, 2012). First of all, it suggests a focus on framing, or reframing, biodiversity and ecosystems in ways that relate to the primary interests and concerns of relevant actors to enable the mobilisation of sector action. Secondly, advantage needs to be taken of emerging sectoral initiatives from a broad range of actors of change and new coalitions of the willing. Thirdly, biodiversity and ecosystem services need to be properly valued (in monetary and non-monetary terms) so that the public and private rules and regulations that govern day-to-day decisions of relevant actors (from primary producers, through the value chain to consumers) take biodiversity into account. Biodiversity will then become part of the new normalcy of sustainable production and consumption. A sectoral vision that includes long-term goals and short- and mid-term targets on biodiversity will help to make that happen.

The next section (Section 7.2) provides an overview of the main barriers and levers for change to mainstreaming biodiversity in sectors. Building on this, and further elaborating the approach taken in this report, the chapter continues to identify four complementary strategic directions to move sectors into a more biodiversity-friendly direction. The first strategy is the broader application of integrated landscape approaches (horizontal integration) that are necessary to reap benefits of ecosystems services in the landscape, to deal with cross-sectoral issues, to protect interests of smallholders and to improve current conservation efforts (Section 7.3). The second strategy focuses on strengthening biodiversity within emerging voluntary sustainability initiatives along national and international supply chains, to link primary production to the market (Section 7.4). The third strategy aims to strengthen the consumption perspective on biodiversity by showing the benefits of biodiversity for food security and healthy and sustainable diets, as well as limiting biodiversity loss through the reduction of food losses and waste and moderate levels of meat consumption (Section 7.5). A sectoral approach to biodiversity requires that biodiversity is embedded in the financial decisions in the sector. The fourth strategy focuses on improving the business case for biodiversity to mobilise sector finance for biodiversity and green investments, anchoring natural capital in companies' non-financial reporting and shifting sectoral investment flows in a biodiversity-friendly direction (Section 7.6). The last section addresses the specific role government policies could play domestically, together internationally in the UN and beyond, and through the CBD (Section 7.7).

7.2. Barriers and levers for mainstreaming biodiversity in sectors

The analysis in the previous chapters, together with reviewed literature (see Karlsson-Vinkhuyzen, 2014; Kok et al., 2010), identifies a number of barriers to mainstreaming biodiversity in sectors, as well as levers for change. This analysis provides important insights (principles, practical steps, etc.) for successful mainstreaming. It has to be noted that there is a mismatch between the documented experiences with mainstreaming in the literature, which mostly assume a traditional government context, and the reality of what governance looks like in the sectors considered in this report. Mainstreaming therefore has to move beyond the traditional, purely governmental approach (Karlsson-Vinkhuyzen, 2013). The barriers to mainstreaming and levers for change (summarised in Table 7.1) follow the hourglass structure applied in the sector analysis (see Figure 1.2), which moves from the production sector through supply chains to the consumption side.

Barriers to mainstreaming biodiversity in sectors

A number of barriers can be recognised in all sectors and amongst many actors. One of these is the lack of awareness of the problems and lack of sense of urgency amongst actors, hindering the mainstreaming process. Furthermore, biodiversity and ecosystem service concepts are often considered too abstract and too complex by sectors, which hinders the inclusion of biodiversity concerns in sustainability strategies. In addition, there is a clear need to move beyond concepts towards visible and proven real-world applications of biodiversity and ecosystem-approaches in sectors, for example by improving natural resource management, certification schemes and natural capital accounting strategies. This is especially important as other issues also compete for attention and the risk of 'mainstreaming overload' always exist. The difficulties in implementing integrated approaches at all levels of private and public decision-making, on the landscape-level and in supply chains, combined with a general lack of attention for biodiversity on the demand side, hinders the mainstreaming of biodiversity in sectors.

Looking at the primary production, there is often a lack of knowledge on more biodiversity-friendly options and the potential that nature offers. Examples identified in the sector chapters are the lack of knowledge amongst smallholder farmers and in the forest sector on best available options, or in the water management sector on nature-based solutions.

When considering the supply chain; despite many sustainability initiatives, there is a lack of attention to biodiversity in supply chains. An important reasons is the domination of short-term interests and the lack of economic incentives for biodiversity. The lack of knowledge on the actual on-ground impact of current sustainability initiatives on biodiversity presents another barrier. An example of this is the lack of knowledge on the actual impact of voluntary certification schemes and corporate social responsibility schemes on on-site biodiversity.

On the consumption side, there are also a number of specific barriers. Examples are the limited understanding among consumers of the opportunities biodiversity provides as well as the causes of biodiversity loss and actions that can be taken. The willingness to pay a premium price for sustainable food products is also still very modest, which provides an obstacle for companies to produce certified products to become more mainstream.

Mainstreaming biodiversity in sectors is also hindered by the lack of financial resources. Examples are the scarcity of investment capital for biodiversity-friendly solutions associated with perceived low return/high risks, for instance in the forestry industry, and the lack of financial resources to invest in biodiversity-friendly technologies by farmers, fishermen and foresters. The large differences in capacities to mainstream biodiversity between sectors and regions of the world, for example when implementing certification, present yet another barrier. For instance, the largest share of certified forests is currently in temperate regions, while tropical regions account for only a small share of total certified area globally (SSI, 2014).

Looking at governments, the separate policy lines for different sectors (agriculture, forestry, fisheries, water management, nature, etc.) showing a lack of integrated policymaking, cross-sectoral perspectives and solutions, provide an important obstacle to the process of mainstreaming biodiversity in sectors.

Levers for change

Despite the above, levers for change have also become visible. In general, normative agreement (a united vision) on the importance of biodiversity is slowly emerging at the global level. Building on the Aichi Biodiversity targets and the 2050 Vision, the framework of the negotiations around the Sustainable Development Goals and negotiations within the UNFCCC on climate change mitigation and adaptation provide opportunities to increase the awareness of biodiversity within sectors. This is also becoming more broadly recognised as part of sustainability efforts within the business community. New partnerships between NGOs and businesses are emerging that take the lead, for example in campaigning to reduce food waste, setting up round tables for sustainable production, and so on.

Looking at the primary production, a lever for change is the increasing number of voluntary initiatives, such as voluntary certification schemes, the Sustainable Agriculture Initiative (SAI), the Sustainability Consortium, the Satoyama initiative (ISPI, 2014) and others.

Throughout the supply chain side, concerns about availability of resources, the license to produce and Corporate Social Responsibility (CSR) initiatives provide levers for change. Businesses throughout the supply chain are getting concerned about resource security and are starting to better understand their dependency on natural resources, as well as how to reduce pressures on biodiversity. Other levers are the pioneers who give a push to those lagging behind, as well as to the operationalisation of biodiversity, ecosystem services and natural capital. An example of this is the Marine Stewardship Council, which provides a strong push for the operationalisation of sustainable fishing practices.

Looking at the consumption side, a lever for change is the increasing awareness of environmental problems among consumers. On the finance side, the emergence of innovative market-based instruments that take into account biodiversity issues, such as voluntary certification schemes, PES, and fiscal and economic incentives, provide levers for change.

From a governance perspective, there are a number of levers for the mainstreaming of biodiversity in sectors. An example is the abundance of soft laws, such as the UNFF guiding principles on forests. In addition, the strengthening of national and regional legal frameworks, including compliance and enforcement, regarding biodiversity issues provide another lever for change.

Table 7.1. Barriers to mainstreaming and levers for change based on the sector analyses in previous chapters.

Barriers to mainstreaming	Levers for change
Lack of awareness of the problems, biodiversity not properly valued and lack of sense of urgency amongst actors.	Normative agreement (united vision) on importance of biodiversity for economic sectors slowly emerging.
'Mainstreaming overload'; the large number of issues that compete for attention.	Increasing attention for resource availability, nature-based solutions and license to produce.
Lack of operationalisation of the concepts of biodiversity, ecosystem services and natural capital.	New partnerships between NGOs and businesses throughout supply chains.
Lack of knowledge and capacities on opportunities and solutions.	Emerging business and biodiversity initiatives in the supply chain to learn from, pioneers may give a push to the market.
Short-term interests dominate, lack of economic incentives and lack of financial resources to invest.	Increasing sustainability reporting.
Lack of knowledge on the actual on-ground impact of tools/initiatives.	Increasing awareness of environmental problems and importance of healthy diets amongst consumers.
Lack of integrated approaches at all levels of private and public decision-making.	Emergence of innovative market-based instruments.

7.3. Integrated approaches at the landscape level

It is increasingly recognised that it is necessary to work at the landscape level to ensure that sectors can capture the benefits of natural capital and to maintain the biodiversity and ecosystems necessary for that. Sectors like agriculture, forestry and water management play an important role in multi-functional production landscapes. Integrated landscape planning processes provide an opportunity to also include biodiversity conservation, create green infrastructure, capture the benefits from ecosystems in production systems and deal with trade-offs between sectoral interests and nature conservation.

Challenges converge at landscape level

Rural landscapes are the nexus where the linked challenges of food and water security, energy production, economic development, nature conservation and climate change converge. The landscape level would seem to be the appropriate level for managing competing demands for land, water and other natural resources like wood, and for nature protection. Rural development and regional landscape-oriented planning approaches have a long history, and varying degrees of success. In both the agricultural and conservation domain, the focus on top-down, often sectoral blueprint policies has gradually shifted towards a more integrated bottom-up approach that simultaneously addresses conservation, food security and livelihood needs at the landscape level (Ellis et al., 2001; Milder et al., 2014). As well as having common geophysical characteristics, socio-economic conditions and/or jurisdictional demarcations, landscapes are also seen as the spatial scale at which many different stakeholders, from the global to local scale, need to cooperate and at which the balancing of competing interests and risk needs to take place (Scherr et al., 2012; Brasser, 2012).

Sustainable landscape approach to development

The 'sustainable landscape approach' integrates spatial, ecological and socio-economic perspectives to overcome regularly-conflicting interests on the limited availability of land, water and forest resources at the landscape level and several of the challenges identified in this report (UNDESA, 2011; Milder et al., 2014, Treguer et al., 2014, Sayer et al., 2012).

The landscape approach can contribute to bringing together sectoral economic development plans and national action plans on biodiversity conservation, water management, desertification and climate change (FAO, 2014). Note for example the emergence of Integrated Water Resources management (IWRM). Another example where landscape level approaches, including the role of ecosystem services, are integrated in higher-level policy frameworks is the Comprehensive African Agricultural Development Programme (CAADP). This Africa-wide programme includes an ecosystem-based approach to achieve sustainable land and water management as one of the four core pillars to boost agricultural productivity. The effectiveness of current global initiatives are reviewed within the Global Landscape Forum and databases on best practices are built as part of this programme (GLF, 2013; Brasser, 2013).

The landscape approach could also provide a mechanism to deal with the rise in Foreign Direct Investment (FDI) in agricultural land in Africa. Governments of host countries often market much of the land as 'idle' and assumed free of claims as property rights structures are often unclear and monitoring and enforcement mechanisms lacking or ineffective. The areas most affected by this are the 'commons', including much of the region's forests, wetlands and rangelands. Therefore, land involved in FDI is often characterised by a high biodiversity value. Developing the capacity to implement integrated land-use planning and locally-organised land tenure is therefore required. If not, FDI in existing agricultural land may further increase pressure on remaining natural areas and marginal lands (Karlsson-Vinkhuyen et al., 2014; Zoomers, 2011; UNEP GEAS, 2011).

The importance of ecosystem restoration and its relation to biodiversity have already been mentioned in several sections of this report. The challenges encountered in the restoration of abandoned agricultural lands, degraded forests, wetlands, river basins, floodplains, streams and in the connectivity of lakes have also been discussed. Generally speaking, for a sustainable landscape approach to successfully address the restoration of ecosystem services, the size of the landscape considered should be large enough to capture all the processes influencing the ecosystems to be restored and it should be possible to identify the stakeholders benefitting from its restoration (Ferweda, 2012). Finding the right – possibly financial – incentive or business case to drive and secure long-term landscape restoration projects remains a challenge, although connecting global initiatives like REDD or carbon credit markets via GEF or PES programmes could create viable opportunities. Monitoring the progress of landscape restoration projects is crucial for sustaining long-term stakeholder support and performance. The FAO is responding to these challenges by proposing the establishment of a Forest and Landscape Restoration Mechanism (FLR Mechanism) that will help countries to achieve their commitments towards the Bonn Challenge – that aims to restore 150 million hectares of the world's degraded and deforested lands by 2020 – and the Aichi Targets on the restoration and degradation of natural resources.

Effects on biodiversity at the landscape level: from land-sparing to eco-agriculture

The conversion of natural areas for agriculture and the impacts of agricultural activities are the main causes of biodiversity loss (MA, 2005; PBL, 2012; this report). There has been much discussion on whether the strategy to protect biodiversity by strictly separating land-use functions (between high-intensity agriculture and protected biodiversity-rich natural areas) or some form of mixed strategy (where natural areas are combined with different forms of biodiversity-friendly agriculture) would result in the best outcome for biodiversity and ecosystem services (Phalan et al., 2010; Fischer, 2011; Scherr et al., 2008; Brussaard et al., 2010). While there is no doubt that many (often endangered) species are better off in large, undisturbed natural areas (Phalan, 2011), at the same time agriculture has to feed a growing, increasingly urban, population, making the sustainable intensification of agricultural production crucial (see also Chapter 3). As noted above, many of these challenges converge at the landscape level. By incorporating the challenges in spatial planning at a landscape level, synergies can be found and tradeoffs dealt with (Scherr, 2008).

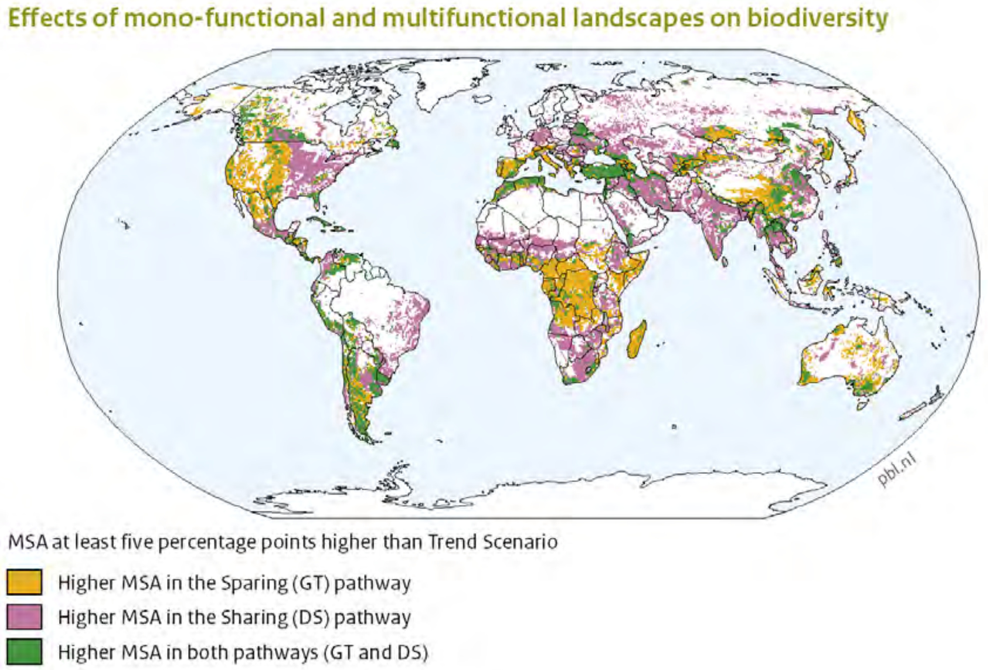


Figure 7.1. Effects of mono-functional and multifunctional landscapes on biodiversity, represented as mean species abundance (MSA) of the original species. Source: PBL, 2012.

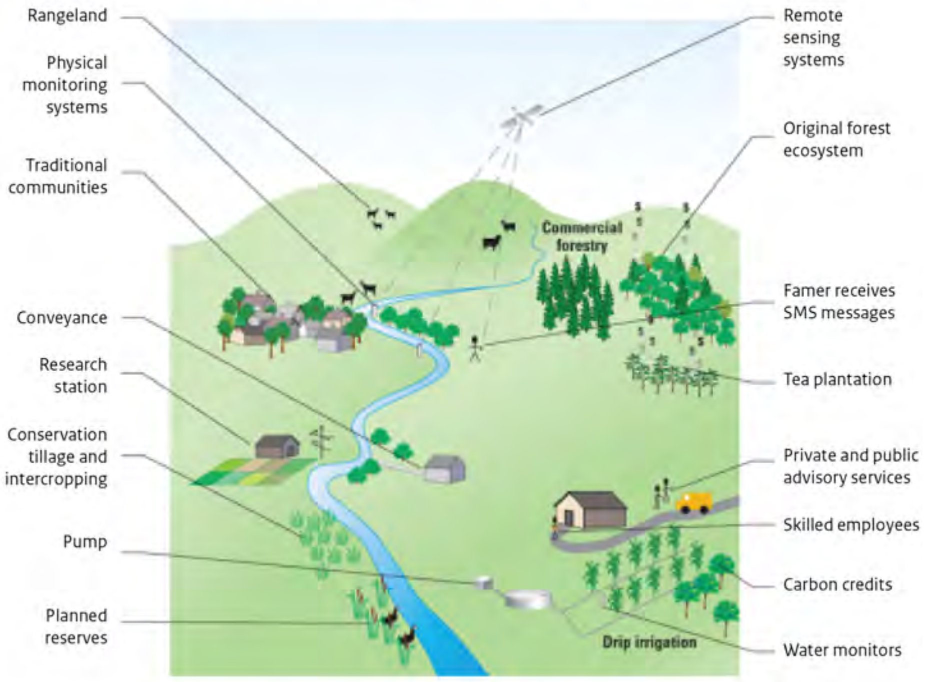
As shown in the Global Technology pathway, high-yielding, land-sparing technologies could be advocated in areas that are physically and socio-economically particularly suited to agricultural production. This pathway emphasises increasing yields in these large-scale agro-technological landscapes and the strict separation of land-use functions. The result is a reduced total claim on land compared with the Trend scenario due to higher productivity on less land, effectively conserving remaining nature areas (Figure 7.1). However, a decrease in biodiversity and ecosystem services in monotonic agricultural landscapes is expected due to increased land-use intensity and lack of refuge for species. Here sustainable intensification becomes a major challenge. The Decentralised Solutions pathway shows that ecologically-oriented land-sharing technologies and approaches could be used in regions with environmental restrictions or highly-valued ecosystems that may be incompatible with intensive agriculture (Bennett & Balvanera, 2007). The consequences are a lower production intensity and a larger claim on land compared with the Global Technology pathway, but also an increase in biodiversity and ecosystem services in agricultural fields and surrounding areas (Tittonell, 2013). In this sense, land-sparing versus land-sharing becomes an optimisation and land-use planning exercise focused on sustainable intensification with respect to different types of ecosystem services, which can be made explicit in integrated landscape approaches (PBL, 2012; Brussaard et al., 2010 (and their references to Ewers et al. (2009) and Hobbs et al. (2008)).

Improved land-use planning and land tenure security for smallholders essential conditions for landscape approach

The management of natural resources like land, water and forests is organised by systems of allocation and tenure that need to provide access, security and incentives for profitable and sustainable use. Traditionally, the predominant form of tenure has been communal, with well-negotiated rules and norms for individual access. The resulting tenure usually provided security and incentives for farmers to invest in – possibly sustainable – land, forest and water management. With the introduction of modern systems of legislation, individual property rights have been overlaid on these traditional institutions. However, modern laws have rarely defined or protected communal rights. Formal and informal land tenure systems now overlap, resulting in all kinds of problems. The lack of secure tenure combined with rigid land markets has resulted in under-investment and inefficiency in resource use (FAO, 2011). Setting up the right incentives to initiate a land and tenure reform remains a challenge; at least 26 countries are currently engaged in tenure reform, mainly in support of local livelihoods (FAO, 2014).

Combined with improved land tenure, effective land-use planning is an essential step on the path to protecting biodiversity and establishing sustainable production landscapes. To reduce the impact on biodiversity and capture the benefits of the sustainable use of ecosystem services in agricultural production landscapes, the two most prominent issues to address in land-use planning and management are: (i) the integration of a more complete set of biodiversity and ecosystem services, and (ii) the improvement of the institutional capacity for land-use planning (PBL, 2012). An increased effort should be made to involve individual smallholders, communities and businesses at the landscape level in all stages of land-use planning (FAO, 2012).

A resilient climate-smart integrated landscape using the ecosystem services nature provides



Source: The World Bank, World Development Report 2010

Figure 7.2. A resilient, climate-smart agricultural landscape of the future using the ecosystem services nature provides would enable farmers to use new technologies and techniques to maximise yields and allow land managers to protect natural systems, with natural habitats integrated into agriculturally-productive landscapes. Source: World Bank WDR (2010).

Attributing costs and benefits from biodiversity in landscape approaches

A specific benefit of the landscape approach is that it enables the effective attribution of the costs and benefits of biodiversity conservation and related ecosystem services to various stakeholders in a landscape. Often, the economic or social consequences of losing biodiversity are not valued or considered a public good and the – economic – opportunities of using ecosystem services are not recognised. The costs and benefits of biodiversity and ecosystem services do not usually end up at the same stakeholder, potentially causing tension or conflicts between for example indigenous populations, subsistence farmers and internationally-operating businesses. In a landscape approach, the providers and users of biodiversity can be made visible (Figure 7.2). When, for example, using financial incentives from REDD programmes or carbon credits to protect or restore ecosystem services, the connected stakeholders may even be located outside the geographical landscape.

Clear agreements on land tenure will enable local stakeholders to take responsibility for their own property, including biodiversity and ecosystem services. Combined with awareness creation, supporting policies and financial incentives, local stakeholders can then be stimulated to practice good land-use management, including biodiversity conservation and restoration, to secure long-term sustainable production on their land. Besides removing counter-productive subsidies, setting up a robust monitoring framework and applying performance-based payments, the effectiveness of financial incentives like Payments for Environmental or Ecosystem Services (PES) could also be increased by more clearly-defined property rights. The bundling or layering of multiple ecosystem services provides more opportunities to increase the synergy of such programmes in the landscape and across sectors (OECD, 2010). This would allow stakeholders to recognise the importance of defining mutual objectives among different actors and the development of long-term management plans for the benefit of all stakeholders (Sayer et al., 2012).

Involvement of businesses and scaling-up farm-level supply chain successes

When looking at multifunctional production landscapes, the landscape approach also enables the inclusion of business and supply chain interests. Here, certification schemes may play an important role in mainstreaming biodiversity (Brasser, 2012; Leibel, 2011). Due to the farm-level focus of standards and certification, limited information is as yet available on regional-level impacts of these systems (Waarts et al., 2013). The notion that businesses are not sufficiently involved in regional development programmes has been growing in recent years (Ferwerda, 2012; Vollaard et al., 2012); in a study on 87 different integrated landscape initiatives (ILIs) in Africa, Milder et al. (2014) showed that businesses were involved in only 14% of these cases. This participation gap may inhibit the effectiveness of these initiatives in addressing weak market linkages. Another risk is that, by leaving out businesses, landscape initiatives are lacking the powerful stakeholders. The landscape approach aims to involve all stakeholders, including indigenous peoples' values and rights, and parts of the physical landscape that are not directly involved in a – possibly certified – supply chain production process (Leibel, 2011).

The challenges of building trust amongst all stakeholders in the landscape and scaling-up local- or farm-level sustainability initiatives to the landscape level can be supported by new technological developments (advanced remote sensing data and analysis tools e.g InVest), improved understanding of multi-scale participatory governance and renewed commitment from governments and donors to address the linked challenges facing rural landscapes. Furthermore it is clear that many –sectoral – initiatives on the landscape level are taken that will benefit from a more integrated perspective as described above (FAO, 2012; Treguer, 2014; Kissinger et al., 2012).

7.4. Biodiversity benefits from initiatives in supply chains

As well as initiatives taken at the landscape level to improve the contribution of primary producers to biodiversity conservation and its sustainable use (horizontal integration), different actors in the supply chain can also have a positive influence on primary production (vertical integration). There is a trend in international supply chains within the sectors addressed in this report towards the sustainable sourcing of natural resources, including taking care of biodiversity and social concerns. A number of business and biodiversity initiatives and tools have emerged in recent years to support different actors in supply chains in the transition to more sustainable production practices. Examples are voluntary standards and certification schemes that include biodiversity criteria, biodiversity performance standards for investors, sustainability assessment and reporting schemes, and so on (TEEB, 2010).

This section pays particular attention to voluntary production standards and certification schemes as the main mechanism for achieving sustainable production in international supply chains at present. It concentrates on the impact of voluntary certification on biodiversity specifically and derives recommendations on how their positive impact could be maximised. It also briefly discusses other business and biodiversity initiatives that provide opportunities for different actors in the supply chain – primary producers, processors, manufacturers, retailers – to reduce their impact on biodiversity.

Private standard setting and voluntary certification of primary producers

Looking along the entire supply chain, including both the production and consumption sides, the largest direct impact on biodiversity is caused by primary producers (Leibel, 2012). For that reason, this section focuses in more detail on the progress of this actor group towards addressing biodiversity issues. Despite the rather high number of other initiatives and available instruments, the main mechanism for achieving sustainable production in international supply chains at present is voluntary certification (for timber, fish, coffee, etc.).

The emergence of certification schemes in the last two decades is the result of many initiatives taken by development and environmental NGOs and businesses together, while several governments have played a facilitating role. In the 1990s, a number of initiatives emerged globally, such as the Sustainable Forest Management System (SFM) standard of the Canadian Standards Association, which was the first national sustainable forest management standard in the world (CSA, 2014), and the Sustainable Forestry Initiative (SFI) of the American Forest Products Association (Bartley, 2007). More recently, national standards – either developed or adopted by governments – have also started to emerge. An example of such national standards is the Indonesian Sustainable Palm Oil (ISPO) standard, launched by the national government of Indonesia.

Recent overviews reveal that market shares of certified products have grown steadily during the last 50 years (Potts et al., 2014; Table 7.2) and are continuing to grow. At present, global market shares of certified commodities total 1–4% for aquaculture and soy (PBL, 2014), 38% for coffee and 23% for wood (Potts et al., 2014). Large differences between regions of origin do however exist and, at present, the main markets for certified products are developed countries, with emerging economies and developing countries still lagging behind (PBL, 2014; Potts et al., 2014). A prime example of differences in market development is wood from tropical forests, which accounts for a very small share of certified wood (4-6% of the global productive forest area) compared with wood from forests in northern developed economies. Consistent with this, when looking at the total certified area, Canada, the USA and Russia account for the largest share of certified forests (Potts et al., 2014).

Table 7.2. Global market shares of certified products in 2008 and 2012. Source: Potts et al. (2014); Bush et al. (2013); SCSKASC (2012).

Commodity	Market share 2008	Market share 2012
Coffee	9%	38%
Wood	-	23%
Cocoa	3%	22%
Palm oil	2%	15%
Tea	6%	12%
Fisheries	-	7%
Aquaculture	-	4.6%
Cotton	1%	3%
Bananas	2%	3%
Sugar	<1%	3%
Soy beans	2%	2%

Towards positive impacts on biodiversity…

As the market share of certified products continues to grow, the question of their actual on-ground impact on biodiversity becomes urgent. Understanding the on-ground impacts of certification schemes on biodiversity is essential to strengthen their credibility as a tool for biodiversity conservation (Mallet, 2012) and to determine whether these schemes successfully achieve the changes that they anticipate (Milder et al., 2012). Due to a lack of sufficient data, it is difficult to derive general conclusions (PBL, 2014), however considerable efforts have recently been made to improve the state of knowledge.

Looking at the forestry sector, studies on the impacts of forest certification on biodiversity generally indicate that forest management practices promoted by certification appear to have beneficial on-ground effects on biodiversity in managed forests (Milder et al., 2012; Cashore & Auld, 2011; van Kuijk et al., 2009; SCSKASC, 2012; WWF, 2010; Karman & Smith, 2009). However, it remains uncertain whether the attained changes will reduce biodiversity loss at higher spatial scales.

When considering fisheries certification, the results are rather mixed, with some studies indicating modest positive impacts of certification (van Hoof & Tatenhove, 2014; Beukers & Harms, 2012), and others registering no positive effects (Ward, 2008). The most recent MSC overview indicates that, in contrast with the results of previous overviews, companies that operate further away from the standard have also now begun entering the certification process in recent years (MSC, 2013). Thus, gradually, there is a tendency towards the adoption of standards by poor performers. On the other hand, there is very little comprehensive data on the actual effects of certification on biodiversity in aquaculture (Boyd, 2011).

Looking at the effects of agriculture certification on biodiversity, there are large differences in the results and the number of studies per commodity. It is important to note that certified organic farming was not considered here (but see Leadley et al., 2014 for analysis of Target 7 on organic farming). When looking at coffee and cocoa certification, studies generally reveal a positive effect on local biodiversity, which is partly related to stimulation of the use of mixed agroforestry systems (COSA, 2013).

On the other hand, the number of studies on the impacts of certified soy and palm oil is very low (PBL, 2014), so that no definitive conclusions on these commodities can be drawn at present. An important issue for round tables (soy and palm oil) is to prevent the further conversion of primary forest for crop production, which can be detected in remote sensing studies. Tools, such as the newly-developed Global Forest Watch system to monitor forest area and land-use change (GFW, 2014), could help understand the on-ground impacts of round tables.

As described above, measuring the on-ground impact of certification schemes on biodiversity is very challenging in all sectors. However, looking at existing literature on the subject leads to the conclusion that certification could contribute to reducing on-site biodiversity loss. Nevertheless, there are differences between local and regional spatial levels, as well as between sectors. For the purpose of maximising the positive impact on biodiversity, barriers to mainstreaming certification and improving its impact have been identified and recommendations for actions by different actors are presented here.

Barriers to mainstreaming certification and maximising its positive impact on biodiversity

A number of the barriers to integrate biodiversity in certification schemes relate to the barriers identified in Section 7.2. More general barriers include higher costs of certified production, lower demand for sustainably-produced products than the current supply, confusion amongst consumers and producers caused by the multitude of certification labels, the lack of level playing field that could weed out the worst performers, difficulties in involving smallholders and poor farmers due to lack of knowledge, limited access to capital and vague land rights (PBL, 2014).

Regarding the impact of certification schemes on biodiversity, there are more specific barriers, such as the prevalence (Potts et al., 2014) of process-based approaches of certification schemes (which focus on the process and rely on the assumption that practices lead to intended outcomes; SCSKASC, 2012) compared with performance-based approaches (which focus on the outcome and thus improve the ability of certification schemes to measure and report the actual impacts; SCSKASC, 2012). Other barriers include the low number of certification schemes that actually include biodiversity criteria (KPMG, 2012) as opposed to broader environmental criteria for instance on GHG emissions or water, and debates concerning the credibility of certification schemes, partly due to the limited knowledge on their actual on-ground impacts on biodiversity, as considered in the previous section. At present, the availability of reports on the impacts differs highly depending on the type of commodity, with a prevalence of studies on the biodiversity impacts of wood and coffee certification, and a lack of such studies on soy and palm oil certification (PBL, 2014). The analysis below offers recommendations to overcome these barriers and increase the positive impact of certification schemes on biodiversity.

How to maximise positive impacts on biodiversity

At present, the most pertinent question for biodiversity policy is if and how the biodiversity benefits of these voluntary initiatives could be improved. This could be done at the level of the certification schemes by including of biodiversity criteria (Figure 7.3), as well as in the up-scaling of their use (increasing number of supply chains, increasing area, etc.; Figure 7.4). Several important directions for improvement, relevant for different actors, are identified here.

- Regarding the biodiversity criteria of certification schemes, the number of schemes that include criteria specifically referring to biodiversity needs to increase, as currently more emphasis is put on other environmental and social criteria. Furthermore, the effectiveness of standards could be improved by strengthening their biodiversity criteria (UNEP-WCMC, 2011).

- There needs to be greater consistency between different standards and certification schemes regarding indicators for and definitions of biodiversity, as well as methodologies for impact assessments. Umbrella organisations such as ISEAL (the International Social and Environmental Accreditation and Labelling Alliance), ISO (the International Organization for Standardization) and SAI (the Sustainable Agriculture Initiative Platform) are already working in this direction (Milder et al., 2012), although further attention is needed for improvement in this direction.

- A transition from the current process-based to performance-based approaches of certification schemes or alternatively a combination of these through the introduction of performance-based elements (FERN, 2001) is important (SCSKASC, 2012). A step in this direction is the development of robust monitoring and evaluation systems (WWF, 2010; van Kuijk et al., 2009), which would contribute to improving the state of knowledge on the impacts of certification on biodiversity and thus strengthen their credibility. Furthermore, such a transition would provide greater flexibility for achieving the desired results (SCSKASC, 2012; FERN, 2001).

- Promoting ecological intensification while taking into account regional differences, as for instance extensification (maintaining productivity while reducing inputs) in certain regions and intensification (increasing productivity in a sustainable, affordable way) in others, is also essential (Tittonell, 2013). However, this process requires complementary policies at the landscape level (as discussed in Section 7.3), outside the direct influence sphere of production certification.

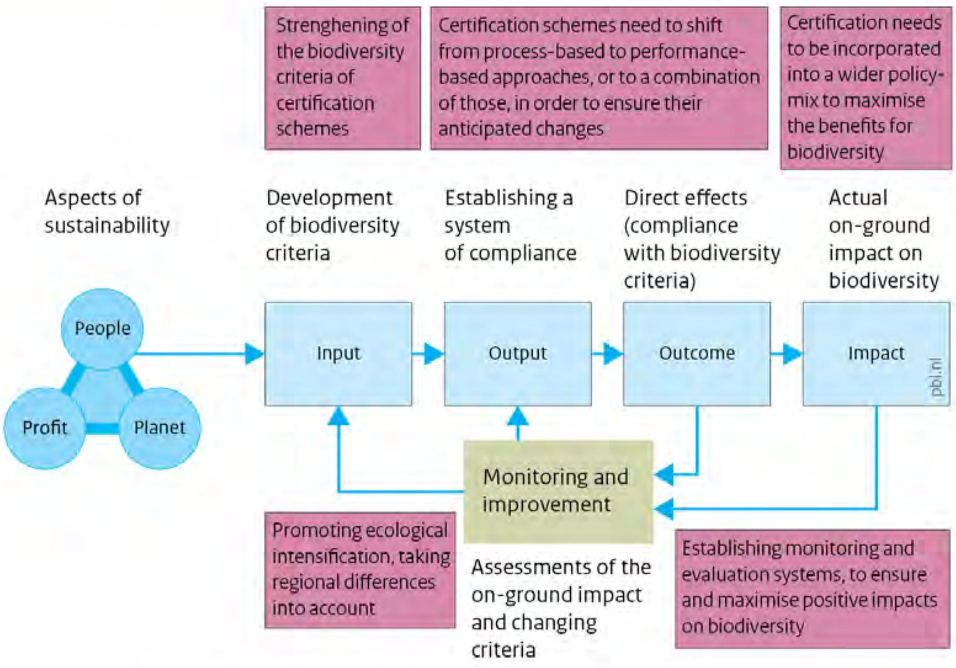
- There is a need to increase the market shares of certified products by promoting market uptake and use on both the consumption (procurement, societal deals) and production side (enabling environment – the creation of a favourable environment for the development of the certified products market through governmental actions; capacity building; extension services) (PBL, 2014).

- It is essential to integrate certification into a wider policy mix (land-use planning; enabling environment), for example in combination with other complementary instruments and policies (WWF, 2010).

- Finally, a comprehensive analysis of domestic and international supply chains, initiated by governments, could help identify national and international supply chains and commodities where certification is important but not yet applied.

Standards are different in their environmental ambitions, and so their effects on biodiversity also differ. The contribution of standards to reduced biodiversity loss can be enhanced by operating with a continuous improvement strategy in mind that includes both stepping-up and scaling-up (Figure 7.4). Stepping-up and scaling-up implies an improvement to ‘low’ standards and a greater uptake of ‘high’ standards, while standards with a growth model require step-by-step improvements. When looking at standards with ‘high’ ambition levels, the expansion of their market share is most important (SCSKASC, 2012; PBL, 2014); however further improvement from a biodiversity perspective is also still possible.

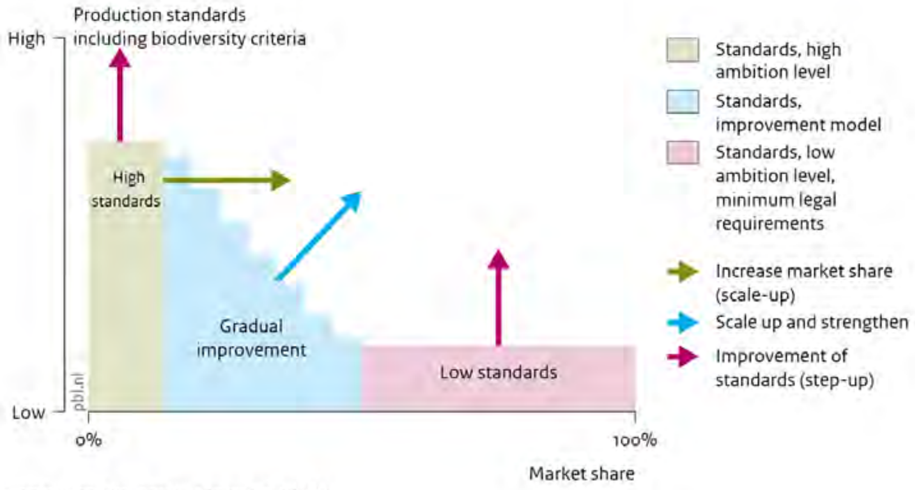
Assessment framework for sustainable supply chain development



Source: Van Tulder, 2010; adaptation by PBL

Figure 7.3. The main recommendations for maximising the positive impact of certification schemes on biodiversity are indicated in the 'I-O-O-I evaluation framework', which connects stepwise the biodiversity criteria of certification schemes (input), through output and outcome, to the actual long-term impacts on biodiversity (impact) (general framework based on van Tulder (2010), adapted by PBL, 2014; Lazarova et al., in prep.).

Contribution of various production standards to more sustainable production



Source: Resolve, 2012; adaptation by PBL

Figure 7.4. Contribution of different standards to reducing biodiversity loss in production systems (adapted from SCSKASC, 2012; PBL, 2014; Lazarova et al., in prep).

The need to go ‘beyond certification’

The discussion above shows that there is a clear potential for voluntary standards and certification schemes to reduce negative impacts of production sectors on biodiversity. When looking at the impacts of standards and certification schemes, limitations to the scope of these initiatives also become evident and hence the need for other, complementary approaches. First of all, a large portion of global production falls outside the sphere of influence of voluntary certification. For instance, certification currently only works for products traded internationally, while other initiatives must be in place at the national level for products intended mainly for domestic use (e.g. rice, cereals and livestock). Furthermore, certification has the potential to influence and improve local production conditions (social and environmental), but not processes and indirect effects at a higher scale (PBL, 2014). For instance, deforestation is beyond the reach of individual wood production companies (Gullison, 2003; Auld et al., 2008; Gulbrandsen, 2010; SCSKASC, 2012) and can only be effectively stopped by coordinated action in the forestry and agricultural sectors in combination with government-led land-use planning. This is also true for other large-scale issues such as overfishing (Gulbrandsen, 2009). Looking at these limitations, the need to go ‘beyond certification’ and integrate this instrument into a wider policy-mix becomes evident.

Sustainability strategies of international companies along the supply chain

Apart from primary producers, there are a number of other actors that play a role in supply chains, such as businesses, processing companies, manufacturers, retailers, financial institutions, investors and reporting institutions (see also Box 7.1). These actor groups play a role in different constellations depending on the sector and commodity. As mentioned before, a number of business and biodiversity initiatives have emerged in recent years, providing a good opportunity for different actors in the supply chain to get involved and help reduce their impact on biodiversity. Despite the recent progress of the business sector in making supply chains more sustainable, there are still numerous challenges regarding the mainstreaming of biodiversity into the business sector (UNEP/CBD/WGRI, 2014). For instance, some companies are ‘greenwashing’ rather than making real improvements and are turning sustainability into a tool for business control (Dauvergne & Lister, 2013). Furthermore, the majority of businesses in supply chains still have a long way to go in including biodiversity in their business (UNEP/CBD/WGRI, 2014). A brief review of key business and biodiversity initiatives, aside from voluntary certification schemes, is given below. It is important to note that different actors in the supply chain have different incentives for becoming involved in such initiatives, as these depend on their relationship with biodiversity (Bouma & van Leenders, 2013).

Some multinational companies have moved towards a better understanding and management of their impact on biodiversity and ecosystem services in recent years (FI, 2010; UNEP, 2010). For instance, a number of large international firms have developed sustainability strategies – various retailers as well as financial institutions. These strategies address environmental impacts across the entire supply chain and set goals to reduce them. However, in general, companies developing sustainability strategies do not include specific biodiversity issues, although these might be addressed implicitly. This relates to one of the barriers to mainstreaming identified in Section 7.2, regarding the lack of operationalisation of the concepts of biodiversity and ecosystem services.

Companies are also starting to engage in ecosystem accounting and to supply insight into their biodiversity impacts, including the entire supply chain of the raw materials they use (BSR, 2014). These companies not only aim to reduce their environmental impact in production and sourcing areas, but also to assess the surrounding landscapes from an environmental and climate change perspective and support measures to protect certain landscape components, restore damaged water catchment areas and ecosystems or enhance the climate resilience of landscapes. An example of a company engaged in ecosystem accounting is PUMA, which accounts for its environmental impacts by placing a monetary value on these impacts along its entire supply chain (PUMA, 2010).

As shown before, the retail sector – and especially large companies – have become increasingly aware of the impact that supply chains could have on biodiversity in recent years, and have therefore begun to address this issue (IFC, 2006). One of the approaches that such businesses are taking is to source only sustainable raw materials and to participate in initiatives such as round tables.

Choice editing for sustainability, which represents the removal of less sustainable products from the marketplace, is one of the approaches that retailers could undertake to reduce the impact of consumption patterns on biodiversity. Research also shows that business can be a driving force in changing consumer patterns (SCR, 2006; see also Section 7.5 on consumption change).

Way forward…

As described above, although biodiversity and ecosystem service issues are becoming increasingly recognised by actors in supply chains, a considerable joint effort by these actors and governments is still needed to make further progress in this direction. As supply chains and actor groups differ across different regions of the world, it is difficult to give one general strategy for all governments globally. The way forward is therefore different for every region of the world. With this in mind, a recommendation for policymakers would be to assess the impact of sectors and actors in supply chains within their countries. Actors and supply chains with the highest impact on biodiversity need to be identified and efforts made to push them towards adopting biodiversity-friendly strategies. Furthermore, as businesses are always profit-oriented, governments should aim to create an environment where the adoption of sustainability initiatives, including biodiversity goals, becomes the more profitable strategy for businesses, but also ensure proper monitoring and evaluation so that on-ground improvements of biodiversity are realised.

7.5. Consumption and biodiversity

Taking a broad perspective on the sectors in this report, including consumption helps to identify levers of change for mainstreaming biodiversity. With a focus on food consumption, there are two main ways to address the ‘demand’ side of food. The first is to emphasise and capture the opportunities biodiversity provides for food security and healthy, sustainable diets, and the second is to mitigate the negative impacts of food production and consumption through a reduction in food losses and waste and a dietary shift towards moderate levels of meat consumption (PBL, 2011).

Food choices

Eating through agriculture and fisheries directly influences biodiversity. Current food consumption choices tend to move towards globalised and standard diets that are linked with highly industrialised agricultural methods. Within the past few decades, the simplification of agricultural food systems has created a reliance on a few crops, namely wheat, maize and rice, coupled with greater intakes of meat and dairy products (Hunter & Fanzo, 2013). The utilisation of a limited diversity in food crops, for example, has decreased the reliance on traditional farming systems where such systems create an environment of conservation and reliance on local crops, boosting their genetic diversity. Such local agricultural food systems pave the way for neglected food crops by safeguarding their distinctive and unique characteristics while maintaining their cultural heritage. In its purest form, agro-biodiversity then is a provider of nutrient diversity – through its range of food varieties available for human consumption – and diet adequacy, through the composition of nutrients available (i.e. macro- and micro-nutrients) in any one distinct food. Although producing sufficient calories, a major challenge in agricultural and food systems is to provide an adequate diversity of nutrients necessary for a healthy, functioning life (FAO, 2010: 144–147).

When linked, agriculture, biodiversity and nutrition can form a common path connecting food with nutritional security, dietary adequacy and nutrient quality, bringing human health and agro-biodiversity together. Agro-biodiversity underpins the sustainability of agricultural production by providing genetic diversity; materials needed for innovation and adaptation and, moreover, is essential for ecosystem services and processes. Agro-biodiversity, 'is at the basis of the value chain and its proper use is important for both food and nutrition security as it can potentially provide a safety net against hunger, enable a rich source of both macro- and micro-nutrients for improved diet diversity and higher diet quality while providing a basis to reinforce the local food system and environmental sustainability' (Hunter & Fanzo, 2013: 50). As over-nutrition (overweight/obesity) and under-nutrition (hidden hunger) – two forms of malnutrition – affect an estimated 2.3 billion people globally, food and nutrition insecurity is increasing in prevalence in both developing and industrialised societies (Pol, 2014: 3). The WHO (2010) estimates that, although more than 900 million people are undernourished, 2 billion people are affected by one or more of the main micro-nutrient deficiencies, while at the same time approximately 1.5 billion adults are overweight, of which 200 million men and about 300 million women are obese.

Contribution of biodiversity to food security and healthy diets

The question here is how dietary choices and consumption changes can create a demand for sectors to move in a more biodiversity-friendly direction. Although biodiversity is not yet of much concern to many consumers, they are increasingly aware of the importance of the food choices they make. Consumer choices are becoming increasingly driven by health, social and environmental concerns. This results in less meat- and dairy-intensive diets, a reduced saturated fatty acid intake, more vegetable- and legume-based diets, and an increased intake of vitamins, minerals and complementary amino-acid compositions.

The attention for the social and environmental contributions of dietary shifts can be explained through the increased appreciation of the value of foods and increased attention for the production circumstances. The Decentralised Solutions pathways focuses on foods from the local area, where production methods respect seasonality and exemplify the unique characteristics of a particular territory and enhance the interest in food and food-related issues. In this way, cultural and historical aspects of consumption become an entry point for changes towards new eating patterns. In the consumption change pathway the focus is on reducing food losses and waste and shifting diets towards a moderate level of meat consumption, to reduce the impacts of the food system on biodiversity and climate change (see Stehfest et al., 2009). In the Global technology pathway quality of foods and health becomes an important driver of change, and points at the role of the food industry in this.

Although these trends towards different consumption patterns are taking place within certain communities, the prevalence of malnutrition – both in terms of under-consumption and over-consumption – alludes to different realities in both developed and developing societies. It is argued that the change in agricultural production, from diverse, culturally-rich food systems towards more simple cereal-based systems may have contributed to poor dietary diversity, significant micro-nutrient deficiencies and resulting malnutrition (Graham, 2008). The lack of diversity in food production and consumption is shown to be a crucial issue affecting food security in the developing world, where societies are faced with the 'dual burden' of both forms of malnutrition. Such trends are coined the 'nutrition transition', where an unbalanced intake of food increases in prevalence (Drewnowski & Popkin, 1997; Mouille et al., 2010). The health implications of these trends are two-fold: an escalating rise in obesity on the one hand and the co-existence of micro-nutrient deficiencies leading to prolonged hunger on the other. Micro-nutrient deficiencies – namely vitamin A, iron and iodine – create higher risks of childhood stunting, blindness, anaemia, stillbirths, goitre and cretinism (Whitney & Rolfes, 2011).

Meanwhile, in developed societies, current eating patterns have created an epidemic of obesity. Standardised diets, with an increasing reliance on processed, fast food, meat and energy-dense foods increase the occurrence of overweight and obesity and associated health risks such as cardiovascular disease, type II diabetes and hypertension (Mouille et al., 2010). Although more calories are consumed, this merely accumulates greater energy density within the body, while micro-nutrient requirements are not necessarily met, even given the availability and abundance of food in the environment (Whitney & Rolfes, 2011).

Influencing consumption choices

While governments are generally reluctant to apply consumer-oriented policies, options for achieving a reduction in food waste and dietary changes would point at the role of health policies, awareness-raising, information and educational campaigns on sustainable, healthy diets and the impacts of food losses and waste, public procurement and education. This would requires that potential of biodiversity for food security and healthy, sustainable diets, as well as of the detrimental effects of current consumption patterns on natural resources and biodiversity becomes much more clear. Consumer demand for certified products also needs to play a role here. However, the focus should be not just on consumers, but on all actors in the food system that influence food choices, such as the media, retailers, training institutions, hotels and restaurants, to show how production conditions and consumer choices are linked and the opportunities biodiversity offer for food security and healthy, sustainable diets. The food industry at large has a key role to play here in both making healthy and sustainable food choices the logical choice, as well as in reducing food wastes and losses. and – through choice-editting –making biodiversity-friendly choices the new normalcy.

7.6. Integrating biodiversity in finance and investment

The analysis in the previous chapters indicated the need to improve the business case for sectors to invest in biodiversity. This section provides estimates of investment flows into biodiversity-related production sectors such as agriculture, forestry, fisheries, water management. These flows are expected to increase with economic growth, especially in developing countries. The sectoral investment flows are compared with estimates of the financial resources required to attain the Aichi targets. This provides background to a summary of ways in which sectoral investments can be steered in a more biodiversity-friendly direction, including the integration of natural capital in public and private investment decision-making. The emphasis is on sectoral investment flows; many other aspects of the financing of biodiversity (such as the Global Environment Facility) are not discussed here.

Foreign and domestic investment in biodiversity-related sectors

Annual investment flows into biodiversity-related sectors are much larger than the flows specifically directed at biodiversity conservation. The first column in Table 7.3 summarises estimates of these flows for the sectors analysed in this report. Furthermore, these sectoral investment flows are expected to increase in the future with increased economic growth.

Sectors traditionally considered as the most biodiversity-relevant include agriculture and forestry. However, a number of other sectors that also harbour ties with biodiversity (although arguably more indirectly) also see large annual investment flows. For example, conservation and sustainable use can sometimes be an important component for the tourism, energy and health sectors (Kettunen et al., 2013).

Table 7.3. Current and future estimated financing flows in a selection of biodiversity-related sectors.

Sector	Current financing flows (billion US$ annually)*		High-level Panel resource-need estimates (total costs in billion US$ for the 2013–2020 period)**
		Year	
Biodiversity	~50		150–440
Sectors addressed in this report			
Agriculture	>200 (global)	2005–2007	366–823
Forestry	~64	2005	88
Water and sanitation	567 (OECD and BRIC countries) 7.4 (ODA commitments in 2007–2008)	2006 2007–2008	2–3
Fisheries	No estimate available for total sector. >10 in subsidies	2000	141–329
Other sectors			
Energy	400 (fossil fuel subsidies) 244 (renewable power)	2011 2012	
Tourism	765	2012–2013	
Climate change mitigation and adaptation	364 (75–80% of which in developed countries)	2011	
Health	18 (in low-income countries) Estimated at 2.4 % of GDP in BRICS countries	2006 2010	

Source: *Kettunen, et al. (2013); **CBD (2012).

Note: This table is intended to provide an order of magnitude. Estimates on current financing flows are crude with differing reference years and sometimes covering only part of a sector (see Kettunen et al., 2013). For the High-level Panel (HLP) estimates, see CBD (2012) for specific actions and methods; sector-specific components of the HLP estimates are added up. The HLP Water and sanitation estimate is quite low (only comprising action 3 under Target 8) while the sector is relatively large.

Investments in these sectors are in general largely financed by domestic public and private sources, with foreign direct investment (FDI) and official development assistance (ODA) being significantly smaller contributors. For instance, 95% of global agricultural investment flows are estimated to be of domestic origin (FAO, 2012). Part of these domestic investment flows are publicly funded, with the state investing in agricultural research or agricultural infrastructure or providing investment subsidies. The other part originates from private domestic investors, including farmers themselves investing in new equipment, for instance. In the forestry sector, estimates from 2006 indicate that 90% of all private investment came from domestic sources

(Tomaselli, 2006). In the water and sanitation sector, there seems to be a shift towards a larger private funding base, whereas these sectors were traditionally largely public (Kettunen et al., 2013). UNCTAD found that private investment in sectors such as basic infrastructure, electricity, water and sanitation, agriculture and climate adaptation is relatively low in general and even lower in developing countries. Public finances are still central in many of these sectors in developing countries, with private investment mostly going to the manufacturing and services industries (UNCTAD, 2014). While there are explanations for this division, the importance of these sectors for development and the limited potential of public finances in developing countries to provide the necessary increase means that private investment in these sectors has to be mobilised further.

Regarding foreign private and public investment flows, foreign direct investment has passed official development assistance in size in many developing countries (Lautier & Moreaub, 2012; UNCTAD, 2014). Still, together these foreign investment flows are still much smaller than domestic investment flows in biodiversity-related sectors (Kettunen et al., 2013). FDI and ODA can be an important channel for technology diffusion and knowledge transfer and spill-overs but, given its size, domestic investment seems important for upscaling. This has implications for policy aiming to steer investment towards including biodiversity conservation and sustainable use. Future research would need to look into the role FDI and ODA play in transferring biodiversity-friendly technologies in the agriculture, forestry and water sectors to developing countries and how FDI and ODA can complement the upscaling role of domestic investment.

Estimated financing needs to transform sectors

In 2012, the High-level Panel on the global assessment of the resources for implementing the CBD strategic plan for biodiversity concluded that the estimated resources required to attain those Aichi targets that address the drivers of biodiversity loss have the highest financing needs. The final column of Table 7.2 summarises the estimates by this High-level Panel for the targets connected to the sectors considered in this report (CBD, 2012). These estimates come with many caveats, as they depend for instance on ambition levels, actions assumed to be taken to attain a target, and the allocation of costs. For instance, success in attaining one target may influence the costs associated with attaining other targets. The Biodiversity Finance Initiative intends to provide bottom-up national assessments of resource needs and financing gaps for biodiversity as well as highlight potential to mainstream biodiversity into sectors (UNDP, 2014).

In addition, as the High-level Panel also notes, the size of the estimated required investment does not necessarily mean that the target is more important. Targets that require less investment may still be hard to attain and/or of high importance in making other targets easier to achieve. Examples of these are the phasing out of incentives harmful to biodiversity (Target 3) and the creation of government plans on sustainable consumption and production (Target 4).

With public budgets strained in many richer countries, governments are seeking ways to leverage more private sector funding. The parties to the CBD agreed to double biodiversity-related international financial resource flows to developing countries to help them attain their share of the Aichi targets (CBD Decision XI/4, paragraph 7(a)).

Redirecting the decision-making on financial investments to biodiversity-friendly options and nature-based solutions is both in the interest of the production sectors themselves and crucial for biodiversity conservation. The estimated size of the investment flows in Table 7.3 underlines the importance of finding ways to influence financial flows in biodiversity-related sectors. There are large flows of capital in sectors with strong links to biodiversity and a high dependency on natural capital. Vice versa, the expected increase in future investment flows will result in increasing pressures on biodiversity (as was shown in Chapter 2) if investment patterns do not shift in a more biodiversity-friendly direction.

Integrate natural capital in finance and investment decisions

The financial sector is increasingly acknowledging that the way in which sectors and companies depend and impact on natural capital should play a role in investment decisions. Finance and investment institutions provide the loans, equity, insurances and financial services that support the sectors discussed in this report and the supply chains that link them. This therefore requires a better understanding of the dependencies and creates a need to design instruments that can assess the risks associated with them. It also requires individual companies to improve their reporting on dependencies and impacts to provide the information that financiers and investors need in their decision-making. Rating agencies are also increasingly taking natural capital into account in their advice, with existing raters expanding into non-financial aspects (e.g. Goldman Sachs with GS SUSTAIN, the Dow Jones Sustainability Indices, MSCI with their MSCI ESG indices) and new raters such as CSRHub and GMI Ratings specialising in environmental risk assessments for investors.

An illustration of financial sector engagement is the Natural Capital Declaration (UNEP, 2012), which aims to integrate natural capital into financial products, accounting and decision-making. Other examples are the International Finance Corporation (IFC) Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources, the Equator Principles which are based on the IFC's performance standards and the Natural Value Initiative (NVI), which works together with the financial sector to assess the risks and opportunities related to the impact and dependence of companies on biodiversity. Still other examples are the UN-supported Principles for Responsible Investment and the Sustainable Stock Exchange Initiative.

There is also the question how the increased engagement of the financial sector, investors and companies can contribute to a better balance in spending on biodiversity between developed and developing regions. It is estimated that 59% of biodiversity finance is spent in developed economies against 41% in developing economies (Parker et al., 2012). Increased attention for the sustainability of production throughout the supply chain of firms may be one solution, as much primary and intermediate production takes place in developing regions.

Three lines of further action for both the financial sector and governments can be deducted from these initiatives:

- Improve understanding of the role that biodiversity and natural capital play in businesses and sectors. This relates to assessing the impacts that sectors have on the environment, and especially the ways in and extent to which they depend on natural capital, the risks associated with those impacts and dependencies, and the opportunities that a better understanding of biodiversity can bring them.

- Work towards improved accounting of and reporting on the biodiversity and ecosystem-related impacts, risks and performance of companies and investment projects. Non-financial reporting is now mainstream among large companies, with the majority regularly providing reports on their environmental, social and governance impacts and performance (KPMG, 2013). This also includes the design of instruments that can value natural capital to provide feedback in financial terms, although monetary valuation of biodiversity and natural capital is still wrought with difficulties and uncertainties. This improved reporting by many companies worldwide informs rating agencies on these companies' risks, helping investors to better steer their investment portfolio. However, biodiversity and ecosystem capacity and services are relatively underdeveloped in this regard (see also Box 7.1).

- Encourage governments to employ policies that offer incentives to invest in biodiversity and natural capital, and to create policy frameworks and regulation that steer finance and investment towards decision-making that takes sustainability into account. An example is the obligations that many countries have put in place surrounding company reporting, making non-financial reporting compulsory and prescribing guidelines to adhere to (UNEP, Global Reporting Initiative, KPMG and Centre for Corporate Governance in Africa 2013). There is however ample room for quality improvement in non-financial reporting, and research is needed into how improved reporting actually leads to change in company sustainability performance.

In addition to accounting and reporting, there are also more direct policy mechanisms that can help redirect finance and investment flows (see below).

Box 7.1 Reporting mechanisms for biodiversity

Sustainability reporting by companies aims to promote sustainability in business practice, based on insights and measurement, and to help consumers make informed purchasing decisions (Bosman, 2013; McKinsey, 2011; INTOSAI, 2013). Taking into consideration the entire supply chain would in theory ensure that all aspects of relevance are considered, as the company would not overlook an important impact factor simply because it occurs further up or down the supply chain (GRI, 2011, 2013; PwC, 2012; KPMG, 2013). So far, only about 20% of reporting companies undertake a supply chain analysis, and of these it is unclear how thorough their analysis is (KPMG, 2013). This is an important point, especially regarding biodiversity reporting. Major biodiversity and ecosystem impacts usually occur at the production and/or resource extraction stage at the beginning of the supply chain. If a company does not go this far, it will probably overlook ecosystem effects (GRI, 2011).

While awareness of impacts and dependence on biodiversity and ecosystems among companies is growing (due to their potential for cost reduction and the increase in demand for sustainable products), it is often still perceived as a broad, diffuse and unstructured issue (Bosman, 2013). The Global Reporting Initiative states that many businesses and other organisations do not assess the benefits they receive from ecosystems systematically, including their economic dependence on such benefits (GRI, 2011). Such under-assessment could lead to weak reporting on this issue, leading in turn to bad practices. For instance, among the best practice examples PricewaterhouseCoopers gives for corporate sustainability reporting, biodiversity and ecosystem impacts are mentioned once, and only in a side note (PwC, 2012). On the other hand, the media and rating company Bloomberg sees an increase in attention for other risks besides climate change and energy, including water and ecosystems (Barton, 2010). In addition, several countries have guidelines on voluntary reporting or are considering some form of obligatory reporting include guidelines on biodiversity reporting. Japan’s guidelines for voluntary reporting for instance include reporting on the sustainable use of resources and the status of biodiversity conservation (GRI, 2013).

When looking at biodiversity, the link between reporting and acting needs to be further explored. While there is evidence that mandatory reporting in countries increases the sustainability performance of companies (Ioannu, 2013), the effect of sustainability reporting on biodiversity is still unclear. This could also be due to a lack of high-quality sustainability reports regarding biodiversity.

Redirect finance and investment flows and improve the business case using different policy instruments

The CBD highlights six innovative financial mechanisms (IFMs). These instrument classes are still rather broadly formulated, with many potential instruments falling under their headings. These instruments can be publicly financed, privately, or via a mix. Until now, instruments like Payments for Ecosystem Services (PES) have mainly been financed from public funds. The challenge is to find ways for these instruments to also involve more private funding flows. Table 7.4 gives a rough indication of which mechanisms are better suited to which sectors. However, this does not mean, for example, that offsets are never used in the agricultural sector, but that they are usually used in other sectors, in this case the extractive industries, forestry and sometimes in tourism. The draft of the Global Monitoring Report provides annexes with examples of the use of these mechanisms in each country (CBD, 2014).

- Environmental fiscal reform for biodiversity intends to shift taxation and other fiscal incentives from activities that are harmful to biodiversity to activities that are less so, or that even yield a beneficial impact. This may include for instance the reduction or abolition of subsidies for capture fisheries or deforestation, and the taxation of pesticides, wastewater discharges or other polluting activities (OECD, 2013). Environmental taxes can raise revenue to spend either on environmental protection (if earmarked) or other government priorities. Currently, most (>90%) of environmentally-related taxes come from transport and energy taxation.

- Payment for Ecosystem Services, or PES, systems are designed around the beneficiary-pays principle, instead of the more classical polluter-pays principle. They are voluntary systems where either private or public entities pay the providers or managers of ecosystem services for the benefit they obtain from them. Most PES systems are constructed around watershed services and they have seen a proliferation in recent years (one estimate is of 300 PES programmes in 2010 (Blackman & Woodward, 2010)). The majority of finance for PES programmes seems to come from publicly-financed programmes (OECD, 2013).

- Offsets are legally required in for example Brazil, South Africa, Australia and the USA. There are also sector-specific laws in countries to specify offsetting or compensation obligations for sectors. Tourism as a sector is not yet obliged to offset its impacts anywhere and experiences are limited to pilots. Offsetting mechanisms could also be applied in tourism infrastructure development.

- Markets for green products and more sustainable supply chains were discussed in Section 7.4. This is a mechanism that is currently primarily driven by private parties and certification schemes. Increasingly, however, governments are stepping in, stimulating both the demand and supply side further. On the demand side, green public procurement by governments is becoming mainstream in the EU. On the supply side, governments are increasingly mandating environmental standards in the production of resources, creating cross-fertilisation with private certification schemes like the FSC and PEFC.

- Biodiversity is increasingly recognised in climate change funding, given that climate change is an important driver of biodiversity loss, as well as the potential for synergies between biodiversity conservation and climate change mitigation and in ecosystem-based adaptation (OECD, 2013). A key area is in Reducing Emissions from Deforestation and Degradation (REDD+). The synergies between climate change mitigation and adaptation and biodiversity and ecosystems, combined with the funds available in the carbon markets for adaptation make this an important potential mechanism.

Table 7.4. Overview of innovative financial mechanisms.

CBD classification	Estimated size in billion US$	Description	Primary sectors associated with scheme
Environmental fiscal reform	- †	Shift taxation to activities that have negative environmental externalities.	Agriculture (e.g. taxes on pesticides), fisheries, forestry.
Payments for ecosystem services	1.8–2.9 (public) 0.37(private)*	Create agreements where beneficiaries of ecosystem services compensate the providers to maintain the service.	Watershed management (water and sanitation, energy, carbon sequestration).
Biodiversity offsets	2.4–4 **	With a strong focus on conservation, offsets intend to compensate for residual impacts on biodiversity of project development after mitigating actions have been taken.	Extractive industries, forestry, tourism.
Markets for green products	59 (organic products)***	Create supply and demand for products that have been produced with less impact than their alternatives, often supported by certification schemes.	Agriculture, fisheries, forestry.
Biodiversity in climate change funding	3.1***	Integrate biodiversity targets and criteria in the increasingly large funding for climate change.	Forestry.
Biodiversity in international development finance	5.7 bn*** (2009–2010)	The potential to leverage existing development finance flows by integrating and mainstreaming biodiversity with other development objectives.	Agriculture, water and sanitation, forestry, energy.

Estimated sizes are intended to provide an order of magnitude, relying on data between the years 2009 and 2012.
† Majority of environmental taxation is energy-related; no estimate of land- or biodiversity-related taxation available.
Sources: *Kettunen et al. (2013); **Madsen et al. (2011); ***OECD (2013)

- Biodiversity in international development finance covers the flows of official development assistance from donor countries to developing countries. Biodiversity-related ODA has increased in recent years, but is still small compared with the financing needs (OECD, 2014). There is currently no clear distinction between international development financing for the global public good aspects of biodiversity and for investment in biodiversity that contributes to developing countries' development. International development finance need not necessarily be through government-to-government support. Attractive alternatives are to use ODA to create public-private partnerships or to provide leverage for or to steer private contributions. For biodiversity, examples are green bonds and trust funds, the outsourcing of conservation and management practices, or co-financing or subsidising sustainable use parts of sectoral investments.

The implementation of these mechanisms may in turn create unintended and undesirable outcomes, although environmental and social safeguards can be implemented to limit that risk. Ituarte-Lima et al. (2014), for instance, provide guiding principles to design and apply safeguards in biodiversity-related finance mechanisms.

Domestic public policy is instrumental in guiding investment in biodiversity-related sectors and in implementing innovative financial mechanisms

Some of the above-mentioned mechanisms are direct government instruments; others require policy support to become effective or to grow in size. In some instances, this may be limited to the provision of information or start-up subsidies (for instance in the markets using certification and labelling); in others it requires tax breaks, subsidies or even regulation to set standards or create markets. In addition, we have shown in this section that the majority of investments in biodiversity-related sectors in developing countries is financed from public and private domestic sources and that investment in these sectors will increase in the coming years. Increased investment in agriculture, water and sanitation and energy sectors is a necessity from a development perspective.

The ability of domestic governments to mobilise as well as guide different investment flows is crucial. While domestic public and private funding in biodiversity-related sectors is dominant, FDI and ODA can have specific roles to play if well-managed. A useful approach would therefore be to consider the relative strengths of the different finance flows into biodiversity-related sectors and how governments can use policies to make the best use of those strengths. Government ability is also required to monitor and evaluate these policies, preventing unintended effects of biodiversity-related financial incentives, for instance through the use of safeguards.

Domestic government ability is all the more important given that investment mobilisation creates a difficult balancing act. Mechanisms that mobilise investment need to generate a rate of return that attracts private investors but does not undermine the accessibility and affordability of the public service components in these sectors (such as for instance in the water and sanitation or energy sectors) or create perverse incentives.

7.7. Implications for biodiversity policies

While the options discussed in the previous sections require the joint effort of private and public actors, public policies will be hugely important to make this happen. A number of suggestions are given in this section for governments to mainstream biodiversity into sectors, domestically and internationally, to effectively influence the sector towards more biodiversity-friendly production and the application of nature-based solutions.

Governance for biodiversity and governance of biodiversity

We make a distinction between ‘governance of biodiversity’ and ‘governance for biodiversity’, as depicted in Figure 7.5. This report makes suggestions to achieve ‘governance for biodiversity’ in sectors. This requires that the policy frameworks and instruments applied within sectors take biodiversity into account. These policies need to be applied in coherence with traditional biodiversity policy instruments (‘governance of biodiversity’), such as National Biodiversity Strategies and Action Plans (NBSAPs), that are so far limited in their inclusion of sector perspectives (Leadley et al., 2014). Sector policies are also influenced by other policy domains like trade, finance, climate change and development assistance. Conditions are also set in these domains for sectors to move in a more biodiversity-friendly direction, and these also need to be taken into account. An obvious case in point is the inclusion of REDD+ in climate policies; different designs of REDD+ will result in quite different biodiversity outcomes for forest management.

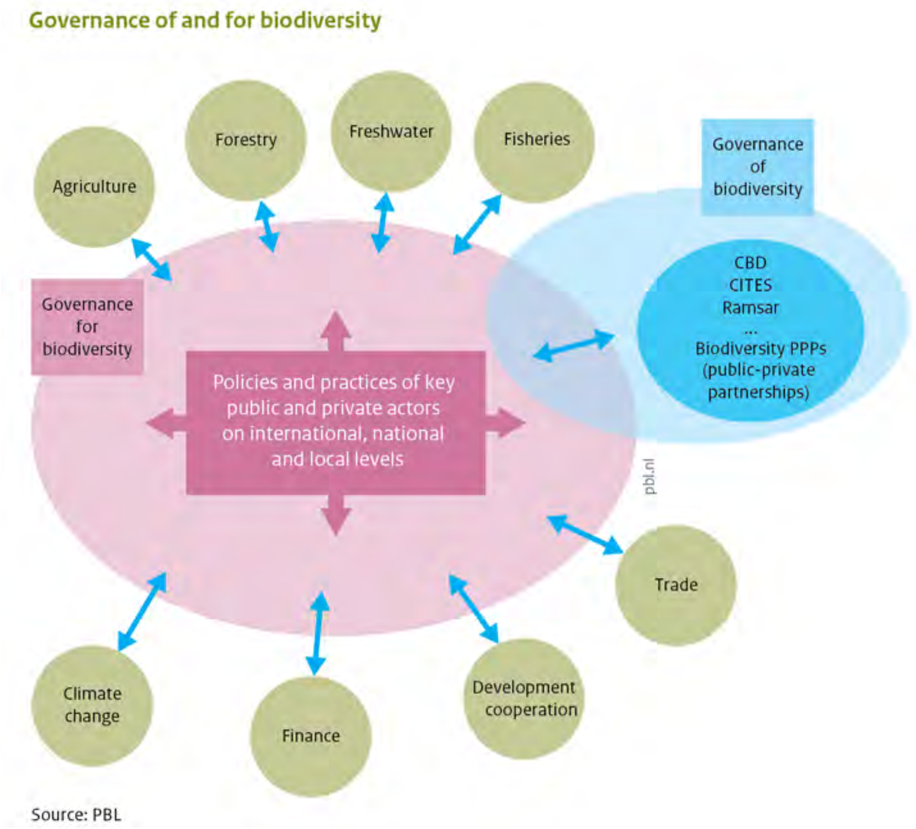


Figure 7.5. Governance of biodiversity and governance for biodiversity.

Importance of shared visions, long-term goals and a sense of urgency

There are several international public and private governance frameworks that address important aspects of biodiversity and ecosystem services and guide sector action, including deforestation (UNFF, ITTA, REDD+), FAO codes of conduct for fisheries, round tables on agricultural commodities and land degradation (UNCCD). The relevance of biodiversity and ecosystems for human development has furthermore been recognised in several existing inter-governmentally agreed goals and targets, including Agenda 21, the outcomes of the World Summit on Sustainable Development (WSSD), the Millennium Development Goals (MDGs) and Rio+20. This relevance for human development is also one of the foundations of the Strategic Plan for Biodiversity 2011–2020. The Strategic plan does provide a 'guiding star' that could play an important role for different groups of stakeholders, but the question is to what extent this star is noted beyond the 'biodiversity community'. Currently, the Strategic Plan and with it the 2020 Aichi Biodiversity Targets and the 2050 Vision seem to have hardly any traction within sectors covered in this report.

The most recent development with respect to global goal-setting is the Sustainable Development Goals (SDGs). The process to formulate and negotiate SDGs is the main outcome of the Rio+20 conference and its development is merged with the follow-up process to the Millennium Development Goals that expire in 2015. While it cannot be predicted what the SDGs will look like, they provide an opportunity to incorporate biodiversity and ecosystem services in a global, long-term and universal agenda for poverty eradication, green growth and sustainable development. While the Aichi Biodiversity Targets provide a good basis for highlighting the importance of biodiversity and ecosystem services, the SDGs may eventually have broader traction in sectors. Proper inclusion of biodiversity in the SDGs would therefore provide an important step forward for the – sectoral –mainstreaming agenda. Agreeing on

SDGs will however be of little value if they are not followed by changes in the rules of the game and actions by sectors.

Tools for mainstreaming biodiversity in sectors

Mainstreaming tools can be used to identify opportunities and risks and give biodiversity the necessary attention in business. Tools for mainstreaming biodiversity can build on tools already applied in environmental mainstreaming activities in other governance contexts. However, these tools require significant adjustment to be useful in various sector contexts for mainstreaming biodiversity, given the difficulties experienced by key actors in sectors in operationalising biodiversity. While there is plenty of literature on the tools and processes for mainstreaming the environment in general, there is much less experience with the tools for mainstreaming biodiversity (UNDP & UNEP, 2009; Dalal-Clayton & Bass, 2002, 2009). Nevertheless, the experience with mainstreaming tools for the environment can serve as a starting point for integrating biodiversity into sectors. In all phases of mainstreaming, from recognition of the importance of biodiversity to strategy development to actual implementation, specific tools for mainstreaming biodiversity are available. Many of the suggested tools reflect the dynamic and adaptive characteristics that the mainstreaming process needs to have, with learning mechanisms through monitoring and feedback and attention to up-scaling and widening the human and financial resources. Different ways to create integrated policymaking include: awareness-raising through portfolio screening, valuation, impact assessment and expenditure reviews; ensuring consistent policies across domains and scales of policymaking; organisational measures within governments like joint task-forces; and creating transparency and accountability by monitoring, benchmarking and feedback.

An important condition in sectors is awareness of and knowledge about the importance of biodiversity conservation and sustainable use. A question is for example whether existing knowledge mechanisms within sectors recognise biodiversity as an issue and make its relevance for the sector visible through data, indicators, and so on. Whether or not this is the case often depends on the character of the knowledge communities linked to the sector. If this community is too limited, then identification of the missing type of expertise and perspectives is valuable as a foundation for initiating mainstreaming. It is also necessary to identify the knowledge requirements related to a (potential, planned or ongoing) mainstreaming process itself such as reporting systems for follow-up of actor commitments, adherence to norms and policies, and so on.

Furthermore it is noteworthy that for example the World Resources Institute, the WBCSD , the Secretariat of the Convention on Biological Diversity, the UNDP-UNEP Environment and Poverty Initiative and IIED (Roe & Mapendembe, 2013) and The Economics of Ecosystems and Biodiversity study (TEEB) have developed guidance materials in the area of biodiversity mainstreaming.

Government policies at the national and international level

The strategies identified above require the joint effort of private and public actors, but governments will have to provide an enabling and regulatory environment through adequate public policies to get these strategies realised. Specific domestic policies in relation to the four strategies are summarised in Table 7.5

Table 7.5. Government policies for four strategies towards biodiversity friendly sustainable production.

Landscape	Supply chain	Consumption	Finance
Improve spatial planning to include all stakeholders. Create institutional capacity and co-management schemes. Ensure land tenure for smallholders and local communities. Combine different incentive schemes for ecosystem services. Monitor impacts. Integrate farm-level initiatives with further upscaling.	Capacity-building. Prioritise national/international supply chains, commodities and regions where largest impacts are and where actions are required. Create (local) markets for sustainable produce, including the use of public procurement. Stimulate certification and labelling Focus on laggards. Improve extension services. Monitor impacts.	Raise awareness through information and education campaigns. Health policies. Public procurement. Develop instruments to push back food waste.	Increase non-financial reporting on biodiversity by companies. Engage with financial sector initiatives. Redirect investment flows in biodiversity-related sectors. Assess and use the relative strengths of domestic and foreign public and private investment flows.

In addition, governments can act in the international arena to further develop a sectoral mainstreaming agenda:

- help realise shared visions and a sense of urgency for biodiversity-inclusive solutions to make biodiversity-friendly production a part of the 'new normalcy' of sustainable production and consumption;
- ensure coherent global norms to monitor and preserve the global public good aspects of biodiversity. This can be done through related Multilateral Environmental Agreements and the proposed Sustainable Development Goals and alignment with other policy domains like trade, finance, development cooperation and climate adaptation and mitigation;
- further develop partnerships with business and include biodiversity in already existing UN partnerships with business such as the Global Compact, the Global Reporting Initiative and the UN Forum on Sustainability Standards;
- support programmes supporting the uptake of Natural Capital Accounting systems in national governments (like the System of Environmental-Economic Accounts adopted by the UN Statistics Commission and the World Bank's WAVES partnership) and in the business world;
- support the inclusion of biodiversity in the further development of private norms, reporting and review mechanisms (e.g. ISEAL or ISO for certification).

The CBD can play a leading role in:

- mainstreaming the spirit and substance of the Aichi targets into public and private governance of sectors;

- ensuring the inclusion of biodiversity concerns in newly-emerging public and private partnerships on sustainability;
- including biodiversity initiatives and goals of sectoral bodies and other conventions into its own strategies;
- creating ownership and leadership amongst key players in public and private governance for biodiversity. Natural Capital Accounting in Central Statistics Offices and companies could play an important role in this.

To conclude

The successful mainstreaming of biodiversity in production sectors will inherently become a diverse, dispersed and long-term process, requiring new engagements between the biodiversity community and production sectors. As the practicalities of a shift towards more biodiversity-friendly production are not yet well-understood in sectors, much more experimentation, showcasing and sharing of experiences between diverse sector contexts around the world is required. Furthermore, the mainstreaming of biodiversity into sectors needs to be seen as part of a broad policy agenda of biodiversity conservation and the promotion of the sustainable use of biodiversity and natural resources. Governments need to play an enabling and regulatory role to involve the relevant private and societal actors. The challenge will be to step up, scale up and speed up action and to ensure a balance between public and private benefits.

Annex A: PBL background information

The following PBL publications provide insight in modelling tools and background studies for this report:

Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M., ten Brink, B. (2009) GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss. *Ecosystems*, 12, 374–390.

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Annex B: Biodiversity indicators and models

Biodiversity indicators and integrated assessment models used for scenario-analysis

B.1 Introduction

Biodiversity is a broad concept with many definitions and indicators to monitor biodiversity trends.

The concept of biodiversity has many dimensions and different interpretations, which influence the way in which changes in biodiversity are measured. The definition most used is that of the Convention on Biological Diversity: *'Biodiversity is equal to the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems'* (CBD, 1992). Other aspects of biodiversity than variability are often also emphasized, such as the importance of naturalness.

State and trends indicators for biodiversity

Biodiversity indicators can be structured using the list of indicator categories agreed upon by the CBD (CBD Decisions VII/30 and VIII/15, 2004). Five of the categories listed are dedicated to the status and trends of the components of biological diversity. These indicators looking into the state of biodiversity are:

1. *Trends in the extent of selected biomes, ecosystems and habitats;*
2. *Trends in abundance and distribution of selected species;*
3. *Change in status of threatened species;*
4. *Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socio-economic importance;*
5. *Coverage of protected areas.*

A subset of these indicators can be produced for future scenarios on a global scale (for an overview, see Leadley et al., 2010). Some indicators, such as the main indicator used in this report (Mean Species Abundance - MSA), relate to several elements on the list, while there are also linkages between the different types of indicators. Some of the indicators used in global assessments are described below, including their strengths and weaknesses, and the relation to the purpose of this report to assess ex ante global biodiversity impacts of sector-based options in the future.

B.2. Key indicators used in this report

Given the purpose of the report, the biodiversity indicators used are: applicable on a global scale and also provide information on underlying ecosystem types; applicable in a scenario context; based on sound scientific principles; meaningful for sectors; policy relevant for the CBD.

Based on these criteria, four indicators have been selected that provide an overview of key biodiversity trends. These indicators directly relate to the list of CBD state indicators discussed in Section B.1. The first is *biome extent* (natural area) expressed in million km^2 and subdivided into a selection of seven globally aggregated biomes. The second is the relative *mean species abundance* of originally occurring species (MSA) as an indicator for trends of species abundance. This indicator is also a measure for the intactness of ecosystems (Alkemade et al., 2009). Third is a combination of ecosystem extent and MSA and yields the *wilderness* indicator, presenting the extent of highly intact natural areas. The fourth indicator is the M*arine*

Depletion Index (DI) (Alder et al., 2007) to indicate the state of living marine resources. An overview is presented in Table B.1.

Table B.1. Overview of biodiversity indicators used in this study.

Indicator	Description	Application
Extent of biomes (natural area)	The size of a biome having its original cover (the original area of a biome minus the converted area used for agriculture, forestry plantation and urbanisation) It does not provide information on the quality of the natural area.	Applied to all options mostly to show the effectiveness of measures to reduce habitat loss by conversion.
MSA	Measures the change in populations of species relative to intact ecosystems It provides supplementary information on the *mean* quality of natural areas and of agricultural areas	Used in this study as the main indicator of biodiversity loss. Applied for all options and scenarios and for all areas, natural and man-made areas. Applied at different levels of scale, in maps of 0.5 by 0.5 degree grid cells, and as quality measure to determine wilderness areas.
Wilderness area	Measures the size of relatively undisturbed (intact) ecosystems, with a MSA value above 0.8 (directly derived from the MSA) Provides supplementary information on which part of the natural area is of high quality.	Applied to all options and scenarios as an additional indicator to determine high-quality natural areas.
Marine depletion index	Measures the change of estimated biomass of living marine resources (29 functional groups) relative to a situation of low fishery pressure (1950). It concerns mainly fish but also crustaceans, bivalves and other exploited groups. The indicator is an abundance indicator and closely related to MSA.	Applied in the changing marine fisheries option.

Biome extent (natural area)

Biome extent is measured by subtracting agricultural areas, forestry plantations, and urban areas from a biome according to the climatic and geographical potential. Agricultural areas include converted land used for crops and fodder, and permanent pastures with relatively high-stocking rates. Forestry areas, except for forestry plantations, are included as natural area because these land uses are exploitation forms of natural or semi-natural forests.

Mean Species Abundance (MSA)

MSA is used in this report as the central biodiversity indicator, with the implication that the focus is more on preserving naturalness, ecosystem intactness and species abundance than, for instance, on species richness. The choice for MSA is based on broad coverage of the biodiversity concept. MSA together with biome extent and wilderness cover most of the categories in the CBD indicator list (see Table 2.1).

The MSA considers the variety of plant and animal species in a certain area and their population sizes. Population size is the number of individuals per species, generally expressed as the abundance of a species or briefly *species abundance*. The various nature types or *biomes* in the world vary greatly in the number of species, their species composition and their species abundance. Obviously a tropical rainforest is entirely different from tundra or tidal mudflats. The process of biodiversity loss is generally characterised by the decrease in abundance of many original species and the increase in abundance of a few other -opportunistic- species, as a result of human activities. As a result, many different ecosystem types are becoming more and more alike, the so-called homogenisation process (Pauly et al., 1998; Ten Brink, 2000; Myers and Worm, 2003; Scholes and Biggs, 2005; MEA, 2005). Decreasing populations are as much a signal of biodiversity loss as highly expanding species, which may sometimes even become plagues in terms of invasions and infestations (see the figures B.2 below showing this process from left to right.

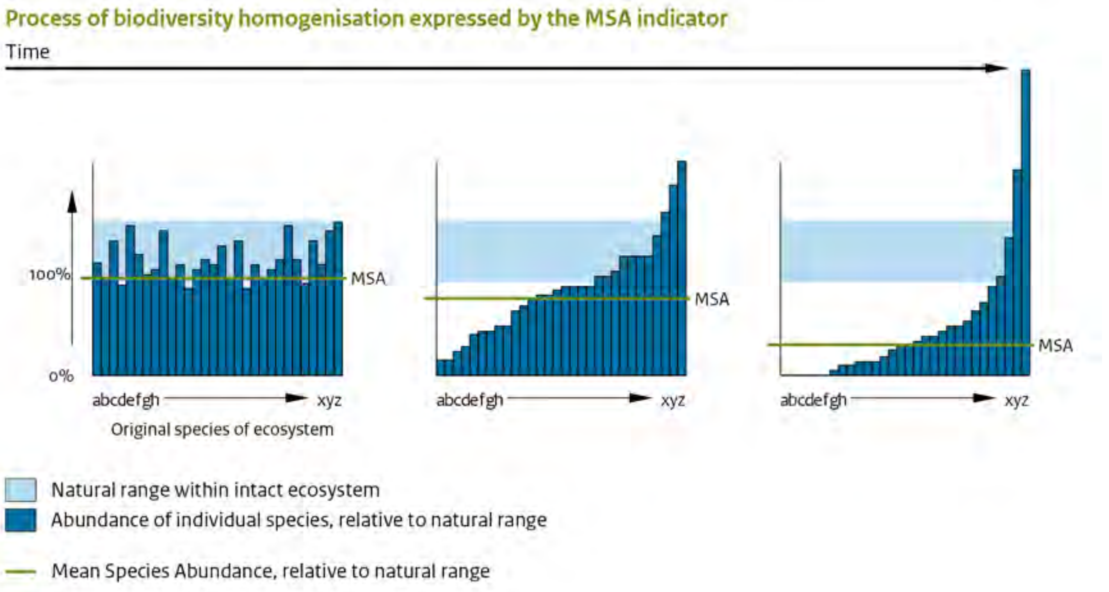


Figure B.2. Biodiversity loss is characterized by a decrease in abundance of original species and the increase in abundance of a few, often opportunistic, species as a result of human interventions. Extinction of species (left hand side of the graph on the right, species a – f) is the last step in the homogenization process.

In this study biodiversity loss is calculated in terms of the *mean species abundance* (MSA) of the original species compared to the natural or low-impacted state. This baseline, the species composition and abundance of the original ecosystem, is used here as a means of comparing different model outputs, rather than as an absolute measure of biodiversity. If the indicator is 100%, the biodiversity is assumed to be similar to the undisturbed or low-impacted state, implying that the abundance of all species equals the natural state. If the indicator is 50%, the average abundance of the original species is 50% of the natural or low-impacted state and so on. To avoid masking, significant increased populations of original species are truncated at 100%, although they should actually have a negative score. Exotic or invasive species are not part of the indicator, but their impact is represented by the decrease in the abundance of the original species they replace. The mean species abundance (MSA) at global and regional levels is the sum of the underlying biome values, in which each square kilometre of every biome is equally weighted (ten Brink, 2000; UNEP, 2003, 2004).

Converting natural systems to agriculture, plantation and urban area is assumed to have an immediate impact on the MSA which can be further reduced by environmental pressures. MSA is determined by multiplying the impact of different pressures and summing the MSA values of different use types and ecosystems. The calculation method is explained in Figure B.3. For more information on MSA and the relationship with environmental pressures, see Alkemade et al. (2009) and www.globio.info

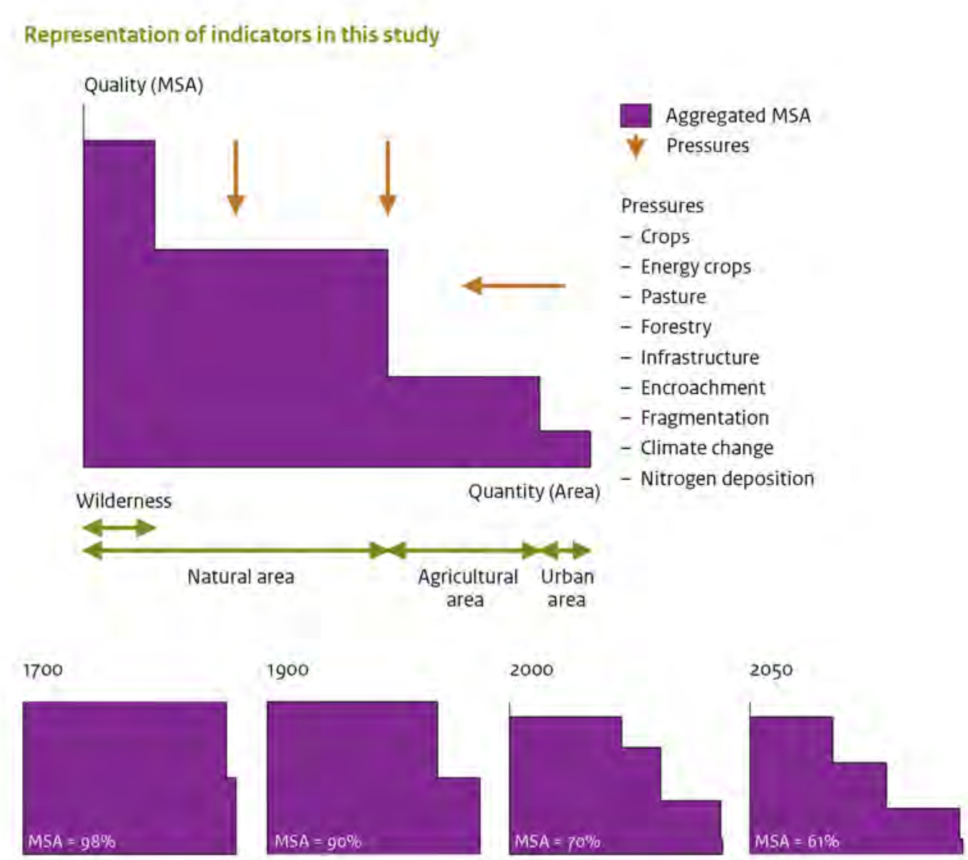


Figure B.3. The MSA methodology. Ecosystems have two components: quantity measured as area and quality measured by MSA. For both components, the original state is used as reference and equals 100%. Pressures including agriculture, forestry, and climate change lead to MSA loss and are most severe in human-dominated areas. Areas of high MSA are denoted as wilderness area (quality value > 80%). The trend from 1700 to 2050 is illustrated in the lower part of the figure. Real calculations at detailed grid level show greater variation in results than suggested here.

How to interpret MSA changes? Global MSA is used throughout this report as an overall indicator of the impact of a certain option. As with any aggregated index, changes in values may be difficult to interpret. As indicated in Figure B.3, changes in MSA values occur because of changes in environmental pressure and the extent of ecosystems. Changes in the values can thus also be expressed in both indicators. The reference MSA value for 2010 of 68% implies that globally 32% of the original naturalness of ecosystems has disappeared. However, a considerable part (24 %) of the global (remaining) MSA is tundra and desert systems, biomes types that are difficult to convert. The total historical loss of 32% is equivalent to a loss of the size of Asia in terms of its biodiversity value. Similarly, future trends can be evaluated. The baseline shows an additional MSA loss of 9 percent points, equivalent to a loss of the size of North America in terms of biodiversity value. The loss is almost exclusively forest and grassland ecosystems, with little change in desert and tundra systems.

The driving forces of biodiversity loss, or pressures, considered in the model-analysis in this report are:

- Agricultural production on croplands, including the production of bio-energy crops.
- The use of pastures by livestock grazing, ranging from extensively used natural grassland to intensive livestock production systems.
- Forestry, including clear-cut, wood plantation and selective logging of natural forests
- Infrastructure. The disturbance of animal populations caused by transport infrastructure and traffic.
- Encroachment. The small scale development of human settlements and the exploitation of natural areas by hunting, extraction of fuel-wood and recreation
- Fragmentation. The reduction of patch sizes of natural areas due to development of agricultural land, forestry, roads and other infrastructure.
- Climate change. Change of local climate conditions.
- Nitrogen deposition. The exceedance of critical loads for nitrogen of natural areas by nitrogen deposition.

Wilderness area

The area of relatively undisturbed ecosystems can be estimated by distinguishing areas of relatively high intactness, for instance a MSA of 80% or more is defined as wilderness in this report. The choice of 80% is somewhat arbitrarily and estimates of wilderness areas are therefore not equivalent to definitions used in other reports (e.g.Mittermeier et al., 2002).

Depletion Index

The trend in species abundance in marine systems is measured using the depletion index (DI). Biomass changes due to fisheries of various functional groups of fish, crustaceans and molluscs are calculated using the EcoOcean model. For each functional group and region, the estimated biomass is divided by the biomass calculated for the year 2004. DI is the weighted mean of these ratios per species and has been adapted from the original depletion index described in Alder et al. (2007).

B3.3 An overview of the IMAGE / GLOBIO framework and its components

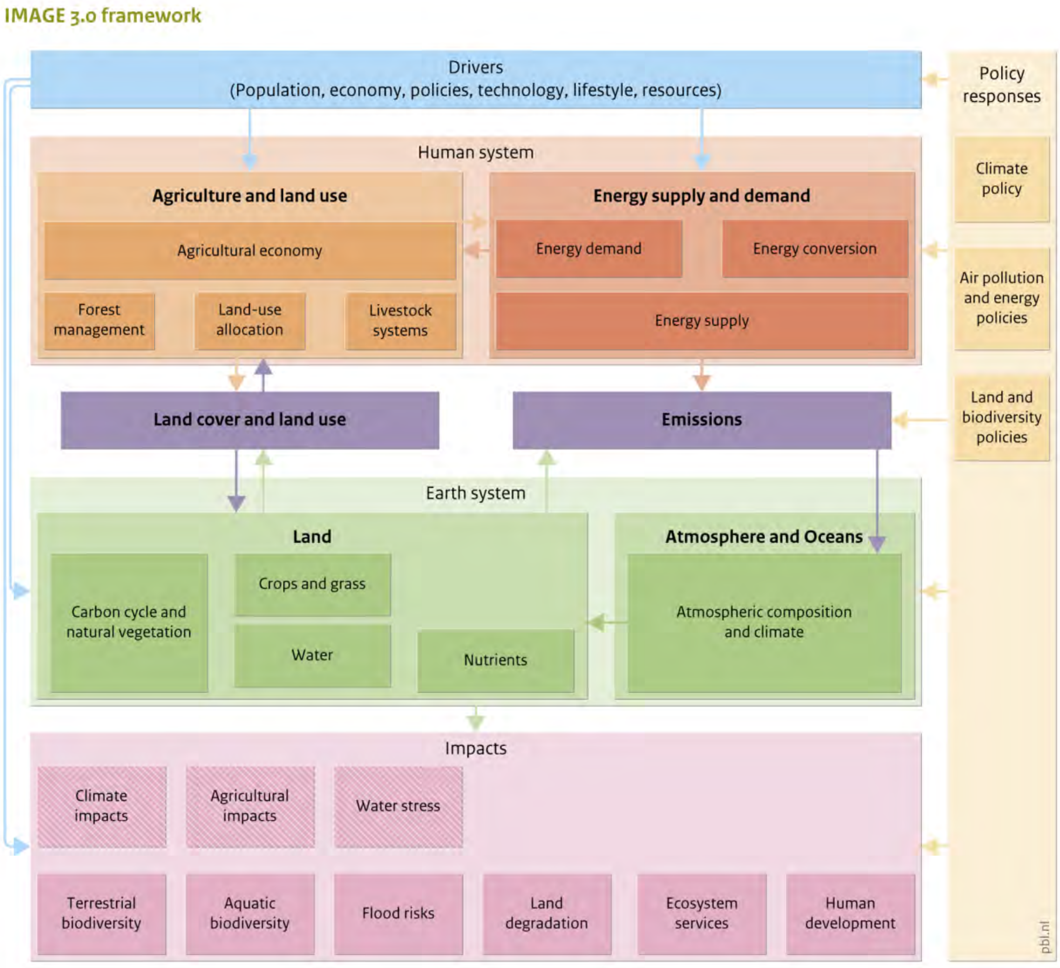
The components of the IMAGE framework are presented in the IMAGE framework schematic (see figure B.4), which also shows the information flow from the key driving factors to the impact indicators. A detailed overview of this framework can be found in http://www.pbl.nl/image and in Stehfest et al., 2014.

As a result of exogenous drivers, IMAGE projects how human activities would develop in the Human system, namely in the energy and agricultural systems. Human activities and associated demand for ecosystem services are squared to the Earth system through the ‘interconnectors’ Land Cover and Land Use, and Emissions (see figure B.4).

Assumed policy interventions lead to model responses, taking into account all internal interactions and feedbacks. Impacts in various forms arise either directly from the model, for example the extent of future land-use for agriculture and forestry, or the average global temperature increase up to 2050. Other indicators are generated by activating additional models that use output from the core IMAGE model, together with other assumptions to estimate the effects, for example, biodiversity (GLOBIO; see Components Terrestrial biodiversity and Aquatic biodiversity and Ecosystem Services).

Currently, impacts emerging from additional models do not influence the outcome of the model run directly. The results obtained can reveal unsustainable or otherwise undesirable impacts, and induce exploration of alternative model assumptions to alleviate the problem. As the alternative is implemented in the linked models, synergies and trade-offs against other indicators are revealed.

The EcoOcean model is no part of the IMAGE framework and is run separately, scenario data from the IMAGE framework are translated in the driving forces of the EcoOcean model.



Source: PBL 2014

Figure B.4 An overview of the IMAGE framework and its components

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Chapter 1

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Annex B

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