The Cost of Policy Inaction

ALTERRA WAGENINGEN UR

ecologic

Fondazione Eni Enrico Mattei

GHK

Institute for European Environmental Policy

Netherlands Environmental Assessment Agency

Witteveen + Bos

The Cost of Policy Inaction

The case of not meeting the 2010 biodiversity target

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with

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ABSTRACT

Braat L. & P. ten Brink, (eds.), with J. Bakkes, K. Bolt, I. Braeuer, B. ten Brink, A. Chiabai, H. Ding, H. Gerdes, M. Jeuken, M. Kettunen, U. Kirchholtes, C. Klok, A. Markandya, P. Nunes, M. van Oorschot, N. Peralta-Bezerra, M. Rayment, C. Travisi, M. Walpole, 2008. *The Cost of Policy Inaction, The case of not meeting the 2010 biodiversity target.* Wageningen, Alterra, Alterra-rapport 1718. 314 blz.; 85 figs.; 45 tables.; 140 refs.

The study presents the social and economic costs to mankind as a consequence of the losses of biodiversity in past, present and future. The losses have been quantified and expressed in monetary terms by an international project team, which conducted the study for the European Commission's Directorate General Environment. The results of the study indicate that the biodiversity policy targets of the CBD and the EU (a significant reduction of the loss and halting the loss of biodiversity, respectively by 2010) will not be met, without additional policies, not even in 2050.
The study employed a so called Baseline scenario (the consequences of no new-policies social and economic development), which has the following characteristics:Population increases from ca 6 billion in 2000 to ca 9.1 billion in 2050; Economic growth at 2.8% per year, a conservative growth scenario; Extra land for agriculture, implying additional conversion of natural systems to agricultural land use; Over-exploitation and crashed fisheries in all oceans; no more ocean fish for human consumption or to feed aquaculture; Disappearance of 1300 million hectares (1.5 x the land area of the United States of America) of pristine natural systems to allow intensive agriculture, biofuels and asphalt.
The physical consequences are loss of ecosystems services, the products which ecosystems deliver and the work ecosystems do, short term maximisation of food production at the cost of natural ecosystems and biodiversity, loss of regulating, buffer capacity of the world's ecosystems, for example climate regulation, flood control, water purification and soil quality maintenance and food and water shortages with associated social deprivation for billions of people
The economic consequences are that the annual loss of biodiversity on land by 2050 will have increased to a sum total of loss of ecosystem services equivalent to 14,000 billion Euro. This is equivalent to ca 7% of projected 2050 GDP. In addition, there are losses of ecosystems services of marine and coastal ecosystems which are expected to run up to several thousands of billion per year by 2050. The social consequences will be dramatic. In particular, in developing countries with great dependency on ecosystems services for daily livelihood and shere survival.

Keywords: biodiversity, economic costs, ecosystem service, global study, scenario, policy

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"The Cost of Policy Inaction: The case of not meeting the 2010 biodiversity target" is a study for the European Commission, DG Environment under contract: ENV.G.1/ETU/2007/0044 (Official Journal reference: 2007 / S 95 – 116033).

The study was conducted by a consortium led by Alterra, Wageningen UR in cooperation with the Institute for European Environmental Policy. The following organisations and people have contributed to the study:

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Preface

The Cost of Policy Inaction project

This report presents the results of the study of ***"The Cost of Policy Inaction (COPI): The case of not meeting the 2010 biodiversity target*** ". The project, which will further be referred to as the **COPI** project, is officially registered as ENV.G.1/ETU/2007/0044. It was carried out by a consortium led by Alterra, together with the Institute for European Environmental Policy (IEEP) and further consisting of Ecologic, FEEM, GHK, NEAA/MNP, UNEP-WCMC and Witteveen & Bos.

> "*In the context of the environment, the cost of policy inaction is defined as the environmental damage occurring in the absence of additional policy or policy revision. Inaction not only refers to the absence of policies, but it also refers to the failure to correct misguided policies in other areas. The costs of policy inaction may be greater than just the environmental damage, if the same inaction also creates societal and economic problems*"(Call for Tender ENV.G.1/ETU/2007/0044, Brussels; EC, 2007).

The COPI project is part of the European Commission's commitment - as mentioned in the Biodiversity Communication Action Plan (COM(2006)216; EC, 2006) – to *"Strengthen understanding and communication of values of natural capital and of ecosystem services, and the taking into account of these values in the policy framework, expand incentives for people to safeguard biodiversity".* The results of this study will have to feed into the process of the Review on the Economics of Biodiversity Loss, which is being prepared under the aegis of the German Presidency of the EU with a view to being presented to the Convention of Biological Diversity (CBD) COP-meeting to be held in May 2008".

The Biodiversity Communication places "*emphasis on the link between biodiversity loss and the decline of ecosystem services, and the potential impact of this decline on prosperity and well being. Biodiversity provides benefits for society on different levels as many economic valuation studies have demonstrated. These benefits include, inter alia, the value of ecosystem provisioning services, in particular for food and health products, of regulating services, e.g. preventing natural disasters, or preserving the quality of resources, e.g. water; of supporting services, e.g. of nutrient cycling and soil formation, of cultural and leisure services*".

As to spatial delineation of the COPI study, the original text in the Call for Tender states: "The scope of the analysis should not be limited to the EU area, but include EU policies that affect wider regions. Ecosystem services are essential to poverty eradication in developing parts of the world, and the EU also depends for its growth and well-being upon the ecosystem goods and services of third countries". In the first meeting of the Working Group on the "Review of the Economics of Biodiversity Loss", however, this specification was altered by the European Commission with consent of the contractor to "a global assessment" (Minutes of the

1st Working Group (WG) meeting on the Review on the economics of Biodiversity Loss, 21 November 2007, Brussels).

Conceptual frameworks used in the COPI analysis

The COPI evaluation builds on a range of tested tools and frameworks. In particular (see Chapter 2 for a full description and discussion of the COPI methodology):

- A Baseline Scenario is used to provide the pathway of economic and social drivers and associated pressures into the future as it is expected to develop without new policies. For this COPI study, the Baseline scenario of the Organisation for Economic Cooperation and Development (OECD) Outlook to 2030 has been used (OECD, 2008) (see Chapter 3)
- The Driver-Pressure-State-Impact-Response framework has proven a useful tool for characterising the inter-linkages between cause and effect for biodiversity loss (see Chapters 3 and 4)
- The Millennium Ecosystem Assessment (MA, 2005a) has created a useful conceptual framework and political commitment to put the value of biodiversity into decision making. It has been a motor for new information on the value of biodiversity and associated ecosystem services (see Chapter 5).
- The Total Economic Value framework (e.g. CBD, 2007) has been applied to frame the array of economic valuation case studies, collected and analysed as part of this COPI analysis (see Chapter 6).

The political and policy context

The Environment Ministers of the G8 countries as well as of Brazil, China, India, Mexico and South Africa, the European Commissioner responsible for the Environment and senior officials from the United Nations and the IUCN (The World Conservation Union) met in Potsdam in March 2007. The meeting resulted in the announcement of a course of action for the conservation of biological diversity and for climate protection: "*The clear message of this meeting is that we must jointly strengthen our endeavours to curb the massive loss of biological diversity. It was agreed that we must no longer delete nature's database, which holds massive potential for economic and social development*" (BMU-Pressedienst No. 077/07; Berlin, 17.03.2007). The so-called "Potsdam Initiative– Biological Diversity 2010" set in motion specific activities for protection and sustainable use of biodiversity (see **Box P.1**).

Box P.1 A summary of the "Potsdam Initiative – Biological Diversity 2010"

(1) The economic significance of the global loss of biological diversity
We will initiate the process of analysing the global economic benefit of biological diversity, the costs of the loss of biodiversity and the failure to take protective measures versus the costs of effective conservation.

2) Science
We will strengthen the scientific basis for biodiversity and are committed to improve the science-policy interface.

3) Communication, Education and Public Awareness
We will explore the development of a "Global Species Information System".

4) Production and consumption patterns
We will enhance the integration of policies which involve governments, industries, civil society and consumers and implement an effective mix of mechanisms including: Regulatory measures, Market incentives and access, Codes of conduct, Certification, Public Procurement and Environmental Impact Assessments.

5) Illegal Trade in Wildlife
We will strengthen our cooperation to combat illegal activities within the framework of CITES and through effective partnerships between governments, international and non-governmental organizations.

6) Invasive Alien Species
We will enhance our efforts in identifying, preventing and controlling invasive alien species and strengthen our international cooperation e.g. through the development of early warning systems, listing of species and information sharing.

7) Global network of marine protected areas
We will intensify our research and enhance our cooperation regarding the high seas in order to identify those habitats that merit protection and to ensure their protection.

8) Biodiversity and climate change
We will ensure that biodiversity aspects are equally considered in the mitigation of and the adaptation to climate change and the reduction of emissions from deforestation.

9) Financing
We will enhance financing from existing financing instruments and explore the need and the options of additional innovative mechanisms to finance the protection and sustainable use of biological diversity, together with the fight against poverty.

10) Commitment to 2010 and beyond
We acknowledge the urgent need to halt human induced extinction of biodiversity as soon as possible. We will develop and implement national targets and strategies in order to achieve the 2010 target and beyond.

Acknowledgements

We would like to express our gratitude to all the members of the Working Group on the Review of the Economics of Biodiversity Loss, led by chairman Patrick Murphy, head of the Nature and Biodiversity Unit (B2) of DG environment, for assisting us in the COPI study. In particular we like to mention the stimulating guidance and critical comments of Aude Neuville (Nature and Biodiversity Unit; B2) and Stephen White (Sustainable Development and Economic Analysis Unit; G1) of DG Environment, and Hans Vos of the European Environment Agency.

Collegues of the project team members at each of the partner institutions participated in discussions, workshops and read parts of the drafts. Their input is appreciated by all of us. Pauline Ticheler of Alterra took care of the complicated administrative managerial tasks.

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Summary

The COPI project

The cost of policy inaction is defined as: the environmental damage occurring in the absence of additional policy or policy revision. Inaction not only refers to the absence of policies, but also to the failure to correct misguided policies in other areas. The costs of policy inaction may be greater than just the environmental damage, if the same inaction also creates societal and economic problems.

The purpose of estimating the cost of policy inaction (COPI) is *to highlight the need for action*, prior to the development of specific policy instruments. COPI is therefore concerned with problem identification, and with understanding the dynamics of ecosystem change and the associated damage costs in the absence of new or revised policy interventions. In practice, it is useful to present the costs of policy action in qualitative terms, in quantitative terms and monetary terms – all the while understanding what each of these covers, and therefore presenting the results in context.

Note that this COPI analysis assesses losses in biodiversity; it is not trying to assess the value of all biodiversity. As such it is a marginal analysis, looking only at the impacts of change.

The full report is available at
http:///ec.europa.eu/nature/biodiversity/economics/index.en_htm

1. Introduction

Biodiversity is the diversity of species, populations, genes but also communities, and ecosystems. Direct benefits of ecosystems to humans such as food, timber, clean water, protection against floods, and aesthetic pleasures all depend on biodiversity, as does the productivity and stability of natural systems. The majority of ecosystems in the world have been seriously modified by humans.

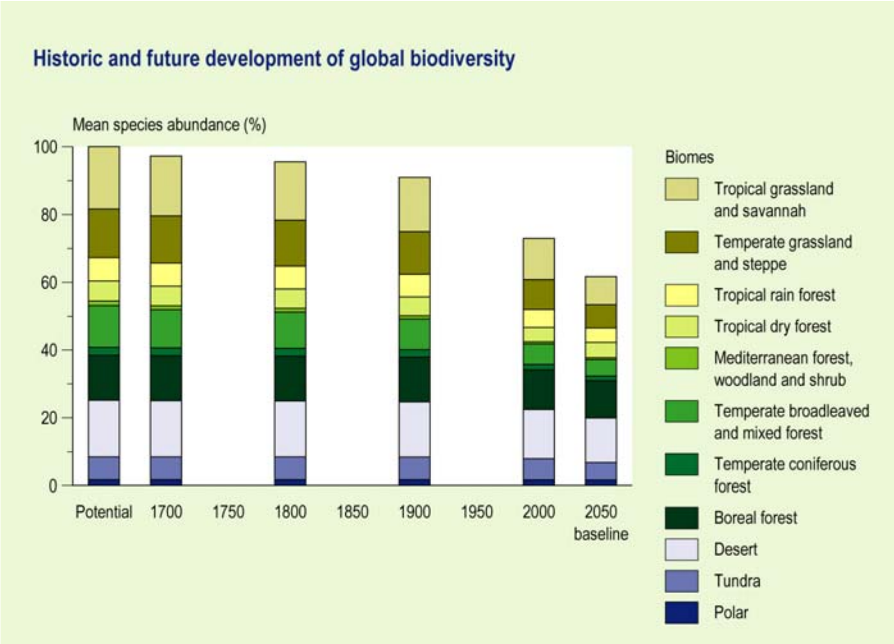


Figure 1 Historic and future development of global biodiversity

2. Overview of the methodology

Before going into the details of the analysis, it is useful to have an overview of the methodology.

Biodiversity loss implies loss of ecosystem goods and services to the human economy, in other words direct and indirect benefits to human well being. These losses of contributions to the economy have for a large part been the consequence of purposefully converting natural systems to food, timber of fuel producing mono-species ecosystems thereby, to some extent unintentionally, causing the loss of other ecosystem services, such as climate regulation, water purification and outdoor recreation. This analysis tries to quantify and then value those changes.

The key parts of the COPI analysis are:

1. **Develop projections of changes in ecosystem services** based on changes in land use, biodiversity and quality factors over the period to 2050.
2. **Development of a database of values** of ecosystem services that can be applied to the changes in ecosystem services.
3. **Apply the values to the changes in ecosystem services** using a spreadsheet model that allows the combination of the ecosystem service values and the land use changes, and the quality factors based on a measure of biodiversity of the land use types.
4. **Complementary analysis of benefits and losses** across other biomes than the land-biomes in the GLOBIO model.

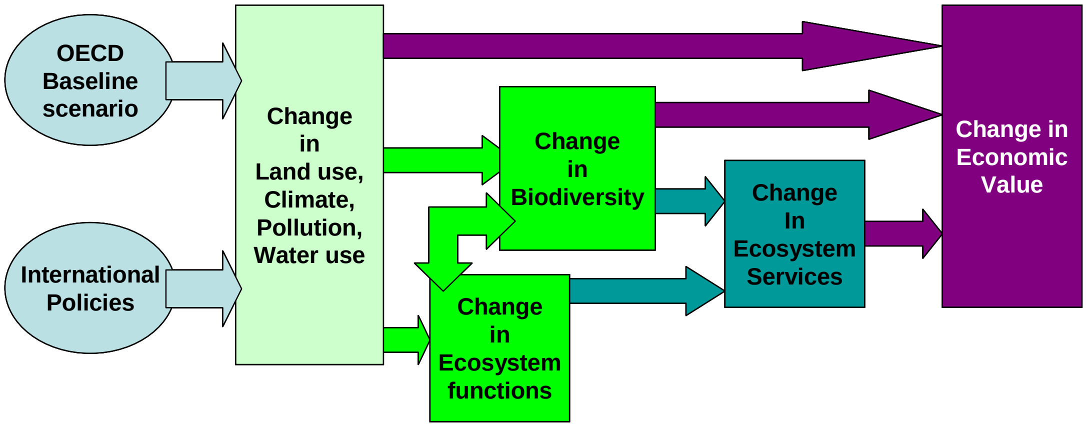


Figure 2 The Conceptual framework of the COPI study

3. What is causing biodiversity loss?

This COPI study used the OECD Environmental Outlook to 2030 as the basis for information about future economic and demographic development. This was then combined with the IMAGE-GLOBIO model to project changes in terrestrial biodiversity to 2050. This is a typical Driver-Pressure-State-Impact framework, so it looked at how the underlying drivers of biodiversity change will put pressure on land use and biodiversity and then produces estimations of biodiversity in the future.

It should be understood that this modeling is peer-reviewed and as robust as is possible. The scenario used is broadly consistent with exercises such as those by the CBD and UNEP.
What follows is a short description of the main underlying drivers.

- **Driver - Population development** - The Baseline uses a so called "medium" population projection of the United Nations, which shows a stabilisation of the world population at around 9.1 billion inhabitants by 2050. World demand for basic needs (food, drinking water, fuel and shelter) based on population increase only, will have increased by about 50%.
- **Driver - Economic development -** The global average growth in real Gross Domestic Product (GDP) is a modest 2.8% per year between 2005 and 2050. China and India grow faster, an average of 5 per cent per year. Although the modelling for the OECD study is more nuanced than assuming a fixed relation between GDP and pressures on biodiversity, the uncertainty in the Baseline leans to the side of more pressures on biodiversity.
- **Driver – Energy Use -** The energy consumption for the OECD Baseline follows more-or-less the 2004 World Energy Outlook scenario of the International Energy Agency,. Final energy consumption increases from 280 EJ in 2000 to ca 600 EJ in 2050.
- **Driver - Food production -** By 2030 global agricultural production will need to increase by more than 50% in order to feed a population more than 25% larger and roughly 80% wealthier than today's. Although it is assumed that productivity

of land will increase substantially, the global agricultural area will have to increase by about 10% to sustain this production, equal to the current agricultural area in the US, Canada and Mexico together. There will be further increases by 2050.

Not all 'drivers' are modeled
An example is invasive alien species. These cause a wide range of ecological and socio-economic impacts including changes in species composition and dynamics, habitat characteristics, provisioning of ecosystem services (e.g. provision of food, water retention and regulation of erosion and forest fires).

Pressure will also continue on marine and coastal ecosystems. With the decline in fish stocks of the last few decades, the lack of success in finding new harvestable stocks, and the ever increasing share of fish of lower levels in the marine food chain, the prospect in the "fisheries for food" situation is poor.

The policy landscape
For "protected area" policies, the implicit assumption is that implementation of current plans will not substantially change current trends. These now cover almost 12% of global land area. However, the biomes represented in that coverage are uneven. The CBD analyses show that full implementation of protected areas will only decrease the biodiversity losses on land by 2-3%-points. Many protected areas are, also, nothing more than 'paper parks'.

For trade in agricultural products the assumption is that there will be no major changes. As to climate change mitigation the Baseline assumes no post-Kyoto regime other than the policies in place and instrumented by 2005. The Baseline further assumes that the EU Common Fisheries Policy and equivalent policies in other world regions, remain in place and continue to be implemented as they are now. The analysis of the current policy landscape indicates clearly that several sector policies still provide substantive incentives to continue and increase short-term economic growth at the expense of long-term environmental sustainability and maintenance of biodiversity.

4. How much biodiversity will we lose?

The biodiversity indicator used in the COPI study is the **Mean Species Abundance (MSA) indicator**. It is similar to the Biodiversity Intactness Index and is a composite of the CBD 2010-indicator 'the abundance and distribution of a selected set of species'.

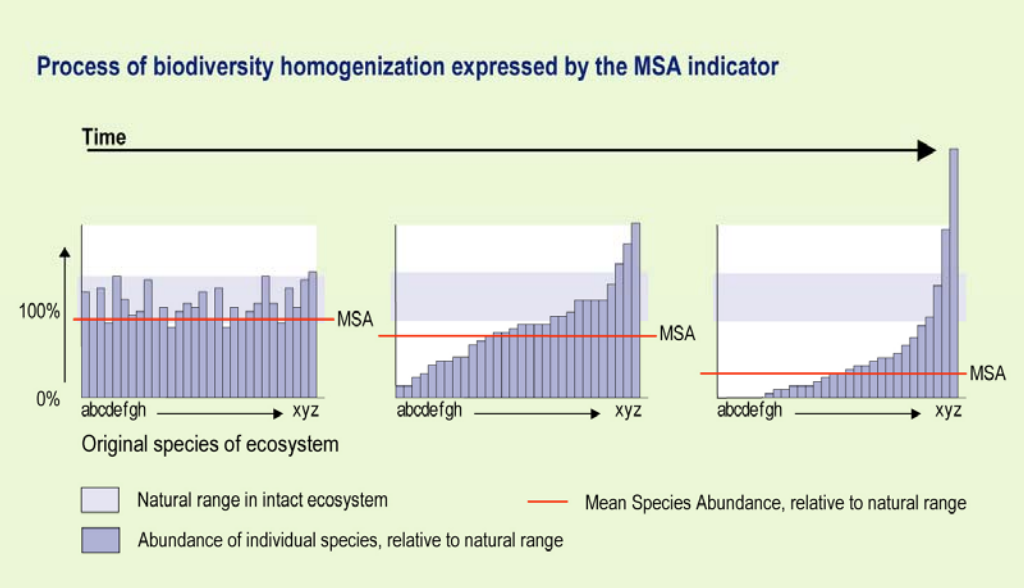


Figure 3 The MSA biodiversity indicator.

Biodiversity loss is characterised by a decrease in abundance of some species and the increase in abundance of a few opportunistic ones. As a result, ecosystem types become more and more alike. Biodiversity loss is therefore calculated as the *mean species abundance of the original species compared to the natural or low-impacted state.* It has the advantage that it measures the key process, is universally applicable, and can be modeled with relative ease.

Global change of terrestrial biodiversity 2000-2050

In 2000, about 73% of the original global biodiversity on land was left. The strongest declines had occurred in the temperate and tropical grasslands and forests. By 2050 an additional 11%-points will have been lost, with losses varying significantly between areas.

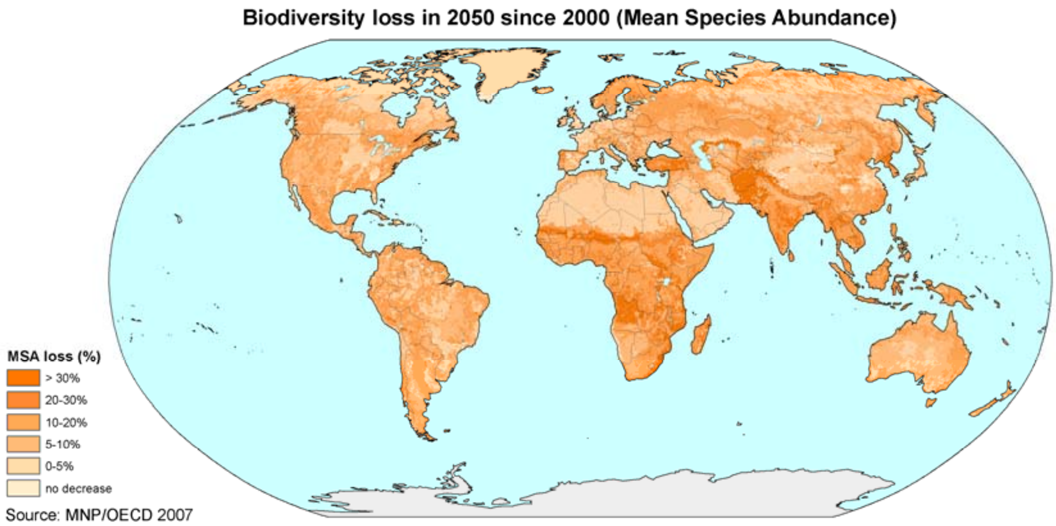


Figure 4 Biodiversity (Mean Species Abundance) loss 2000-2050

The global annual rate of loss increased dramatically in the twentieth century, and especially in Europe, in comparison to previous centuries. The loss rate for Europe in the period 2000-2050 is expected to decrease, while the global average actually increases.

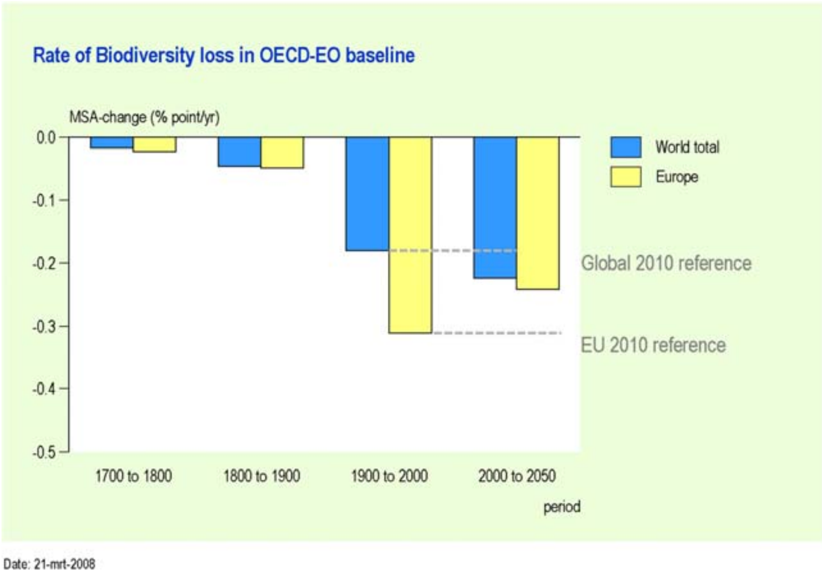


Figure 5 Rate of Biodiversity loss 1700 – 2050

Trends in the marine biome

Fishing pressure in the past century has been such that the biomass of larger high-value fish and those caught incidentally has been reduced considerably. Many commercial fisheries are under considerable pressure.

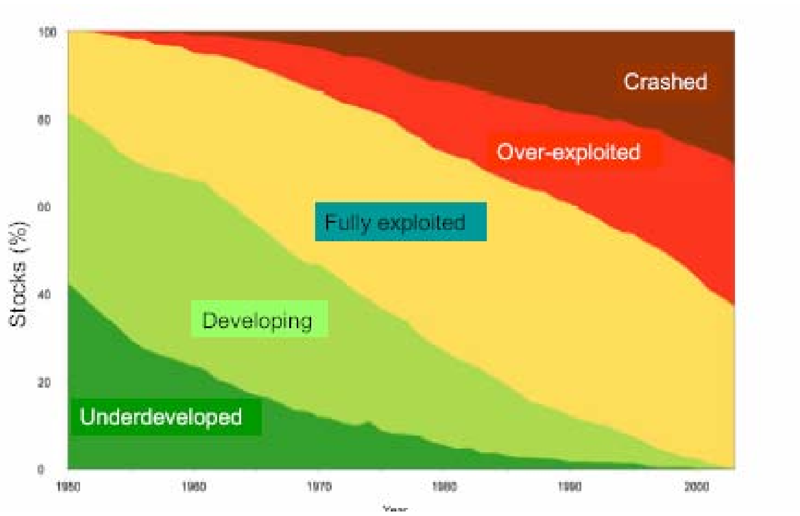


Figure 6 The unsustainability of global marine fisheries 1950- 2000

The scenarios analysed indicate that with current trends or increased effort whether for commercial or recreational fisheries all lead to collapses in stocks and ecosystems; they differed only in their rates of decline. Other related trends include:

- **Coastal ecosystems -** There has been a substantial loss of estuaries and associated wetlands. In the United States, for example, over 50% of original estuarine and wetland areas have been substantially altered.
- **Mangroves** - over the last 25 years, 3.6 million hectares of mangroves, about 20 percent of the total extent found in 1980, have disappeared worldwide.
- **Coral reefs** - it is estimated that around 20% of reefs have been destroyed and at least another 20% badly degraded or under imminent risk of collapse.

5. Changes in ecosystem services

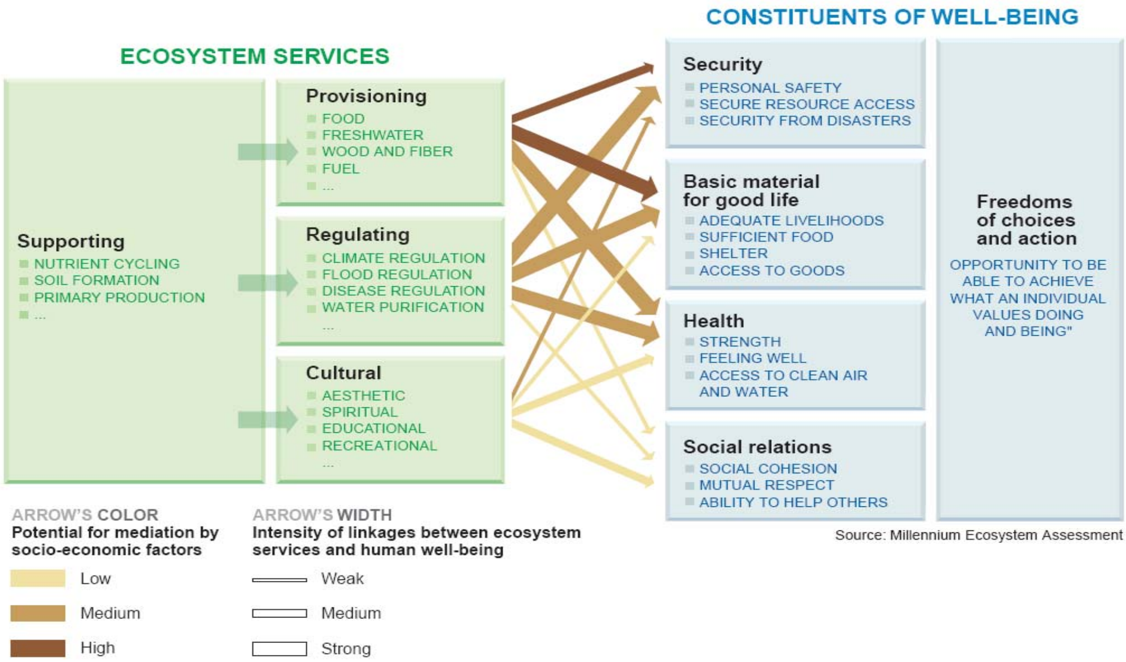


Figure 7 Ecosystem services – Well being relationships (Millennium Ecosystem Assessment)

Conversions of natural ecosystems to other forms of land use, such as cropland, pasture land or urban land alter the total flow of Ecosystem Services. Different Ecosystem Services are often in competition between each other. Unfortunately, choices about conversion and these trade-offs are often the wrong choices, at least from a social (or economic) point-of-view.

- The changes often bring short-term economic benefits at the expense of longer-term costs.
- Many ecosystem services are not fully understood, there is a lack of information so they are ignored
- Sometimes choices are made to the benefit of a restricted number of individuals, and at the expense of wider communities.

To produce food, timber and fuel, pristine ecosystems are often converted to single purpose land uses with great loss of biodiversity and risk of total degradation. Figure 8 illustrates the relationships between different ecosystems.

- In diagram 1, the service levels in a natural ecosystem are depicted to be in some kind of balance, fitting the capability of the particular ecosystem.
- In diagram 2, the system has been converted to extensive use for *food* production, thereby decreasing the potential and actual service levels of the other provisioning (energy, freshwater), regulating (climate) and supporting services (soil protection).
- In diagram 3, representing an intensive food production system, the other services have been reduced to very low levels.

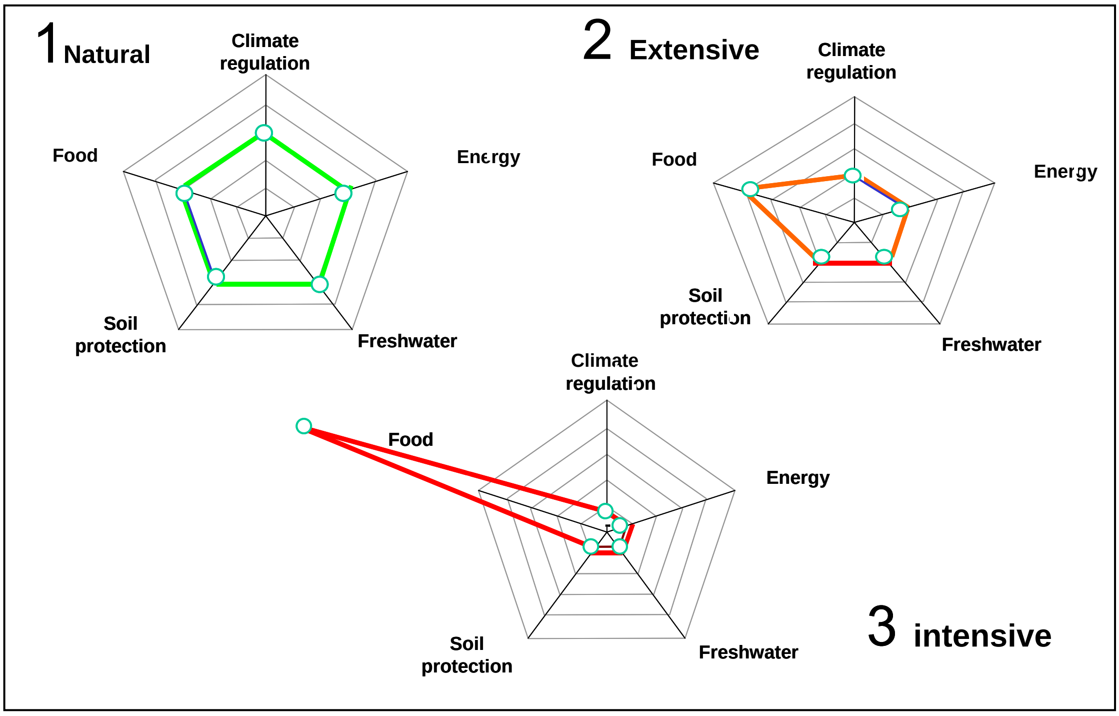


Figure 8 The loss of services in conversion of natural systems to food production systems degradation in forest and grassland biomes.

From an economic view-point, it is these ecosystem services that are of value and not biodiversity itself *per se.* A key step in the COPI analysis was to build a set of simplified functional relationships that translate future changes in biodiversity into changes in ecosystem services (Figure 9).

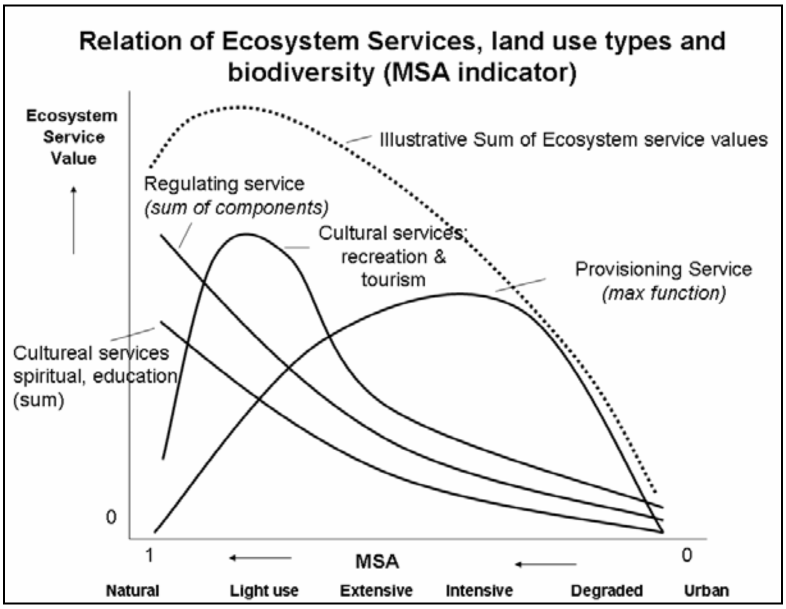


Figure 9 The generalized relationships between land use / biodiversity and ecosystem services.

- **Provisioning services (P)**: There is no provisioning service, by definition, in a pristine ecosystem. With increasing intensity of use and conversion of the structure, species composition and thus functioning of the original natural area (MSA, mean species abundance) decreases (from 1 to 0) and the benefit flow (EV, ecosystem service value) increases. Adding labor, fertiliser, irrigation, pest control etc. will raise the gross benefits, and possibly the net.
- **Regulating services (R):** Regulating services are complex processes at the ecosystem level. As ecosystems are converted, their regulating service capability drops more or less proportionally with the decrease of MSA along the range of land use types.
- **Cultural – recreation services (Cr):** A crucial feature in the valuation of the recreational services of ecosystems is accessibility. The service value therefore increases from low value at pristine systems to high values in accessible light use systems and subsequent drops to low values for degraded systems.
- **Cultural – Information services (Ci):** Most of the other cultural ecosystem services and their values are a function of the information content which is generally decreases with the degree of conversion.

Of course, there is uncertainty over these relationships – which may vary considerably from area to area as well.

One issue they make clear is that it is essential to take account of the **net change in services**, as some benefits may increase while others get lost. Increasing one particular local service with private benefits generally leads to losses of the regional or global services with public benefits. It is also essential to assess the **net benefits of changes**, as many human interventions require additional energy or other inputs.

Social and economic consequences of changes in ecosystem services

It is estimated that 1 billion people worldwide are dependent on fish as their sole or main source of animal protein, while fish provided more than 2.6 billion people with at least 20 percent of their average per capita animal protein intake. The expected decline of ocean fisheries will therefore have severe social consequences. Similarly, water scarcity is a globally significant and accelerating condition for 1–2 billion people worldwide, leading to problems with food production, human health, and economic development.

6. The Cost of Policy Inaction – in Monetary terms

Box 1: COPI values: Welfare, GDP and interpreting the numbers

It is important for understanding the COPI assessment, to appreciate that the COPI costs are actually a mixture of cost types – some are actual costs, some are income foregone (e.g. lost food production); some are stated welfare costs (e.g. building on willingness to pay (WTP) estimation approaches). Some directly translate into money terms that would filter directly into GDP (gross domestic product); some would have an effect indirectly, and others would not be picked up by GDP statistics. The combined COPI costs should be seen as welfare costs, and for the sake of ease of comparison are given as % of GDP.

COPI Core Step 1: Data for land-use change over the period 2000 to 2050.

The underlying values within the GLOBIO work were used; these combine two elements - change in land-use (see *table 2*) and a loss of quality of the land due to climate change, pollution, fragmentation – which is represented by the mean species abundance (MSA) index used in the model. Both elements form a basis for the monetary evaluation.

Table 1 Total Area by Land-use; Global total aggregated across all biomes

Actual	2000	2050	Difference
Area	**Million km^2**	**million km^2**	**2000 to 2050**
Natural areas	**65.5**	**58.0**	**-11%**
Bare natural	**3.3**	**3.0**	**-9%**
Forest managed	**4.2**	**7.0**	**70%**
Extensive agriculture	**5.0**	**3.0**	**-39%**
Intensive agriculture	**11.0**	**15.8**	**44%**
Woody biofuels	**0.1**	**0.5**	**626%**
Cultivated grazing	**19.1**	**20.8**	**9%**
Artificial surfaces	**0.2**	**0.2**	**0%**
World Total *	**108.4**	**108.4**	**0%**

Core Step 2: Develop and populate a matrix of ecosystem service values across land-uses for each biome (and for each region)

There are different levels of information for different regions, different biomes, different ecosystem service types and also for different value types. To populate the matrix entailed:

- Do a literature review of ecosystem service values,
- Develop representative values from the data available,

- Own analysis to develop ecosystem service values – carried out for forestry biomes by the COPI Team,
- Gap Filling, to address gaps in ecosystem service values by land uses, biomes, geography and into the future.

Core Step 3: Gap filling for ecosystem services values within a biome – across landuse types:
The data from the literature did not give enough detail on different values for different land used within a given biome. A range of approaches were used by the COPI team to fill these gaps. The first significant gap filling was carried out to develop values for different land use types within a given biome. In general, the evaluation literature provided a value for ecosystem services for a given landuse type within a biome (usually for natural areas that were being studied). If only these were to be applied, then there would be too many gaps to derive a total value for the change in landuse.

Core Step 4: Gap filling for ecosystem services across biomes:
The available data from the literature also leads to some gaps in Ecosystem Service values for some biomes. In some cases it is clear that there are services and that these are broadly similar between biomes. Where a broad relationship was established, the values from one biome were transferred to another.

Core Step 5: Applying "conventional" benefits transfer:
A "conventional" benefits transfer approach was applied to address the gaps in Ecosystem Service coverage for geographic regions, and across time. For transferring values across regions, GDP (in purchasing price parity (PPP) terms)/capita ratios between countries was used if common global values were not available.

Core Step 6: Extrapolation of "today's" ecosystem service values into the future.
Extrapolation into the future from current numbers is by its nature risky and imprecise. World population growth, income level growth, change in societal preferences, and increased competition for decling natural resources will all affect value. Hence assumptions are needed to attempt to take these into account..

Core Step 7: COPI Analysis: Combine the land use changes with the values for ecosystem services under each land use for each region to derive values for the change in ecosystem services.
There will be a shift from the Ecosystem Service from natural areas and forests to Ecosystem Service from intensive agriculture and plantations, and hence a trade-off between the different provision of services. The resulting net changes in value are calculated, but there are of course gaps that need to be understood.

Core Step 8: Ecosystem services are also lost where there are reductions in the quality of the land.
As an ecosystem is degraded generally this leads to a loss of ecosystem services. To capture these losses, the land-use and coverage in the final year of the analysis (2050)

is taken (million hectares) and multiplied by the value of the services in that year (as per earlier analysis and method steps) and then multiplied by the loss of MSA index between 2000 and 2050 for the land use.

Results: analysis of land-use change

Two estimates are produced - a **partial estimate** and a **fuller estimate**. The main difference is that there are more gaps in the partial estimate but more certainty about the numbers in it. Even under the fuller estimate there are still many gaps.
Currently, we **lose biodiversity each year that would have produced Ecosystem Services worth around 50 billion Euros per year, in every subsequent year**. These losses mount. Taking 2000 as the baseline (or point for comparison), within a year losses will be around 50 billion Euros. Within two years, they will be around 100 billion Euros. Within three years, around 150 billion Euros. **By 2010, the loss 'grows to' 545 billion EUR in that year** compared to 2000, for the land based ecosystems alone. Th**is is just under 1% of world GDP in 2010**.
This continues to increase until by 2050, the opportunity cost from not having preserved biodiversity since 2000, is a loss in the value of flow of services of $14 trillion (thousand billion) a year (see *table 3*). The opportunity costs will continue to rise beyond that as long as biodiversity and ecosystem losses are not halted. Even if halted, the losses would continue long into the future.

The cumulative losses will be equivalent to around 7% of global consumption by 2050. This is a conservative estimate for three main reasons: 1) it is only partial, as not all ecosystem services are valued - significant ecosystem losses from coral reefs, fisheries, wetlands, and invasive aliens are not included 2) the estimates for the rate of land use change and biodiversity loss are fairly conservative 3) values do not account for non-linearities and threshold effects.

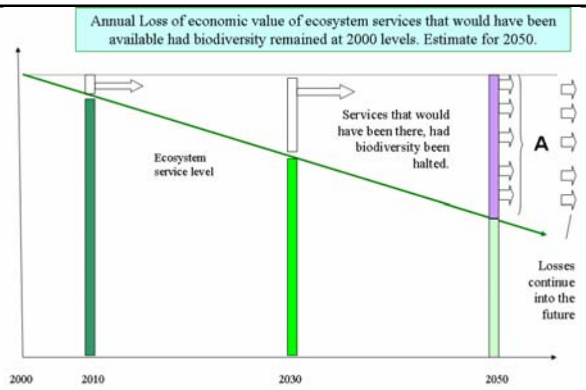
Overall, the analysis suggests that without halting biodiversity loss, the world in 2050 shall benefit much less from the flow of ecosystem services than in 2000.

Table 2 Annual Loss in 2050: The value of ecosystem services that would have benefitted mankind had biodiversity not been lost & remained at 2000 & 2010 levels.

	Value of Ecosystem service losses - Annual Billion (10^9) EUR lost							
	Fuller Estimation		**Partial Estimation**		**Fuller Estimation**		**Partial Estimation**	
	Relative to 2000	**Relative to 2010**	**Relative to 2000**	**Relative to 2010**	**Relative to 2000**	**Relative to 2010**	**Relative to 2000**	**Relative to 2010**
Area	**Billion EUR**	**Billion EUR**	**Billion EUR**	**Billion EUR**	**% GDP in 2050**	**% GDP in 2050**	**% GDP in 2050**	**% GDP in 2050**
Natural areas	-15568	-12703	-2119	-1679	-7.96%	-6.50%	-1.08%	-0.86%
Bare natural	-10	-6	-2	-1	-0.01%	0.00%	0.00%	0.00%
Forest managed	1852	1691	258	213	0.95%	0.87%	0.13%	0.12%
Extensive Agriculture	-1109	-819	-206	-141	-0.57%	-0.42%	-0.11%	-0.08%
Intensive Agriculture	1303	736	307	143	0.67%	0.38%	0.16%	0.09%
Woody biofuels	381	348	55	50	0.19%	0.18%	0.03%	0.03%
Cultivated grazing	-786	-1181	-184	-215	-0.40%	-0.60%	-0.09%	-0.13%
Artificial surfaces	0	0	0	0	0.00%	0.00%	0.00%	0.00%
World Total (Land-based ecosystems*)	-13938	-11933	-1891	-1518	-7.1%	-6.1%	-1.0%	-0.8%

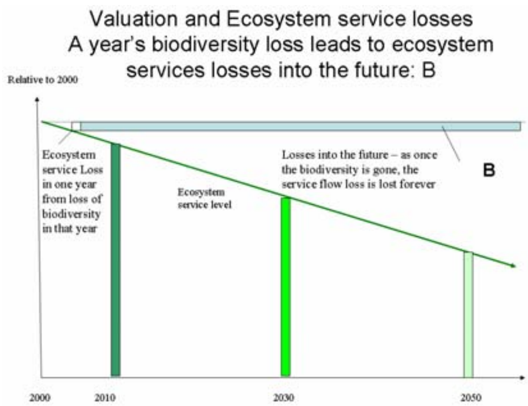
Overall, the analysis suggests that without halting biodiversity loss, the world in 2050 shall benefit much less from the flow of ecosystem services than in 2000.

Box 2: Different ways of presenting the scale of the COPI of biodiversity loss – example for the forestry biomes.



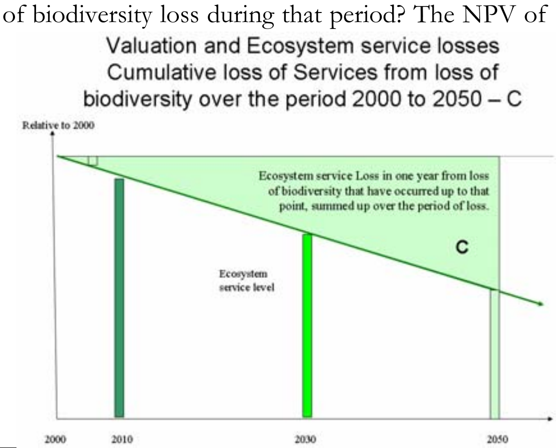
There are several ways of representing the losses for ecosystem services over a time period, with each different approach responding to different audience's perspectives. The COPI approach focused primarily on the estimation of the cumulative losses of biodiversity, by looking at the value of the loss in a given year, here 2050. This is an indication of the scale of the benefits from biodiversity that our children or grandchildren would not appreciate due to the loss of biodiversity due to the current generation's inaction. The schematic for this value is presented below - A.

There are, however, other ways of presenting the value. In the financial sector there is a preference for looking at the capitalized value of the future loss of services due to loss of ecosystems and biodiversity. This is the "net present value" (NPV) of the future stream of loss of value from one year's loss of natural capital. As the loss of biodiversity and hence ecosystem services continues into the future, the losses add up, and this can be presented by the aggregated loss. The schematics for theses values are presented below – B and C. For the latter two, to derive associated NPVs requires the application of a "discount rate". Here two illustrative values are used – a 4% real and a 1% real discount rate.



What is the value over the next 50 years of a year's biodiversity loss today? Using a 4% discount rate the NPV of the loss of ecosystem services from forest biomes is around 1.35 trillion (10^12) EUR (the fuller estimate). With a 1% discount rate the NPV is significantly higher at 3.1 trillion (10^12) EUR.

What is the cumulative value between 2000 and 2050 of biodiversity loss during that period? The NPV of the cumulative losses is 33.3 trillion EUR with a 4% discount rate and 95.1 trillion EUR with a 1% discount rate.



These are several messages. First whichever way the cost of not halting biodiversity loss is presented, the numbers are large and underline the need for urgent action. Secondly, the choice of discount rate plays an important role in the perception of value in the present. The COPI study has sought to use the loss in a 2050 to communicate the level and importance of the loss and avoid any discounting trap.

Losses across regions

While the welfare losses presented as an average of global GDP is 7%, the welfare losses due to ecosystem and biodiversity losses in the regions range from very small to 17% in Africa, 23 to 24% in Brazil, other Latin America & Caribbean and Russia, and highest in Australia/New Zealand. A significant share of the losses is due to loss of the value of carbon storage, and hence a global loss rather than one felt directly by the local populations. Water regulation, air pollution regulation, cultural values and tourism losses, however, do affect national populations.

Losses across biomes

The greatest losses are from the tropical forest biomes. The next greatest total losses are from other forest biomes. In fact, the information was best for the forest biomes with least benefits transfer needed. The losses of Ecosystem Services from for the 6 forest biomes together are equivalent to 1.3 trillion (10^12) EUR (partial estimation) and 10.8 trillion (10^12) EUR (fuller estimation) in 2050 from the loss over the period 2000 to 2050. These numbers have been calculated using values for 8 ecosystem services. When compared to the projected GDP for 2050, these values equate to 0.7% of GDP for the partial estimate, and 5.5% of GDP for the fuller estimate.

For a range of biomes there have been no estimations – particularly in the partial estimation scenario, though also in the fuller estimation scenario. These gaps underline that the numbers should be seen as underestimates.

Losses and gains per ecosystem service type

Climate regulation, soil quality maintenance and air quality maintenance are the main items. Food, fiber and fuel are generally positive, with losses stemming from natural areas and extensive agriculture as these are (generally) converted to intensive agriculture. Other ecosystem services are not presented in the table here (eg bio-prospecting), usually reflecting limits of data availability rather than any certainty over their magnitude.

Table 3 Total Annual loss of value of various ecosystem Services in 2050 (relative to 2000)

2050 relative to 2000: Fuller Estimation	Total	Food, fiber, fuel	Air quality maintenance	Soil quality maintenance	Climate regulation (i.e. carbon storage)	Water regulation, & water purification and waste management	Cultural diversity, identity, heritage & Recreation & ecotourism
World Total (Land-based ecosystems*)	-13938	192	-2019	-1856	-9093	-782	-303
Natural areas	-15568	-383	-2025	-1778	-10274	-748	-291
Bare natural	-10	0	-1	-1	-6	0	-2
Forest managed	1852	184	208	166	1188	70	31
Extensive Agriculture	-1109	-256	-56	-50	-712	-23	-8
Intensive Agriculture	1303	746	38	41	448	21	6
Woody biofuels	381	29	33	30	270	15	2
Cultivated grazing	-786	-128	-217	-264	-6	-116	-41
Artificial surfaces	0	0	0	0	0	0	0

* (Exl Ice / Hot Desert)

The importance of change in quality of the ecosystems and ecosystem services

It is also useful to look at the relative contribution of a) land-use area change and b) ecological quality changes to the total monetary losses. At a *net level*, the loss for land-use change is smaller than that due to the quality change, given the increases in provision from the managed forest, intensive agriculture, and woody biofuels.

Feedback effect

Furthermore, the stepwise analysis (scenario drivers-> pressures-changes) does not allow a feedback of the economic impact results back into the OECD economic model, and hence losses to the economy related to ecosystem service losses from biodiversity losses do not link back to the OECD economic projections. A fuller analysis would allow a feedback to take into account changes in inputs to the economy from loss of ecosystem service outputs, and change on manmade inputs to compensate for the loss (Eg growth in water purification, desalination). This will change the overall numbers, but probably not the high level messages.

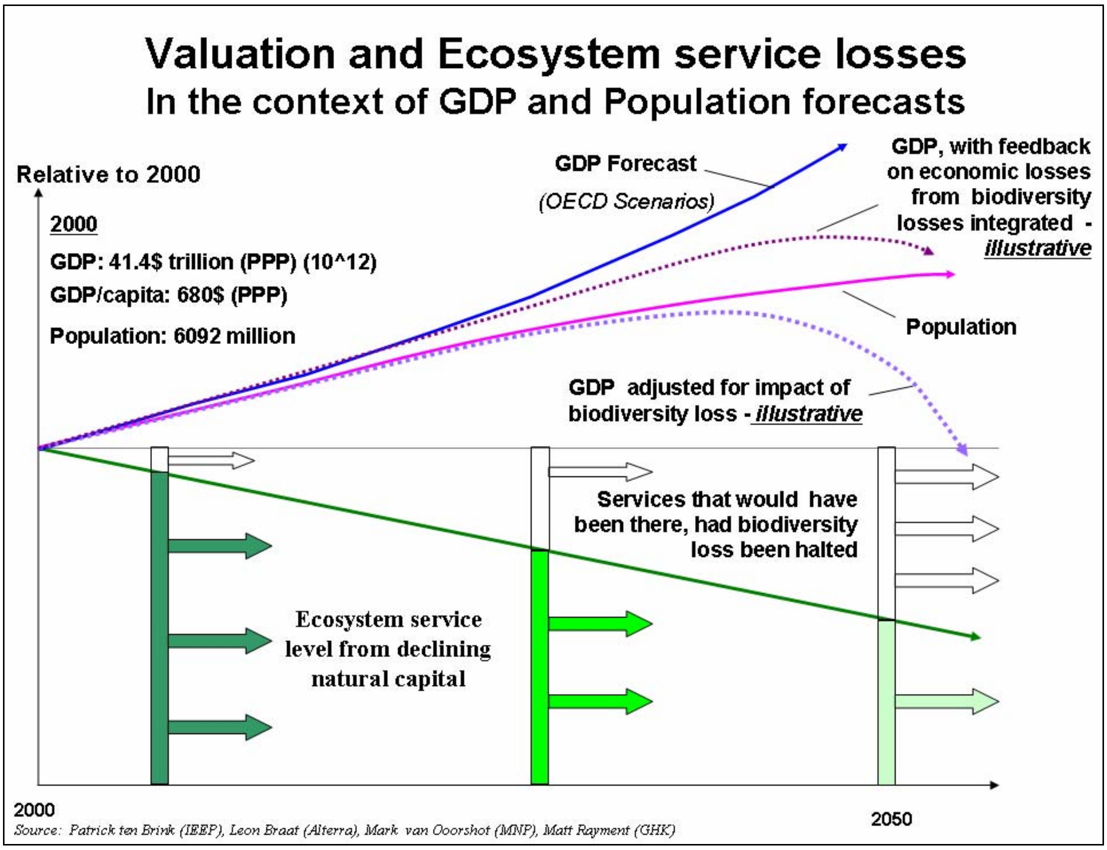


Figure 10 Economic projections, ecosystem service losses and economic consequences.

Other values of ecosystem and biodiversity loss outside the modeling

The modeling above has only covered land based changes, and not even all of those. Other issues could be significant and worth reporting to show the real value of changes beyond the modeled impacts. All of these ecosystems are deteriorating at the global level.

- **Coral reefs*:*** A recent review by the French Government found that different studies have estimated the value of coastal protection at $55 to $260,000/ha/yr; biodiversity and existence values at $12 to $46,000/ha/yr; recreation and tourism at $45 to $10,320/ha/yr; fishing at $120 to $360/ha/yr; and total economic value at $1,000 to $893,000/ha/yr.
- **Wetlands:** For Europe, an estimate for the total annual flow of ecosystem services for wetlands is 6 billion (10^9) EUR/year. The Zambezi Basin wetlands provide over *$70 million* in livestock grazing, almost *$80 million* in fish production, and *$50 million* in flood plain agriculture. Carbon sequestration is also a significant value.
- **Watershed protection:** The value of the watershed protection that is provided by intact coastal ecosystems, such as mangroves and other wetlands, has been estimated at $845/ha/year in Malaysia and $1,022/ha/year in Hawaii, USA

- For **recreation and the economic impact of tourist activities**, values can be very large. For example, the economic impact of forest recreation in national forests in the USA, was valued $6.8 billion in 1993 and 139,000 jobs in 1996. The wider contribution to GDP was estimated at $110 billion/year. Total economic value of fishing in national forests: $1.3-2.1 billion in 1996.
- **Pollination:** The value of bee pollination for coffee production worthies estimated at US$361/ha/year, although the benefits were only felt by producers located within 1km of natural forests.
- **Invasive alien species -** the zebra mussel has caused damage to US and European over the period 1988-2000 of between $750 million and $1 billion
- For the ecosystem service "**biochemicals, natural medicines and pharmaceuticals**", found in tropical forests, the values for bioprospecting have been estimated at $1/ha to $265/ha, including locations with the highest biodiversity.
- For **provisioning services**, marine capture fisheries have an estimated value of $84,900 million, with an estimated 38 million people employed directly by fishing, and many more in the processing stages.

7. Conclusions and recommendations

The study has shown that the problem of the economic and social consequences of biodiversity loss is potentially severe and economically significant, but that significant gaps remain in our knowledge, both ecologically and economically, about the impacts of future biodiversity loss.

- The world is expected to have lost Ecosystem Services worth around 1% of world GDP in 2010 due to biodiversity loss between 2000 and 2010
- The world is expected to have lost Ecosystem Services worth around 7% of world GDP in 2050 due to biodiversity loss between 2000 and 2050

These values relate only to land-based ecosystem changes, and not even all of those. As such, they are probably an underestimate.

Further work is needed, which can usefully build on the insights gleaned in this first scoping valuation exercise. Indeed, this COPI analysis was aimed not just at calculating illustrative numbers, but also at creating and testing a methodology for future evaluations.

Policy recommendations

The existence, use and improvement of valuation information can be valuable for policy making and policy tools in a number of areas. Valuation can help:

- in providing information on the benefits of ecosystems and biodiversity, and underpin payments for environmental services (PES) and benefits sharing.
- in providing information on the costs of losses of ecosystems and biodiversity, to strengthen liability rules, compensation requirements and evaluation of subsidies.

- decision-making at the local, regional and national levels can be improved for planning, investment allocations and prioritisation.

Research recommendations

Areas for further study are:

- to widen the range of models and scenarios so as to assess the value of ecosystem and biodiversity across all the main biomes and services.
- fill in data gaps on ecosystem service values – notably for regulatory functions, and other areas where values are non market.
- values of different land use types within different biomes.
- better understanding of the production functions of the different services and clarify which elements are due to the contribution of natural ecosystems rather than "man-made" inputs such as fertiliser, pesticides, machinery and labour.
- better understanding the relationship between area loss and ecosystem service provision changes.
- further understanding of ecosystem resilience (not just to changes in area, but also to other pressures) and critical thresholds and how these could usefully be addressed in evaluation and in policy making.
- the issue of substitutability of services and its limits and ethical issues
- further work on clarifying how other tools, such as risk assessment tools can complement the valuation tool.

1 Introduction

Leon Braat & *Patrick ten Brink*

Summary

Biodiversity is both a factor in and an indicator of the health of all ecosystem processes. The majority of ecosystems across the globe have been greatly modified by humans. The evidence suggests that many wildlife populations are declining as a result of human activities. The result will be a more homogenized biosphere with lower diversity at regional and global scales. These changes in biodiversity have already important implications for the functioning of ecosystems and services to human society. The Costs of Policy Inaction (COPI) study aims to highlight the need for action, prior to the specific development and appraisal of policy instruments. A COPI assessment is therefore concerned with problem identification and with understanding the dynamics of ecosystem change and the associated damage costs in the absence of new or revised policy interventions. The main objective of the study is therefore to illustrate the impact of not meeting the 2010 biodiversity target globally in several different terms to ensure a full picture – which includes qualitative, quantitative and monetary impacts.

1.1 The urgency of addressing the loss of biodiversity

Biodiversity is the diversity of species, populations, genes but also communities, and ecosystems. It is both a factor in and an indicator of the health of all ecosystem processes. These processes form the environment on which organisms, including people, depend. Direct benefits of ecosystems to humans such as food, timber, clean water , protection against floods, and aesthetic pleasures all depend on biodiversity, as does the productivity and stability of natural systems.

The decrease of biodiversity over the last few centuries is shown in *figure 1.1*. The measure of biodiversity used is Mean Species Abundance (MSA) which reflects the result of the total of pressures, of human origin and others (see Chapter 4 for details). Measuring change in the abundance of species populations is important for understanding the link between biodiversity and ecosystem function, as changes in populations can have important implications for the functioning of ecosystems long before any species actually goes extinct.

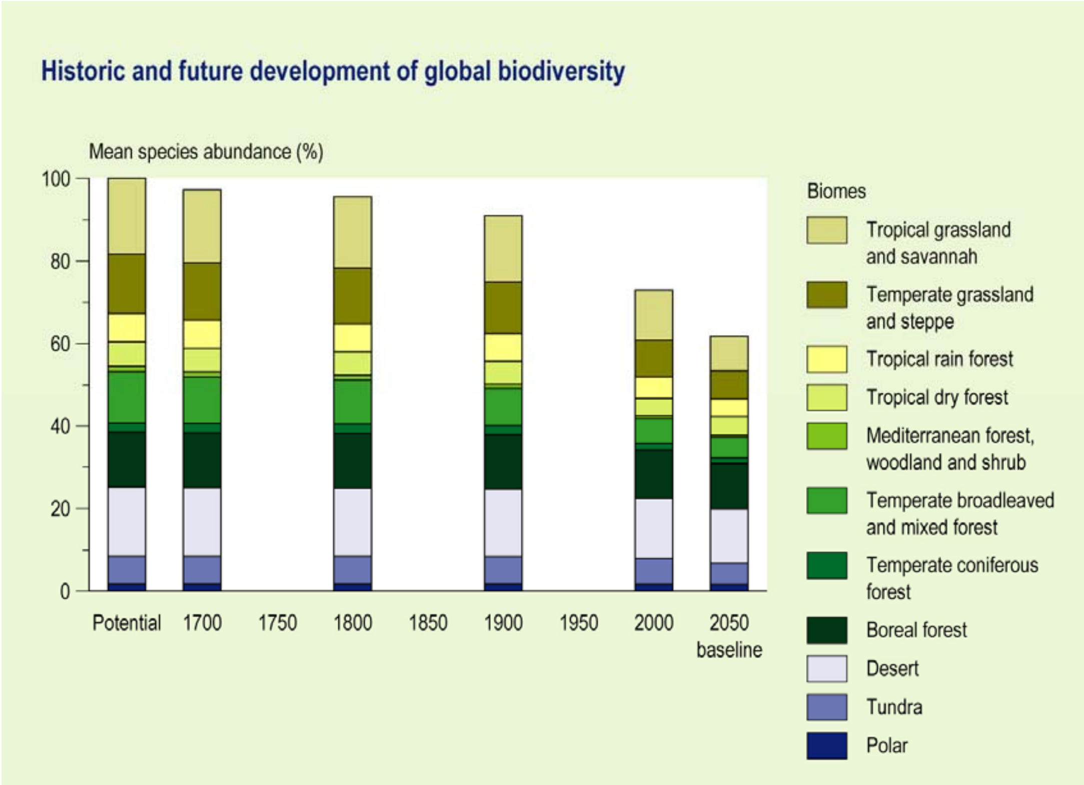


Figure 1.1 Historical and future development of world biodiversity

The majority of biomes have been seriously modified by humans. By 2000, between 20% and 50% of 9 of the 14 terrestrial biomes had been transformed to croplands. Tropical dry forests have been reduced most by cultivation, with almost half of the biome's native habitats replaced with cultivated lands. Temperate grasslands, temperate broadleaf forests, and Mediterranean forests have experienced 35% or more conversion. Biomes that have so far been least reduced by cultivation include deserts, boreal forests, and tundra. While cultivated lands provide many provisioning services, such as grains, fruits, and meat, habitat conversion to agriculture typically leads to reductions in native biodiversity.

A similar picture has unfolded across the marine and coastal systems on the globe. With the onset of industrial fisheries, stocks of commercially interesting fish and other marine species and the area and structure of coastal systems such as mangroves and estuaries have declined. Overall, the emerging evidence suggests that, for larger organisms, especially those with small areas of distribution, most populations are declining as a result of human activities and are being replaced by individuals from a much smaller number of expanding species that thrive in human-altered environments. The result will be a more homogenized biosphere with lower diversity at regional and global scales.

The 2010 Biodiversity policy target, as agreed at WSSD (World Summit on Sustainable Development) in 2002 and adopted by the parties to the Convention on Biological Diversity, is an important goal for biodiversity management. The global target is to "*significantly reduce the rate of loss of biodiversity by 2010*". However, now, in

April 2008, we consider it already too late to reverse the near-term trends in biodiversity loss, and achieve this goal by 2010, given the lag times in ecosystem responses. Until a measure of control is achieved on the critical drivers, most declines seem likely to continue at the same or increased rates, although there is evidence that biodiversity loss is slowing or even recovering for some habitats (such as temperate woodlands) and species (birds in the temperate biomes, for example). Some of this positive news can be attributed to the effect of conservation policies.

A large proportion of the world's terrestrial species richness is concentrated in a small area of the world, mostly in the tropics. Regions of high species richness broadly correspond with centres of evolutionary diversity, and tropical moist forests are especially important for both overall variability and unique evolutionary history. Homogenization, the process whereby species assemblages become increasingly dominated by a small number of widespread, human-adapted species, represents further losses in biodiversity that are often missed when only considering changes in absolute numbers of species. The many species that are declining as a result of human activities tend to be replaced by a much smaller number of expanding species that thrive in human altered environments.

Over the past few centuries humans may have increased the species extinction rate by as much as three orders of magnitude. The available information, based on recorded extinctions of known species over the past 100 years, indicates extinction rates are at least 100 times if not 1000 times (MA, 2005) greater than rates characteristic of species in the fossil record. Up to about 50% of species within well-studied higher taxa, such as birds and mammals, are threatened with extinction. This is particularly relevant to humans as for many ecosystem services, local population extinctions are more significant than global extinctions, as many human communities still depend for their wellbeing on populations of species that are accessible to them.

The main causes of species extinction vary geographically and between species groups, and whilst introductions of new species to old habitats and overexploitation have always been major threats, habitat loss and degradation are currently the most significant. Climate change is becoming an important pressure. Recent empirical evidence, logical extrapolation of trends and scenario studies suggest that climate change will unavoidably lead to further population losses. Studies of amphibians globally, African mammals, birds in intensively managed agricultural lands, British butterflies, Caribbean corals, water birds, and fish species show the majority of species to be declining in range or number. Those species that are increasing have benefited from management interventions such as protection in reserves or elimination of threats such as overexploitation or are species that tend to thrive in human-dominated landscapes (*adapted from MA, 2005b*).

1.2 The economics of biodiversity loss

As a reference for the discussion in this report, the essential dynamics of a typical regional ecological-economic system are captured in *figure 1.2*. The "Natural

Ecosystem" (with associated biodiversity "B") is shown to provide an array of ecosystem services, some to the "Agricultural ecological-economic system", some to the consumers in the "Urban/Industrial system" and some exported (incorporating human services as well). Payments (€) for these services do, of course, not go to the ecosystems but to the production, harvesting and trade sectors of the Agricultural and Urban systems, respectively. Since the industrial age, an increasing part of the economic dynamics has become determined by the "Imported goods and services, including fuels," and trade, and *consequently the direct dependency of the agricultural and urban prosperity on local and regional ecosystems decreased!*

Psychologically, this has led to estrangement of the regional population from their local resource base, with decreasing care for management and for sustainability of use. However, in reality, the local systems still provide a real value to both the local and the global economy through various types of services. In the second half of the 20th century, globalization, world trade discussions and increasing worries about the quality of environmental conditions in developing countries, which export their raw materials, have led to re-evaluation of the role of ecosystem services in regional economies.

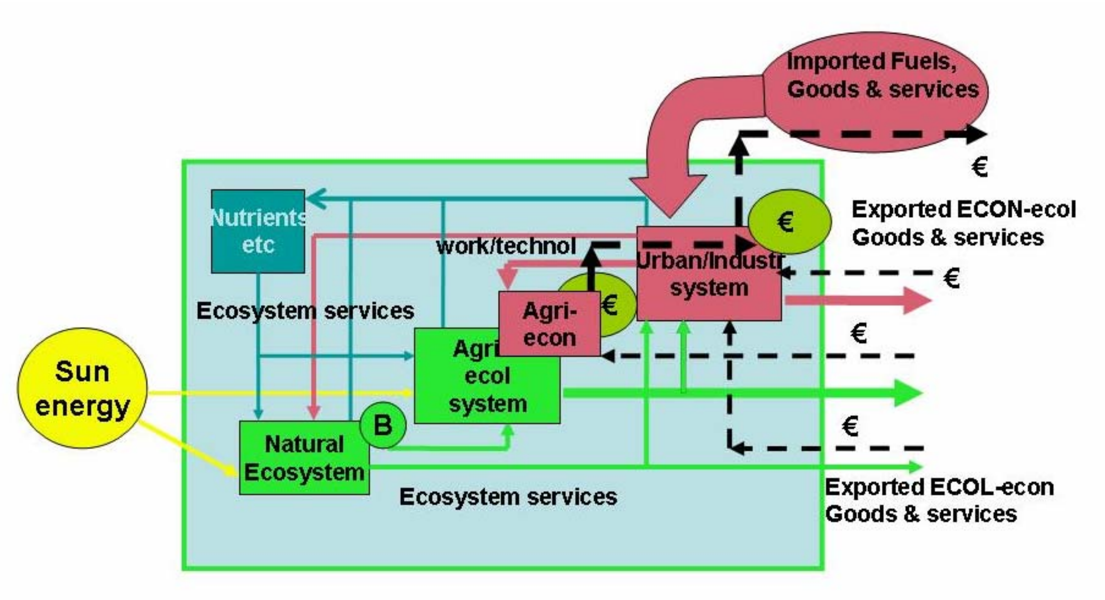


Figure 1.2 The generalised ecological – economic system (Braat, in prep.).

The diagram indicates the various types of ecosystem services, as distinguished by the Millennium Ecosystem Assessment (MA, 2005a). The green boxes and arrows represent the direct and indirect contributions by the bio-geo-chemical processes in ecological systems (both natural and man-influenced agricultural), called provisioning services when actual food, fiber or clean water is delivered to human systems and called supporting services when referring to the work done within the ecosystems which makes deliveries possible. The blue box and arrows represent the so called regulating services, where ecosystems by means of their structure and processes absorb, neutralise and recycle waste products of human systems, as well as locally excessive natural energy flows, such as floods and fires (see Chapter 5).

1.3 The position of the COPI project in the policy life-cycle

The position of COPI in the so-called policy life-cycle is shown in *figure 1.3* (Bakkes et al., 2006)

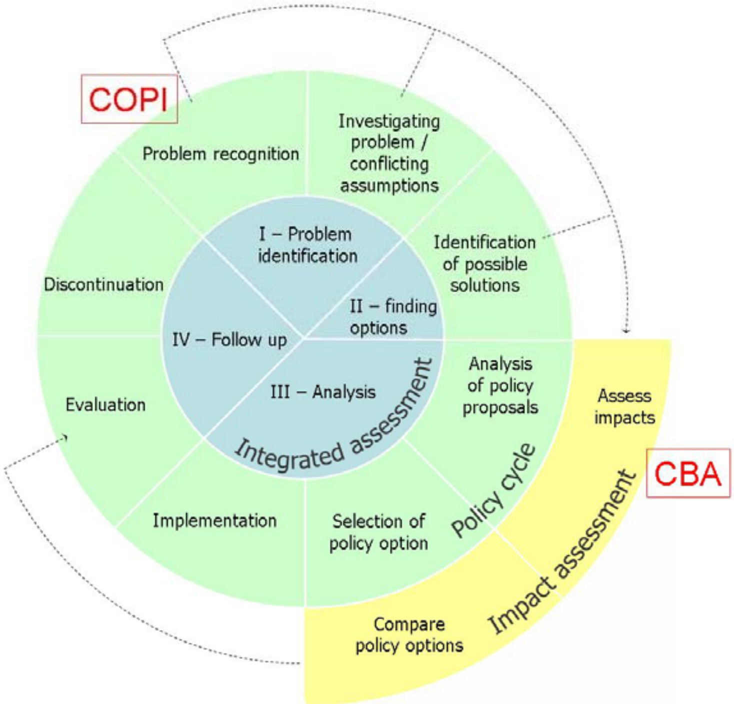


Figure 1.3 Place of COPI in the policy life cycle

The purpose of estimating the costs of policy inaction is *to highlight the need for action*, prior to the specific development and appraisal of policy instruments. COPI is therefore concerned with problem identification, and with understanding the dynamics of ecosystem change and the associated damage costs in the absence of new or revised policy interventions. A COPI-analysis differs from a Cost-Benefit analysis - in that:

- COPI is undertaken prior to the identification of policy choices, while Cost-Benefit analysis relates to a defined policy option and choice;
- COPI addresses the total costs of not changing, while Cost-Benefit analysis is concerned with the marginal net benefits of change or the marginal net costs of not changing;
- COPI is concerned either with a range of pressures on an environmental domain, or with the effect of a given pressure on a range of environmental domains, or some combination; Cost Benefit analysis relates to the specific policy options and the related defined pressure and a particular aspect of the environment

The most important guiding principle for a COPI analysis is to say what can be said, in terms that are clear, understandable, with results that are useful and can be traced and explained. In practice, it is valuable to present the costs of policy action in all three manners – in qualitative terms, in quantitative terms and monetary terms – all the while understanding what each of these covers, and therefore presenting the results in context.

1.4 Objectives and outcomes of the study

The objectives of this COPI study are:

1. To develop an exhaustive inventory of the economic evaluations of biodiversity so far

For a COPI assessment there needs to be as good a coverage as possible of the different ecosystem service values for the different biome types. The inventory of the economic evaluations of biodiversity therefore needs to as 'exhaustive' as possible, in the sense that the combinations of "biome-land use" units, as distinguished in this report, with "sets of the ecosystem services", derived from the Millennium Ecosystem Assessment, are representative for the full range of existing and potential combinations. It will be 'exhaustive' also in the sense of presenting the most relevant parts of the information that are available. Note that experience suggests that for some biome types and ecosystem services quite good information is available, and in other areas there will be gaps. It is considered important to both present ranges of values for where there are several estimates, and also important to be clear on the gaps – some can be addressed by estimation, others will have to be left blank if insufficient information is there for an estimate. The insights on both where the gaps are, and methods on how to address the gaps, will be helpful to clarify task and challenges for evaluation work building on the findings of this work. *Details of the inventory are presented in Annex I*

2. To analyse and to present the economic evaluations in a coherent framework

The case studies from the inventory have been put in a spatially explicit, ecological – economic database to allow for an analysis of the case study data and a synthesis of results into economically, politically and geographically relevant systems. The choice as to which biome-habitat types the analysis builds on reflects those in the OECD scenario work to ensure compatibility. *Details are presented in Chapter 2 and Annex I.*

3. To illustrate the impact of not meeting the 2010 biodiversity target globally

The illustrations of the impact are specified in several different terms to ensure a full picture – which includes qualitative, quantitative and monetary impacts:

- Qualitative: most important losses of biomes and of ecosystem services
- Quantitative: aggregated physical indicators
- Loss of services: percentage loss of appropriate indicators
- Monetary: An aggregate monetary value of the COPI

Details are presented in Chapters 3 to 6 and Annexes II and III.

4. To help setting priorities within the field of biodiversity conservation in the EU

With a set of conclusions and a discussion of the merits and uncertainties of the analyses, the basis is to be formed for recommendations as to potential improvements in policy and management. *Details on the policy perspective are presented in Chapters 3 to 7.*

The wider objectives: COPI in context

The COPI study is one of a series of studies being carried out in parallel, all of which contribute to the wider study on The Economics of Ecosystems and Biodiversity (TEEB). The results of COPI will feed into the Phase 1 report of the TEEB that is being presented at the CBD COP9 in Bonn in May 2009. Furthermore, the methodological insights will help form a basis from which the TEEB phase 2 will build. The results of the COPI work therefore have a dual purpose – both as a study on the costs of policy inaction in its own right, but also as a contributor to a wider and bigger process of understanding and assessing the economics of ecosystems and biodiversity and thereby contributing to the much wider efforts to halt biodiversity loss.

1.5 Structure of the report

The overall COPI methodology applied in this study is presented in Chapter 2. Chapter 3 summarises the developments of the demographic and economic drivers of biodiversity change as calculated in the Baseline OECD scenario, and resulting changes in land use and other pressures for the period 2000-2050. Chapter 3 also presents the policies which are considered part of the baseline. Chapter 4 presents the changes in biodiversity, an extension of work done in the course of the OECD Environmental Outlook to 2030. Biodiversity changes in marine and coastal systems are added. In Chapter 5 the available knowledge with respect to the changes in ecosystem services is summarised and linked to the Baseline scenario. This is to form the basis for an assessment of losses of ecosystem services benefits. Chapter 6 introduces the monetary assessment work. Valuation results are linked to different biomes and land use types, and also take into account the geographic location, and the demographic and economic contexts of the case studies. Chapter 7 presents the conclusions and recommendations, both with respect to policy as to necessary research. The COPI valuation database is presented in Annex I, a detailed case study of economic valuation of forests around the world in Annex II and of invasive alien species in Annex III.

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2 The COPI methodology and Valuation Database

Leon Braat, Patrick ten Brink, Ingo Bräuer and Holger Gerdes

Summary

The COPI analysis covers a chain of scenario-driven changes. The first step is to develop projections with the OECD-scenario and IMAGE-GLOBIO-model of changes in land use, biodiversity and ecosystem services over the period to 2050. At the same time, a database of values of ecosystem services is developed that can be applied to the land use changes. Development of a spreadsheet model allows the combination of the ecosystem service values and the land use changes, and the quality factors based on a measure of biodiversity of the land use types. To deal with data gaps this also includes methodological solutions for benefits transfer, up-scaling and gap-filling. Given that the GLOBIO model focuses on land-based biomes, the evaluation results are only a partial representation of the total global ecosystem services losses that come from biodiversity and ecosystem function losses. Hence, complementary analysis of benefits and losses across other biomes was carried out. These steps are complemented by a policy analysis, which seeks to see the OECD-baseline scenario in a policy perspective, help clarify the drivers for biodiversity losses and create a platform for policy recommendations.

2.1 Introduction

The COPI analysis covers a chain of scenario-driven changes (*figure 2.1*). For each part of the conceptual model a basic "conceptual" framework has been used to organise the data, information and knowledge. These frameworks are discussed in Section 2.2. Details of the models, indicators, databases and information sources are presented in the chapters where they are most pertinent.

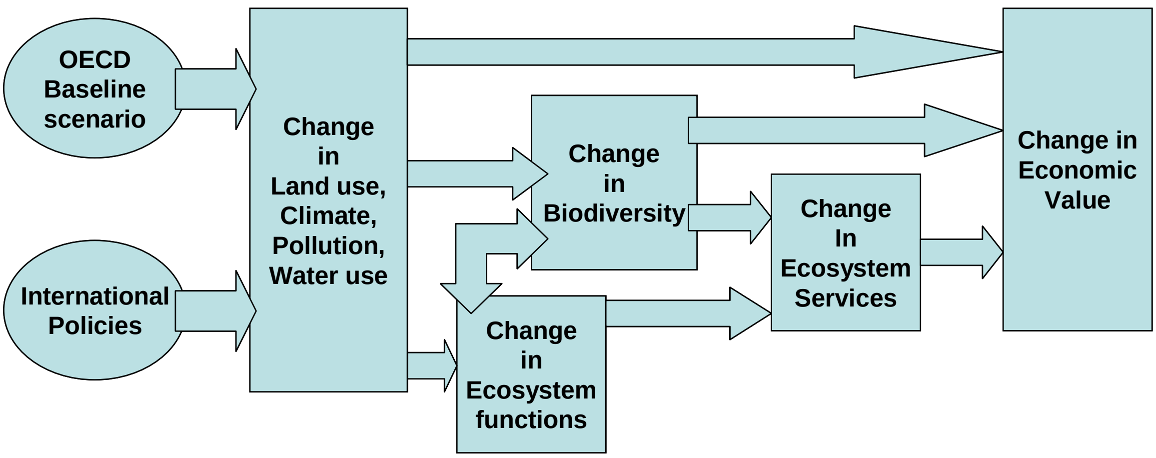


Figure 2.1 The conceptual model of the COPI analysis

The key steps of the COPI Analysis are:

5. **Develop projections with the OECD-scenario and IMAGE-GLOBIO-model** of changes in land use, biodiversity and ecosystem services over the period to 2050. The details of this are in Chapter 3, 4 and 5.
6. **Development of a database of values** of ecosystem services that can be applied to the land use changes. These therefore need to be in a Euro/hectare/year format. The unit values in the database are derived from two types of sources – one is a wide literature survey, and the other is primary research on the forestry biome. Details on the former are given in section 2.3, and details of the latter in Annex 1.
7. **Development of a spreadsheet model** that allows the combination of the ecosystem service values and the land use changes, and the quality factors based on a measure of biodiversity of the land use types. To deal with data gaps this will need to also include methodological solutions for benefits transfer, up-scaling and gap-filling. The model is available in electronic form and the steps in the analysis are presented in the Chapter 6, section 6.2.
8. Given that the GLOBIO model focuses on land-based biomes, the evaluation results presented in Chapter 6 will only be a partial representation of the total global ecosystem services losses that come from biodiversity and ecosystem function losses. Hence, some **complementary analysis of benefits and losses** across other biomes was carried out, presented in Chapter 6.

These steps are complemented by a policy analysis, which seeks to see the OECD-baseline scenario (see Chapter 3) in a policy perspective, help clarify the drivers for biodiversity losses and create a platform for policy recommendations.

2.2 The role of existing frameworks in the COPI analysis

2.2.1 The OECD Baseline Scenario

Quite a few organisations have worked at creating scenarios for future developments in land cover. A number of global studies have been published in 2007, e.g. IPCC (Intergovernmental Panel on Climate Change, 2007) and Global Environmental Outlook (United Nations, 2007) and in the first few months of 2008, e.g. IAASTD (International Assessment of Agricultural Science and Technology Development, 2008) and OECD Environmental Outlook to 2030 (OECD, 2008). They constitute essential contextual frameworks for the COPI analysis.
In the OECD Environmental Outlook to 2030 a set of demographic and economic scenarios are used, of which the so called "Baseline Scenario" is used in the COPI study. As the COPI study is about the cost of "inaction", a scenario was selected which uses realistic, mid range projection for population and economic development, with associated changes in the consumption of resources (including energy, land and ecosystems). The Baseline Scenario is a *no-new- policies* scenario: while "deep" drivers (efficiency improvements, demographic change) continue to evolve, no policy initiatives are included that would change dynamics. Policies in the pipeline that are currently decided upon and believably instrumented are included in the baseline.

Compared to scenarios as developed by IPCC-SRES, the Millennium Ecosystem Assessment and the Global Environment Outlook, the OECD Baseline can be characterized as middle-of-the-road. The OECD Baseline is defined worldwide, in terms of 34 economic and 24 environmental regions. The policy horizon is 2030, the impact horizon 2050. In economic terms, the OECD baseline is quantified using the ENV-Linkages model of OECD. This model is derived from the Linkages model of the World Bank and part of JOBS, GREEN and GTAP tradition of models. Analysis of the OECD Baseline in physical terms has been mainly developed by NEAA/MNP (Bakkes & Bosch, 2008). This includes intermediate projections such as areas of cropland and grazing land (see Chapter 3).

In the COPI study we distinguish between various classes of policies within the Policy Landscape (biodiversity conservation, mitigating policies with respect to environmental pressures and economic development policies) and between stages of policy development (intention/goal statement, agreement / signature, instruments and financing). As to the range of policies included in the scenario, the notion is that policies currently in place are included, new policies, currently with the status of "under discussion" are not included.

2.2.2 The Driver-Pressure-State-Impact-Response framework

The Driver-Pressure-State-Impact-Response framework has proven to be a useful tool for characterising the inter-linkages between cause and effect for biodiversity loss (e.g. EEA, 1995). The changes in area and quality of ecosystem services (see Chapter 5), which in varying degrees determine the changes in economic value of biodiversity to society (see Chapter 6), result from the interactive and cumulative effects of a number of social and economic drivers including biodiversity conservation and economic development policies, next to, of course, autonomous ecological processes. In the GLOBIO model (see Chapter 4) the changes in biodiversity indicators are calculated on the basis of projected changes in such drivers and processes. The "feedback loop" from the perceived and experienced impacts to the previous elements of the framework is the so called response step, including legislation, economic instruments and technology as well as social action (see *figure 2.2*). In Chapter 7, we discuss options and their implications to address the consequences of a Baseline future.

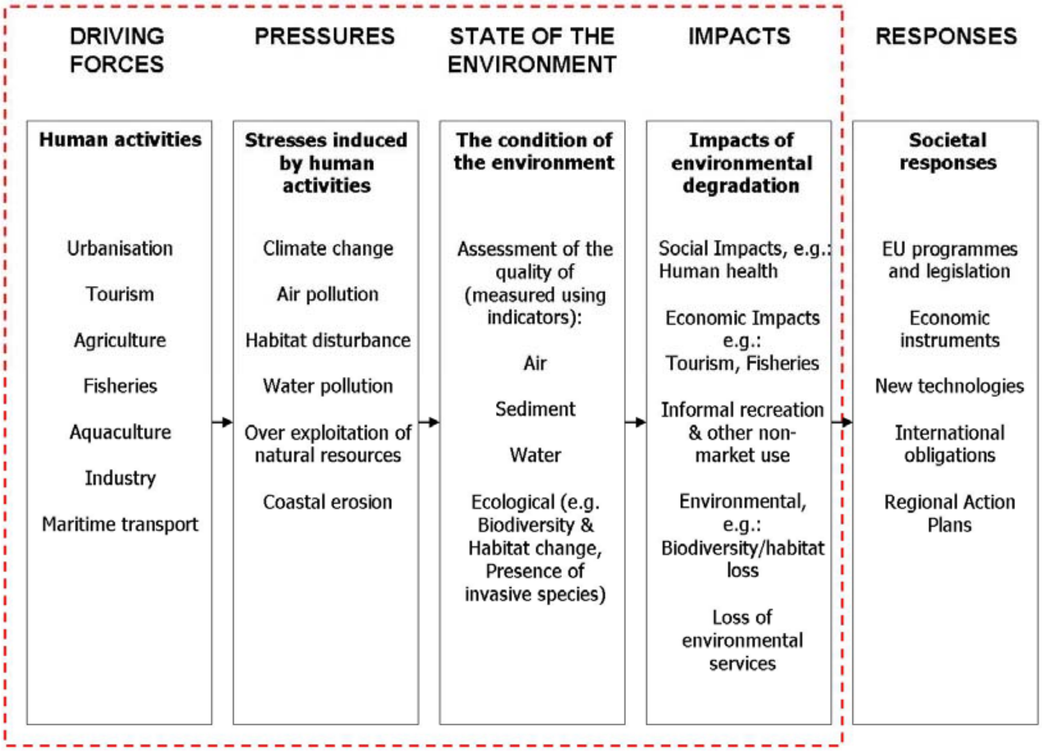


Figure 2.2 The DPSIR Framework

2.2.3 Indicators of Biodiversity change

The Convention on Biological diversity (CBD) has led to the development of sets of operational biodiversity indicators (*see table 2.1*). As a support to the Conference of Parties 8 the CBD has produced a 2nd Global Biodiversity Outlook (CBD, 2006). Part of the outlook was based on analyses with the Global Biodiversity model (GLOBIO; Ten Brink et al, 2006) which expresses the change in "biodiversity" in terms of the indicators "Mean Species Abundance" and "Extent (area) of ecosystems", accepted by the CBD and EU as part of the Headline Indicator Framework (see EEA, 2007). The indicators used by the Convention on Biological Diversity and adopted by the European Commission cover a wide range of biodiversity aspects ranging from ecological to social, cultural and economic, and the policies set in motion by the European Commission and described in detail in Action Plans of the Biodiversity Communication (EC, 2006). Several of these indicators are used to present the consequences of the Baseline scenario developments of economic and social drivers for biodiversity (see Chapter 4).

Table 2.1 The current set of 2010 Indicators, by Focal Areas of the CBD.

Focal Area	Indicator
Status and trends of the components of biodiversity	Trends in extent of selected biomes, ecosystems, and habitats Trends in abundance and distribution of selected species Coverage of protected areas Change in status of threatened species
	Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance
	Area of forest, agricultural and aquaculture ecosystems under sustainable management Proportion of products derived from sustainable sources Ecological footprint and related concepts
Threats to biodiversity	Nitrogen deposition Trends in invasive alien species
Ecosystem integrity and ecosystem goods and services	Marine Trophic Index Water quality of freshwater ecosystems Trophic integrity of other ecosystems Connectivity / fragmentation of ecosystems Incidence of human-induced ecosystem failure Health and well-being of communities who depend directly on local ecosystem goods and services Biodiversity for food and medicine
Status of traditional knowledge, innovations and practices	Status and trends of linguistic diversity and numbers of speakers of indigenous languages Other indicator of the status of indigenous and traditional knowledge
Status of access and benefits sharing	Indicator of access and benefit-sharing
Status of resource transfers	Official development assistance provided in support of the Convention Indicator of technology transfer

2.2.4 Change in ecosystem services

The Millennium Ecosystem Assessment (MA, 2005a) has revived the awareness and understanding of the interdependency between human prosperity and well-being and the natural environment through the *economic concept* of ecosystem services. The MA framework (*figure 2.3*) has been used already in many valuation studies and is a basic element in the COPI methodology developed within this study (see Chapter 5).

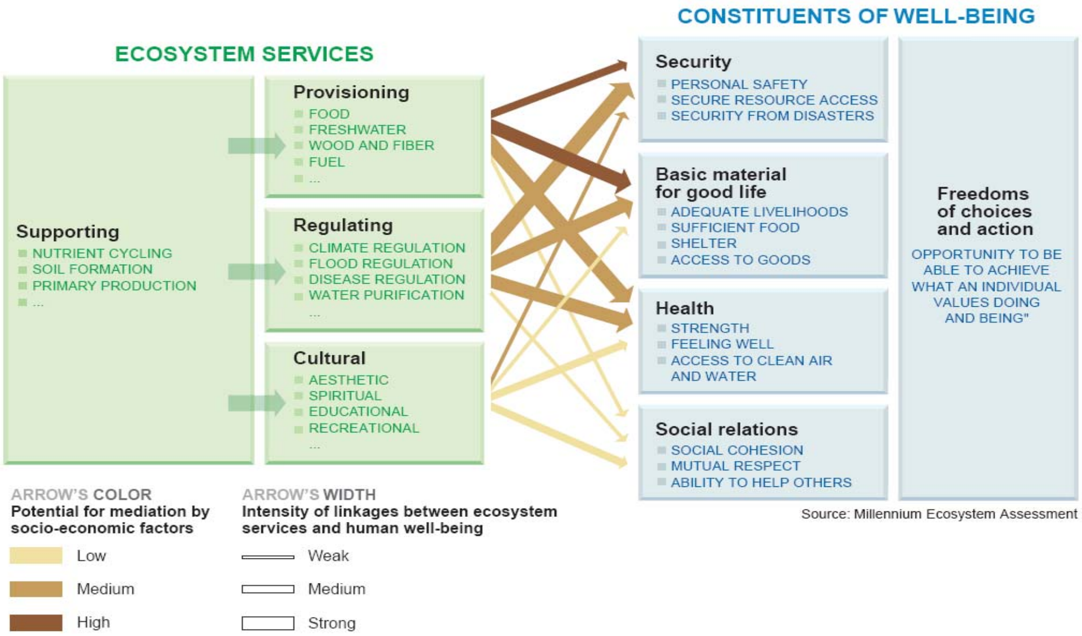


Figure 2.3 The Millennium Ecosystem framework (MA, 2005a)

Many of the studies reported over the last decade in scientific journals, such as Ecological Economics, have dealt with the relationship between ecosystems and economic growth and human well-being, and many case studies have been undertaken to document, quantify and monetise the economic importance of healthy and productive ecosystems. New views on the classification of services in relation to ecosystem processes and use in economic production and human consumption are reported in Rodrigues et al. (2008).

The MA stresses the risk aspects of biodiversity loss. The COPI analysis therefore not only evaluates the monetary costs of more or less continuous ecosystem degradation, but also addresses the costs in case of discontinuities (e.g. critical thresholds being breached). The MA has created a useful conceptual framework and political commitment to put the value of biodiversity into decision making. It has been a motor for new information on the value of biodiversity and associated ecosystem services. The MA classification of ecosystem services and their analyses constitute one axis in the COPI framework of analysis. We are aware that the MA clearly states the difficulty of fully assessing the costs and benefits of ecosystem changes.

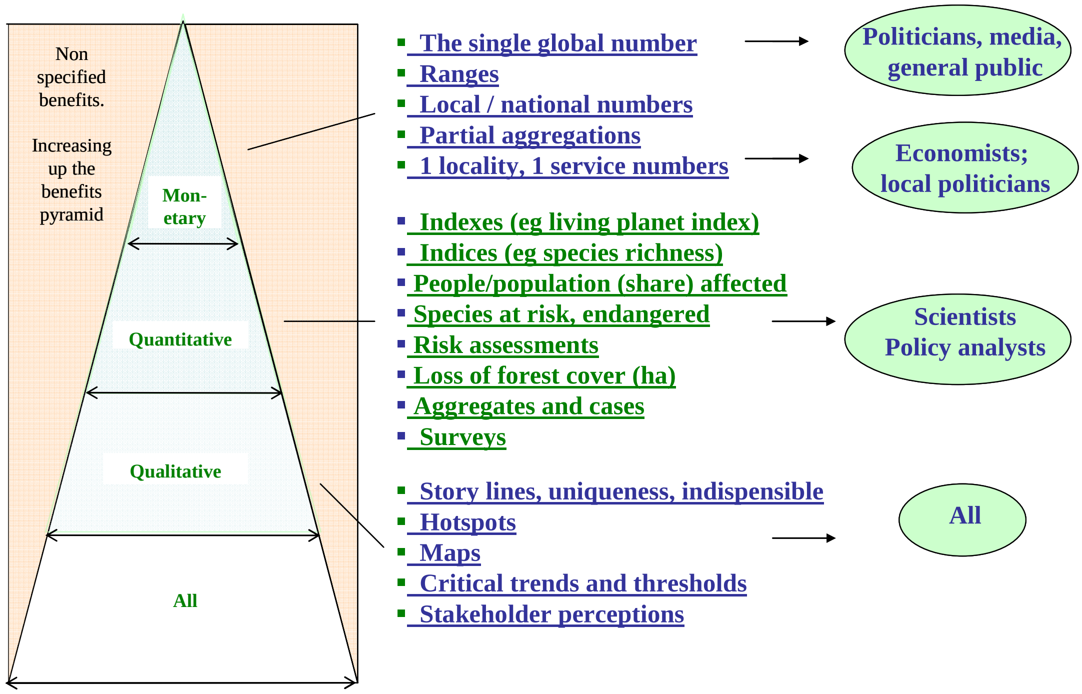
The reports of the Millennium Ecosystem Assessment project also provide us with a great amount of assessment information on the state and trends in the world's ecosystems (MA, 2005b). *The COPI analysis on biodiversity change has made extensive use of this information, and some sections of MA chapters have been reproduced in this report, be it in, shortened and adapted versions* (see references in the text throughout the report).

2.2.5 Changes in economic value

An avalanche of publications on the economic valuation of biodiversity, ecosystem services and natural capital has been produced since the early 1990s and recently a number of summaries of current experiences and developments in methodology have been published. The notion of Total Economic Value (see e.g. CBD, 2007) is used to set a theoretical framework for the monetization of the ecosystem goods and services (see also Chapters 6 and 7).

In the context of biodiversity and ecosystem services, the cost of policy inaction (COPI) may be defined (arguably a narrow focus definition) as the 'ecological damage costs occurring in the absence of additional policy or of policy revision'. These damage costs are projected to accrue under existing (sector and biodiversity conservation) policy commitments. Various damage cost estimates are possible to take account of different levels of implementation of the existing commitments – higher damage costs with lower levels of implementation. In addition, it is possible to have a more inclusive COPI valuation - an 'extended COPI' - in which the costs of inaction are extended to include wider societal and economic costs, and where the definition of COPI is the 'total social (private and external) costs occurring in the absence of additional policy or policy revision'. This report presents such an "Extended COPI assessment" which is referred to simply as 'COPI' assessment. The COPI assessment is focused on measures of loss of biodiversity and the associated ecosystem services over the projected period, or in particular future years, compared with some reference year and situation. The time profile of this loss over the period (linear or non-linear) may influence the final assessment. Because changes in ecosystems may increase the delivery of some ecosystem services while reducing others, this COPI exercise has also sought to factor in the benefits of inaction (net-COPI).

At the core of the methodology in this study is the "valuation of biodiversity", in other words the assessment of the (total) value of ecosystems to mankind. *We concentrate on the valuation of the "flows" (the ecosystem goods and services) rather than on valuation of the biodiversity "stock".* In light of the previous statements, there is a clear need for a comprehensive, qualitative, quantitative and where relevant and possible, monetised, overview of the total value of biodiversity and ecosystem services lost, due to policy-inaction in order to support policy development and decision-making. Depending on the target audience, and the platform of discussion, the COPI results can be presented in one or more formats, appropriate to the occasion (see *figure 2.4*).



Source: *Patrick ten Brink (IEEP)* presentation at the Workshop: ***The Economics of the Global Loss of Biological Diversity 5-6 March 2008, Brussels, Belgium***

Figure 2.4 Communication of COPI assessment results

2.3 The Valuation Database

2.3.1 Introduction

The overall task of the Valuation Database was to provide a framework that allows for the generation of an inventory of the current state of economic valuation studies of biodiversity and ecosystem services that are suitable for a COPI assessment based on the GLOBIO-model results. The database is not just a compilation of studies dealing with the issue of economic evaluation, as are current databases like EVRI and others, but rather a focused database looking at and categorising ecosystem services values that can be used to arrive at COPI values when linked to a land-use change type model – hence seeking Ecosystem Service (ESS) per hectare values.[1] Furthermore, the work has a role as a scoping exercise in order to get a better picture on the overall data availability and to provide a framework for the general data processing for future work in The Economics of Ecosystems and Biodiversity (TEEB) project. The database also provides the basis for the first indicative assessment of the costs of policy inaction as given in Chapter 6.

The inventory of economic valuation studies is a core foundation for the COPI-project. Its roles can be summarised as follows:

[1] Note that other values were collected and collated to allow complementary analysis – eg of coral reefs, wetlands, and invasive alien species though these were not integrated into the structured database.

- **structuring the data**: it provides the data in a structured form, from which the integrated COPI assessments at various levels are developed;
- **characterising the data**: it documents the nature of the valuations and the range or forms they can take;
- **identifying gaps and opportunities**: to develop suggestions for new and additional policies and priorities needed in response to insights on ecosystem services across relevant geographical and sectoral examples.

To fulfil these objectives, a database has been developed that meets these key criteria.

- **Contains up-scalable data**: the main precondition for the data recorded in this database is that the numbers can be used for an up-scaling exercise on a global level. In addition, it is essential that the values be suitable for benefit transfer given the fact that there is a very uneven distribution of available information across ESS, biomes and geographical regions. To fulfil these requirements, the database presents data in economic values that are comparable and explicit in respect to the evaluated environmental good to avoid double counting.
- **Identifies data coverage and gaps**: the database is structured in such a way that it clearly indicates which data are available and where data gaps are, to give advice for the phase II.
- **Accommodates future needs**: the database is flexible in a way that new data can easily be added.

To ensure that the above-mentioned criteria are met, the database contains only studies for which data can be presented on a €/ha basis and which can also be attached to a specific biome, ecosystem function and region. These stringent criteria result in a significantly smaller number of suitable case studies. This is necessary to ensure a sound and robust COPI assessment.

2.3.2 Methodology

This section describes the methodological features of the database.

1. Data gathering:

Because part of the aim of the project is to provide a scoping exercise on what a worldwide COPI assessment could look like in phase II, the literature search tried to use existing databases, such as the Environmental Valuation Reference Inventory (EVRI) to the extent possible. Even though a considerable number of studies have been identified that provide economic values for specific ecosystem services, only a small proportion of these studies provided information detailed enough to be incorporated in the COPI Valuation Database. Hence, in addition, a literature search of scientific databases (Web of Science, Agricola) for peer-reviewed publications was conducted, as well as an internet search for grey literature, to allow the team to have sufficient data upon which to base the COPI illustrative assessment

2. Mean values for ecosystem function:
Taking into account that 19 different ecosystem services (ESS) in combination with 13 different biomes and 14 geographic regions would result in 27,664 necessary values to feed into the COPI-assessment, there is an obvious and urgent need to reduce complexity and fill in gaps. As a first step to reduce the complexity, mean values for different EES-biome combinations across regions were calculated in Euro for the year 2007 using the Purchase Power Parity/GDP index from the OECD study. These mean values serve as a good starting point for the up-scaling procedure presented in Chapter 6. Annex II "the forest study" presents a statistical way to do this assessment if sufficient information is available to undertake a benefit transfer based on transfer functions. In addition for each ESS it has to be checked whether the underlying studies evaluate competing or non-competing uses. In the first case, mean values can be used, but in the latter case the non-competing values must be added together to find the overall value for the respective ESS (see *table 2.3*).

3. Min-max procedure:
To assess the suitability of using the calculated mean values, minimum and maximum values were identified for each ESS-biome combination and compared with the mean. This allowed assessment of representativeness and hence transferability for each ESS-biome combination. The results of this comparison are presented in *table 2.3*. Where the ranges were found to be appropriate, mean values were fed into the COPI assessment. Where value ranges were found to be extremely large, they have been taken into account in the COPI assessment by stating minimum and maximum values to be used for the different scenario calculations.

4. Cross-check of single values:
Available estimates were used when they were regarded as representative and methodologically sound. For some ESS-biome combinations data availability is limited to individual studies. To ensure that these are suitable for the up-scaling procedure, they must be verified.[2] Given the scope of this study, this assessment could not take the form of a statistical procedure, so consisted instead of a basic plausibility check. The underlying rationale here is that economic evaluation studies and their results may not be representative for a specific biome. This is due to the fact that these studies are frequently undertaken to highlight the importance of a specific ecosystem service in the case-study area and to raise awareness in the decision-making process. The results of the studies have therefore to be critically assessed by comparing them with related studies using expert judgement. For an example of what such an assessment might look like, see Box 2-1 (calculation procedure). This assessment eliminated certain economic values from the database, because they represented people's willingness to pay for a certain ecosystem service at very prominent places, i.e. where the reported value is quite likely much higher than the assumed global average value.

5. Fixed data processing procedures:
The database contains several summary tables containing information on (i) the overall count of studies for specific ESS-biome combinations, (ii) the mean value,

[2] Please note that all studies have to pass a quality check in order to be incorporated into the database.

(iii) maximum and (iv) minimum values as well as (v) sums for selected ESS where the underlying values represent sub-functions of a given ESS that must be summed up to represent the overall value of the function.

6. Filling the gaps:

Filling the gaps is discussed in Chapter 5, where the relation between ESS and Landuse type (and hence a basis for transferring values between Landuse types within the same biome) is described and in Chapter 6, which presents the evaluation results. It is useful to transparently show the results in the context of the up-scaling and gap-filling approaches so that the numbers can be seen in perspective. Note that two scenarios were created – a partial analysis scenario, where there was a lesser level of gap filling/estimation, and a fuller analysis scenario, where more (but not all) of the gaps were filled. The choice of two scenarios reflected the opposing principles – one of theoretical purity (i.e. only use numbers from original data and selective gap filling where fair rationales exist) and one of the ambition of having a representative number (without the gaps filled, the final answers would arguably not be very representative of reality). Details are given in Chapter 6.

2.3.3 The COPI Valuation Database - structure and available data

The COPI Value Database contains the figures to be used for the completion of the monetary biome-landcover sheet in the COPI spreadsheet. It provides the monetary values needed for the eventual COPI assessment and thus represents the core of the COPI spreadsheet. By linking an estimate for a specific ecosystem service to a biome, a land use type and a geographic region, one can assess the overall loss of ecosystem services over the period 2000 to 2050.

The data in the database are displayed in two parts:

- Part 1 is the core of the database. Estimates have been summarised in a seven-column table, from which the values will feed into the monetary biome-landcover sheet. *Table 2.2* represents the synthesis of the Valuation Reference Database.
- Part 2 contains all relevant information that characterises each value/the respective study in detail, e.g. the actual location of the case study. A detailed description can be found in the Annex I.

Table 2.2 Core of the Valuation Database

Used in COPI assessment	Useable value	PPP-adjusted usable values	ESS reference	Biome	Landuse type	Geo-graphic region
1 = yes 0 = no	EUR/ha in the year 2007	EUR/ha adjusted by PPP to feed into matrix	# from ESS table to allow sorting (1-19)	# ref to allow sorting (1-13)	# ref to allow sorting (1-8)	# region from Globio (1-14)

2.3.4 Values for ecosystem services across biomes

At this moment, the database contains a total of 186 monetary values, split over several biomes, land-cover types and geographic regions. Nevertheless, the literature search for the database revealed a very unequal distribution of the available evidence for the different biomes and ecosystem services. Out of the total dataset, only around 30 values cover scrublands and grasslands, and 20 values cover temperate and tropical forests[3]. A major part of the values cover wetlands, swamps and floodplains (27), mangroves (15) and marine ecosystems such as coral reefs (19). Even though these values cannot be attached to one of the biomes from the GLOBIO model, they have been recorded, because they are valuable information that can be used in the additional estimates (see also Annex III on invasive alien species, IAS). Regarding the regional distribution it becomes apparent that there is a greater number of values available for Europe and America (North and South) than for Africa or Asia. This is not surprising. A look at the regional distribution of the entries in the EVRI database confirms this. An additional literature review has been undertaken to even out this imbalance.The second main issue is that there is considerably variation between the values within one EES-Biome category.

Table 2.3 Available data for the different biome/ecosystem service combinations (details on the calculation of means are described in the Box 2-1).

		PPP-adjusted values (EUR/ha) / [number of usable values] / range			
		Biome category			
ESS ref	**Ecosystem service (ESS)**	**Grassland**	**Scrubland**	**Tropical Forest**	**Temperate Forest**
1	Food, fiber, fuel	106 [3] (28 – 243)	779 [2] (515 – 1044)		246/14/99/107142**
2	Biochemicals, natural medicines, pharmaceuticals	0 [1]		514 [5] (12 – 2394)	3 [2] 2,2-3,6
4	Fresh water			9,6 [1]	
5	Air quality maintenance		793 [2]*		
6	Soil quality maintenance			1176[4] [1]	
7	Climate regulation	36 [3] (0 – 102)	347 [1]		240/ 542/382/240/ 382**
9	Water regulation	2,4 [1]		503/1356[3] 80-3062	344 [3] 0,2-980
10	Erosion control	23 [3] (1 – 44)	44 [1]		
11	Water purification and waste management	240 [3]*	838 [4]*	104,16 [1]	104 [1]
13	Biological control and pollination	57 [2]*			5 [1]
14	Natural hazards control / mitigation			6 [1]	

3 note that for forests, a wider set was used directly in the FEEM led work in Annex II. See annex II for details.
4 Adjustment of the mean. See Box 2-1 "Assessment procedure".

		PPP-adjusted values (EUR/ha) / [number of usable values] / range			
		Biome category			
ESS ref	**Ecosystem service (ESS)**	**Grassland**	**Scrubland**	**Tropical Forest**	**Temperate Forest**
15	Cultural diversity and values		112,4 [1][5]	8 [2] (2 – 173[6])	99/25,4/11,9/ 9,9/11,9**
16	Living comfort due to environmental amenities				
17	Recreation and ecotourism			91 [1]	1,3/1,3/1,3/1, 3/1,3**
19	Primary production, nutrient cycling, soil formation			1116 [2]*	12 [1]
SUM	**Individual values extracted from reference database**	**18**	**11**	**15**	**14**
SUM	**Values used in COPI assessment**	**7**	**6**	**9**	**7**

* Value is the sum of the different underlying studies as these studies have evaluated different sub-functions of the respective ecosystem function. In these cases, a calculation of a mean would not be appropriate, hence no ranges are presented.

** Values derived from the extra study on forests (see Annex). The different values are referring to the following forest biomes: boreal forests, warm mixed forests, temperate mixed forest, cool coniferous forests, and temperate deciduous forests.

In *table 2.3*, the majority of values are mean values. Nevertheless, there is always a cross-checking necessary to assure that the subsumed values are exclusive or non-exclusive uses. There are cases where an aggregate has been used for the COPI assessment. Here, different sub-functions of the same ecosystem service have been summed up to come to an aggregate value. For instance, food production and the supply of raw materials are two sub-functions under ecosystem service 1 (food, fiber, fuel). These functions can be summed up, because they are distinct and non-exclusive. In cases of identical functions, or when functions exclude each other, mean values have been calculated and were used in the further COPI assessment.

As can be seen from *table 2.3*, some values are well documented, while others are less well documented. In Box 2.1, additional information is provided on the mean values to be used in the COPI assessment and explain in detail how the individual mean values have been developed to ensure transparency of the process.

Box 2-1: Assessment procedure for the final values used in the COPI assessment.

Grassland / food, fiber, fuel [15/1] The mean value was derived from three individual studies. Fleischer et al. (2006) estimate the value of herbaceous biomass for meet production at EUR 243/ha; Costanza et al. (1997)[7] estimate the value of food production at EUR 46/ha (net rent), and Ruijgrok et al. (2006) estimate the value of food, fibre and fuel production at EUR 28/ha (WTP). The estimates

[5] Adjustment of the mean. See Box 2-1 "Assessment procedure".

[6] Adjustment of the mean. See Box 2-1 "Assessment procedure".

[7] Costanza et al. (1997) values were included in the database analysis, because they are often enough valuable reference points. In addition, they were compiled by highly recommended researchers in the field of ecosystem service valuation and are often based on meta analyses.

stem from Israel, the US, and the Netherlands, respectively. The mean value was calculated without any adjustments.

Grassland / climate regulation [15/7] The mean value was derived from two individual studies. Costanza et al. (1997) estimate the value of climate regulation between EUR 0/ha and EUR 6/ha (opportunity cost), depending on the specific site. Ruijgrok et al. (2006) estimate the value of carbon storage at EUR 102/ha (WTP). The estimates stem from North America and Europe, respectively.

Grassland / erosion control [15/10] The mean value was derived from two individual studies. Costanza et al. (1997) estimate the value of soil formation at EUR 0.81/ha (opportunity cost) and the value of erosion control at EUR 24/ha (net rent). Ruijgrok et al. (2006) estimate the value of erosion control at EUR 44/ha (avoided cost method). The estimates stem from North America and Europe, respectively.

Scrubland / food, fiber, fuel [17/1] The mean value was derived from two individual studies. Rodriguez et al. (2006) estimate the value of food, fiber and fuel provision at 1044 EUR/ha (cultural domain analysis). Ruijgrok et al. (2006) value the same service at EUR 515/ha (WTP). The estimates stem from Europe and Latin America, respectively.

Scrubland / cultural diversity [17/15] Here only one value is available. As WTP studies on this issue generally evaluate specific sites of a broader interest, the value can not be used directly. For a simple and pragmatic benefit transfer it was assumed that only up to 10% of all scrublands a specific cultural value can be attached – otherwise they would not be special. (Please note, if more data becomes available the adjustment procedure as presented for the forest values should be used (see Annex).

Tropical forest / biochemicals, natural medicines, pharmaceuticals [20/2] The mean value was derived from four individual studies. Simpson et al. (1996) estimate the values of pharmaceuticals at EUR 13/ha on a global scale (modelling market price), while Costello and Ward (2006) value the same service at EUR 109/ha on a global scale (modelling market price). Costanza et al. (1997) estimate genetic resources at EUR 33/ha (market value). Eade and Moran (1996) estimate genetic material at EUR 24/ha and medicine at EUR 2394/ha. The regional values stem from studies from North and Latin America.

Tropical forest / soil quality maintenance [20/6] Here just one value has been available provided by Eade and Moran 1996, in a case study for the Rio Bravo. As the normed value of the original study (EUR 5880 /ha) seemed to be very high in comparison to the figures available on the value of nutrient cycling (ESS 19) it was assumed that this value is very case-study specific and was hence adjusted. To ensure a conservative calculation only 20% of the original value entered into the final COPI calculation.

Tropical forest / water regulation [20/9] For this EES, three individual studies were available that differ significantly. Kaiser and Roumasset (2002) estimate watershed protection at EUR 926/ha for North America, while Emerton (1999) estimates the value of watershed protection Mount Kenya at EUR 3061/ha. Eade and Moran (1996) estimate the value of flood control in Latin America at EUR 80/ha. As the benefits of flood control highly depend on site-specific conditions such as precipitation but also vulnerable infrastructure, an adjustment of the mean value was undertaken to ensure conservative calculations. In this case, two means where calculated, the one considering all three values will only be used in the higher scenario, while for the lower scenario the mean of the lower two values will be used.

Tropical forest / cultural diversity and values [20/15] Here two values of different natures were available. Costanza et al. (1997) estimate the cultural value at EUR 2/ha on a global scale (CVM). Eade and Moran (1996) estimate the existence value at EUR 173/ha. The latter study stems from Latin America.

Temperate forest / biochemicals, natural medicines, pharmaceuticals [1212/2] The mean value was derived from two individual studies. Rosales et al. (2005) estimate the value of pharmaceuticals at

EUR 3.55/ha, while Howard (1995) estimates the same service at EUR 2.24/ha. The studies stem from South-East Asia and Africa, respectively.

Temperate forest / water regulation [1212/9] The mean value was derived from three individual studies. Rosales et al. (2005) estimate the value of flood control at EUR 980/ha (varied methods). Howard (1995) estimates the value of watershed protection at EUR 51/ha. Costanza et al. (1997) estimate the value of water regulation at EUR 0.17/ha (damage costs). The studies stem form South-East Asia and Latin America, respectively.

2.3.5 Insights – strengths, gaps, methods for using values, and needs

The proposed database, structured along ecosystem services and biomes, offers the possibility to generate numbers to feed into the COPI assessment in a transparent and structured way. Nevertheless, in order to qualify for further processing in the COPI database, the valuation studies had to fulfil certain criteria. Firstly, monetary or quantitative values were required on a per hectare and annual basis. Secondly, the values needed to be assignable to a certain biome, landcover type and geographic region. These essential selection criteria reduce the number of usable economic evaluation studies dramatically.

This has been foreseen to some extent, since it is clear that most economic valuation studies have been conducted to evaluate specific conservation programs or specific locations rather than to generate mean values per biome. For this purpose, most studies generate figures more correlated to the project or habitat (e.g. aggregated value of the WTP per visit, or WTP for the protection of a specific area) than on a per-hectare basis. The majority of the available studies corresponds to specific entities like specific forests or lakes and are therefore difficult to transfer or interpret in a more general context. In addition, studies tend to focus on rather attractive or ecologically valuable habitats like wetlands, coral reefs etc., leaving a paucity of evidence for habitats with a lower profile. We must acknowledge that the dimensions of this problem are surprisingly large.

In respect to the aims of the database, it can be concluded that it has been useful to:
- define representative samples of case studies per biome/ecosystem service unit
- analyse relevant samples and insert them in a spatially explicit framework
- ensure the possibility of a benefit transfer
- provide information about knowledge gaps

It seems that a considerable part of the data needed is not or not easily available in the public literature. Currently, for some ecosystem services there are only few corresponding values in the Value Reference Database, e.g. with regard to water supply as a provisioning service. In this respect, the figures that will be retrieved from the final COPI assessment can only be interpreted as a lower-bound estimate. During the second phase of the review, the existing gaps will have to be filled in order to come to more representative figures. In summary, though there are information gaps in the current database, a first approach has been developed that is suitable to further elaboration in a second phase when more resources and time are available.

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3 The Baseline Scenario

Jan Bakkes, Marianne Kettunen, Mark van Oorschot, Leon Braat and Patrick ten Brink

Summary

The Baseline assumes that many aspects of today's world remain the same – not frozen in time, but evolving along the same lines as today. The Baseline shows a stabilisation of the world population at around 9.1 billion inhabitants by 2050. The Baseline trends combine to produce a modest, but uniformly positive growth in real Global Gross Domestic Product (GDP) of 2.8% per year between 2005 and 2050. Although the modelling for this study is more nuanced than assuming a fixed relation between GDP and pressures on biodiversity, the uncertainty in the baseline leans to the side of more pressures on biodiversity. Final energy consumption increases from 280 EJ in 2000 to 470 EJ in 2030, and ca 600 EJ in 2050. Up to 2030, it is projected that global agricultural production will need to increase by more than 50% in order to feed a population more than 27% larger and roughly 83% wealthier than today's. Although it is assumed that productivity of land will increase substantially, the global agricultural area will have to increase by roughly 10% to sustain this production, roughly the current agricultural area in the US, Canada and Mexico together.

Regarding "protected area" policies, the implicit assumption in the Baseline is that its implementation will not substantially change current trends. An important assumption in the Baseline is that agricultural productivity, in terms of yield per unit of agricultural area, can continue to improve over the coming decades. Regarding trade in agricultural products the assumption is that there will be no major changes in the spirit of a new Doha round. As to climate change mitigation the Baseline assumes no post-Kyoto regime other than the policies in place and instrumented by 2005. The existing trading scheme for emission credits is included and only second generation, woody, biofuels are considered. Explicit adaptation policies are not included in the baseline. The Baseline assumes that the EU Common Fisheries Policy and equivalent policies in other world regions, remain in place and continue to be implemented as they are now. Several sector policies still provide substantive incentives to support short-term economic growth at the expense of long-term environmental sustainability and maintenance of biodiversity. Even though policies supporting conservation and sustainable use of biodiversity exist they tend to lack enforceability and suffer from ineffective implementation.

3.1 Introduction

Introduction

This COPI analysis is aimed at an estimate of the economic consequences of biodiversity loss. In this Chapter we present the quantitative basis of the projected future changes in the drivers and pressures on the ecosystems of the world with their biodiversity, ecological functions and services and subsequent changes in economic value to society. The OECD Baseline scenario (upper red oval in *figure 3.1*) encompasses the drivers which are translated into pressures (red rectangular box) which are also influenced by international (and national) policies.

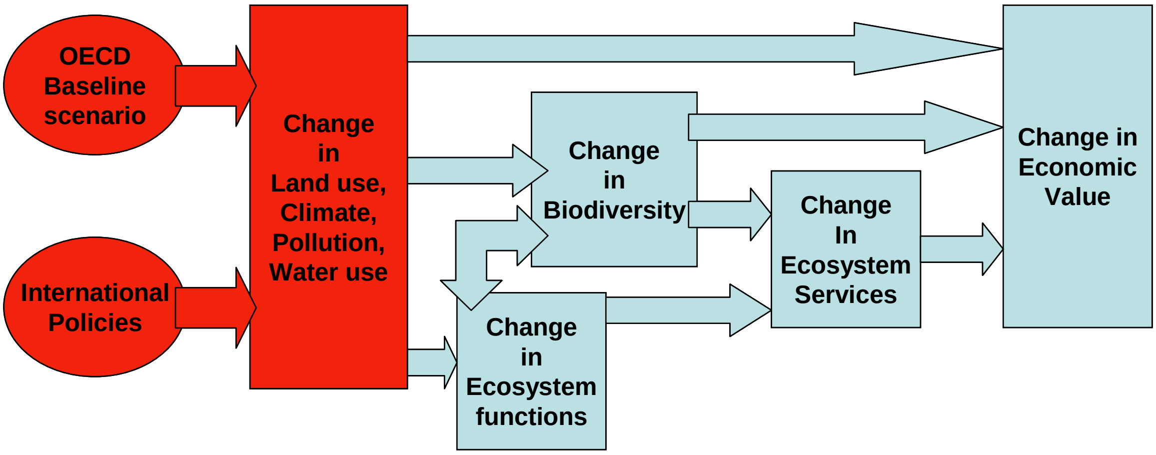


Figure 3.1 Chapter 3 in the Conceptual framework of the COPI analysis

By design, the Baseline scenario is a no-new-policies scenario. It imagines the world developing over the next decades largely as it does today, without new or intensified policies in response to projected developments. The Baseline assumes that many aspects of today's world remain the same – not frozen in time, but evolving along the same lines as today. Population and income are projected to increase, and diet, mobility demand and other consumption preferences keep shifting and increasing with income in the same way as in the past. By implication, the Baseline is not the most plausible future development. It is likely that decision makers in governments and elsewhere will react to all sorts of developments, including the environmental trends described in the Environmental Outlook, and that the Baseline trends will never occur in reality. *The Baseline is thus only a benchmark for comparison.* The purpose of a well-described Baseline is to identify the need for new policies in certain areas, and to provide a background for assessing the effect of new policies.

Although the Baseline shows a continuously increasing burden on the environment, the models used behave as if the projected quality of the environment would not disturb demographic and economic development! In Chapter 8 we shall return to and discuss the implications of this phenomenon. Because the purpose of the Baseline is to support a discussion that concentrates on policy options and possible alliances, rather than on the merits of the Baseline, it has been aligned as much as possible with authoritative thematic projections (as for population, energy, agriculture) and long-term historic series (in particular long-term growth rates of labour productivity).

3.2 The Baseline Scenario: Drivers

3.2.1 Population

The Baseline uses the “medium” population projection of the United Nations, which shows a stabilisation of the world population at around 9.1 billion inhabitants by the middle of this century (UN, 2005). Almost all of this increase will be in developing countries (see *Figure 3.2* and *Table 3.1*). The UN population projection is a “middle-ground” scenario with 8.2 billion people in 2030, compared to the extremes of the IIASA probabilistic population projections, that range between 7.7 and 8.8 billion in 2030 (Lutz et al., 2004).

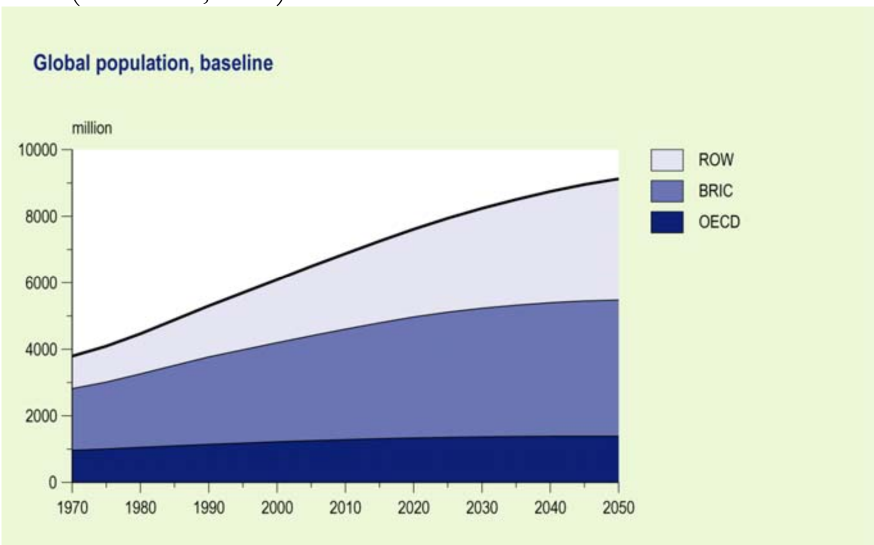


Figure 3.2 World population, baseline *Source: UN (2005)*

Table 3.1 Population increase, baseline

	1970-2000	2000-2030	2020-2050
	%		
North America	43	27	15
OECD Europe	17	5	-2
OECD Asia	27	0	-11
OECD Pacific	44	26	18
Brazil	72	34	15
Russia & Caucasus	15	-13	-16
South Asia	79	33	15
China region	47	14	-2
Middle East	156	74	42
Other Asia	84	49	26
Eastern Europe & Central Asia	29	3	-7
Other Latin America & Caribbean	74	43	21
Africa	120	85	57
World	61	35	20

note: overlapping 30-year periods: 2000-2030 and 2020-2050
Source: UN (2005, 2006)

3.2.2 Economic developments

The Baseline projects for the next half-century a world that is very similar to today's in factors such as the role and size of government, policy priorities, taxes, technology diffusion, intellectual property rights, liability rules and resource ownership. Hence ongoing technological change will impact on the economy in much the same way it has in the past. The economic undercurrents of the baseline trends combine to produce a modest, but uniformly positive growth in real Gross Domestic Product (GDP) for the world as a whole under Baseline conditions: the *global average is 2.8% per year between 2005 and 2030*. China and India would see growth rates of 5 per cent per year averaged over the whole period (from approximately 7% per year in the first years to approximately 4% during 2020-2030). *Figures 3.3 and 3.4* show the resulting levels of GDP and GDP per capita.

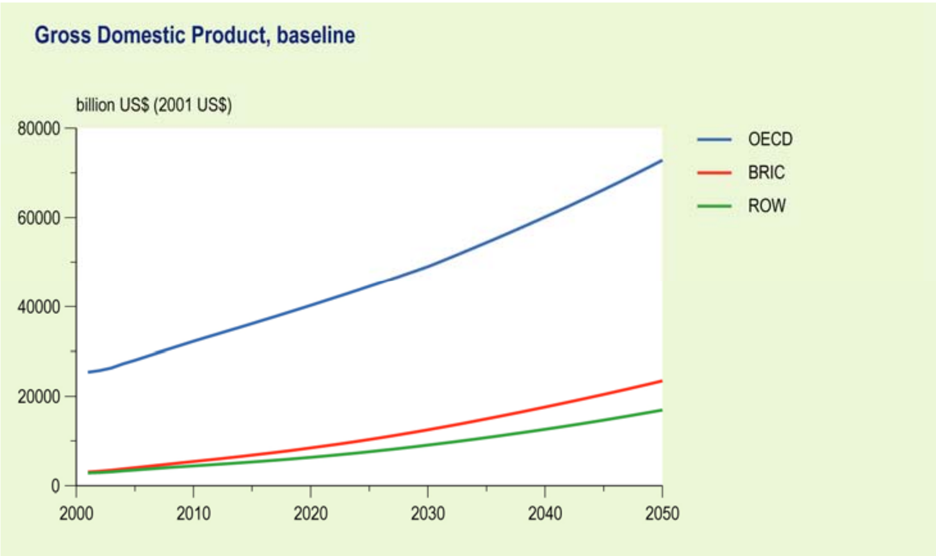


Figure 3.3 Gross Domestic Product, Baseline

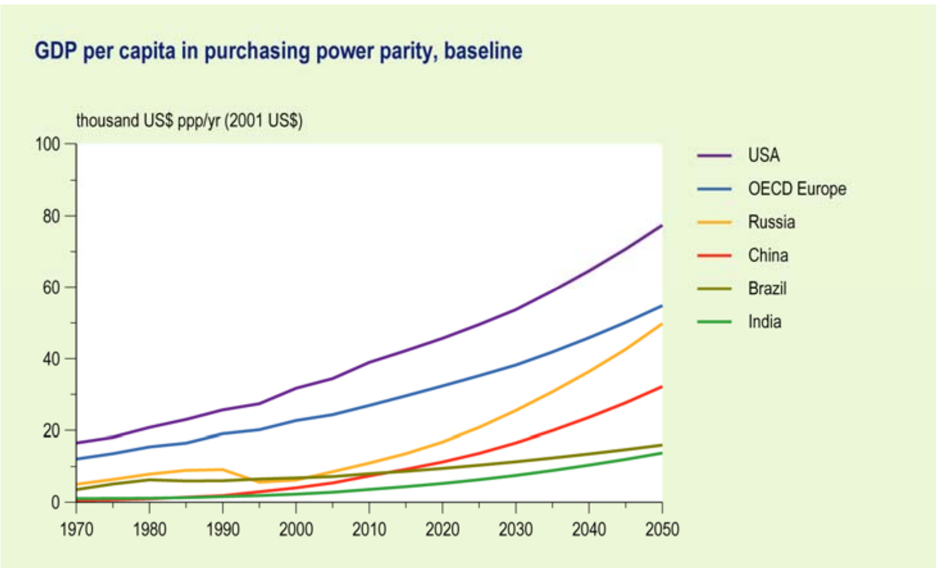


Figure 3.4 Gross Domestic Product per capita, baseline

The graphs show that the BRIC group, notwithstanding its strong and sustained growth, remains at a large distance from the OECD average in terms GDP per capita. By and large, this implies a similar distance for the average standard of living in this regional group. The baseline leads to shifts in sector composition over time, with the familiar pattern of stronger growth in the service sectors than in for example agriculture (*figure 3.5*). Thus, by 2030 or 2050 the weight of agriculture compared with the other sectors in most economies will be less than today. But this only means that the value added of other sectors has increased more than that of agriculture. It does not necessarily mean that the activity in agriculture in that region will shrink in physical terms. In most regions, it will not.

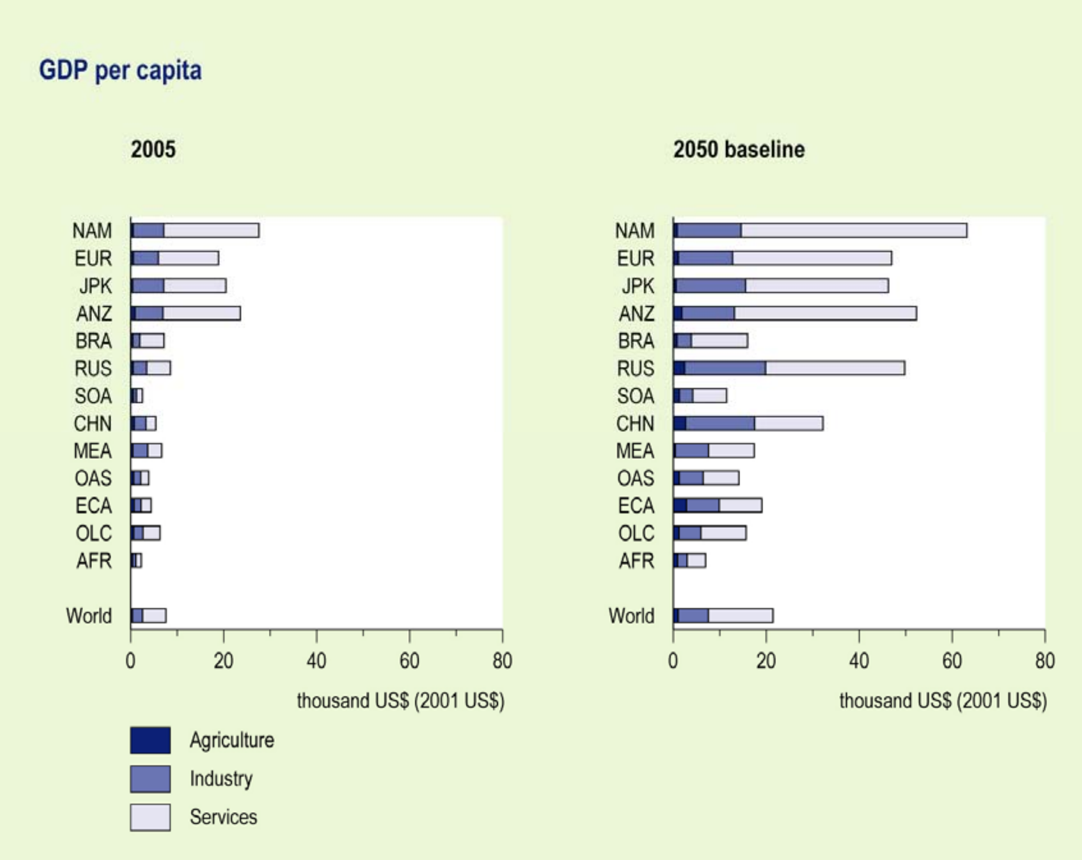


Figure 3.5 Sectoral value added, baseline

Figure 3.5 shows also that the increase in GDP per capita is especially fast in Russia, China and India. Details are given in chapter 3 Economic Development of the outlook main report.

In most regions, imports and exports have grown faster than the regional economy in general, as measured by GDP. To the extent that this is the result of explicit policies on tariffs and quotas, the Baseline assumes no new policies and therefore a gradual levelling off of the rate of trade growth. Thus, eventually, the Baseline features trade growing at just the same rate as the economy in general. This is shown in *figure 3.6*, depicting imports relative to GDP.

Against the background of a wider notion of uncertainties for the outlook, the key uncertainties have been identified in the three driving forces of the economic Baseline. Most importantly, a variant was explored for the recent history to which the Baseline is grafted. The Baseline evolves from growth rates in the 1980-2000 period.

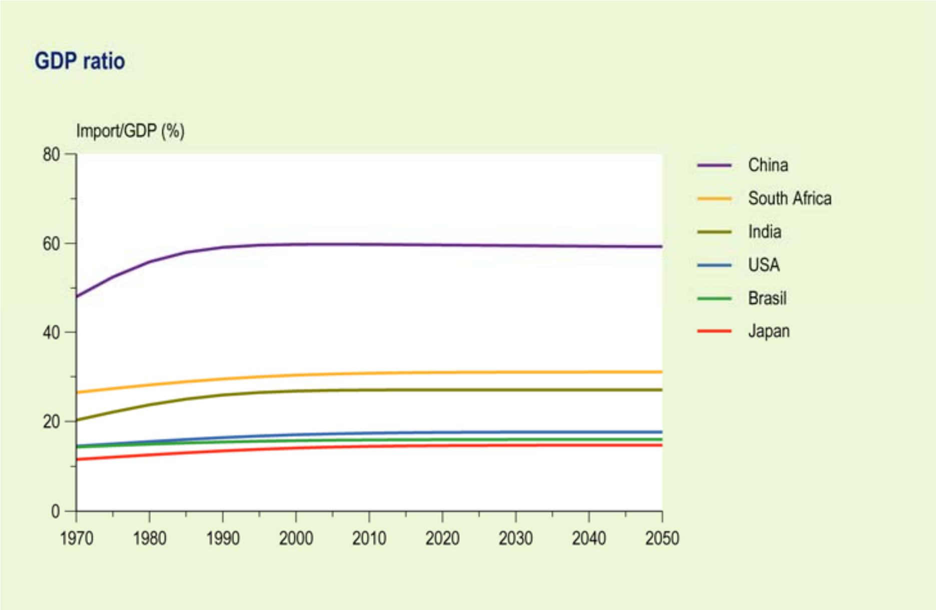


Figure 3.6 Imports in proportion to GDP, baseline

In contrast, the variant is derived from five-year growth rates around the year 2000 – for important countries a period of fast growth. Key lessons are:

- In a no-new-policies future, the volume of economic activity can be less, but also much more than projected as Baseline. The latter could happen if productivity trends in coming decades resemble the past few years, rather than the past two decades. Activity volumes in BRIC countries in particular may be larger.
- Autonomous developments such as a further decrease in transportation cost (money-wise or time-wise), could increase international trade more than projected in the Baseline. This can influence location as well as spatial distribution of production.

3.2.3 Energy use

The energy consumption for the OECD Baseline follows more-or-less the 2004 World Energy Outlook scenario of the International Energy Agency, adjusted for small differences in economic growth assumptions of this Baseline and for the higher energy price trajectory adopted from WEO 2006. This implies that final energy consumption increases from 280 EJ in 2000 to 470 EJ in 2030, somewhat faster than the historic trend. This is due to (1) specific events that have slowed down energy consumption in the last decades, e.g. the energy crisis in the OECD, the economic transition of the countries of Central and Eastern Europe, the Caucasus and Central Asia, and the Asia crisis, and (2) the increasing weight of developing countries, with typically higher growth rates, in the global total. While OECD countries accounted for more than half of the energy consumption in 2000 (53%), their share drops by 10 percentage points in 2030. In absolute terms, the energy consumption in BRIC and ROW groups roughly doubles until 2030. (Figure 3.7)

The oil price in the Baseline reaches a level of 60 US $ per barrel in 2005. After a slow relaxation to 45 $ per barrel around 2020 it climbs, as a result of depletion, to a value of just over 60$ per barrel in 2050. The relatively high price of oil leads to a lower share for oil products in final energy, partly replaced by modern bio-fuels in the transport sector. Coal use increases slightly, as the price differential with oil and gas makes it attractive for large industrial users to burn coal. This offsets the ongoing trend in the residential and services sector in OECD countries– where coal use is gradually phased out. Natural gas keeps its market share and, as observed in the past, the share of electricity in final energy use keeps increasing to reach 23% in 2030 (from 17% in 2000). All this must be considered again in view of the current oil prices (more than 100 US$ per barrel). All sorts of shifts may happen in the short and medium run, such as consumer reactions to fuel prices, slowing down of the phasing out of coal etc.

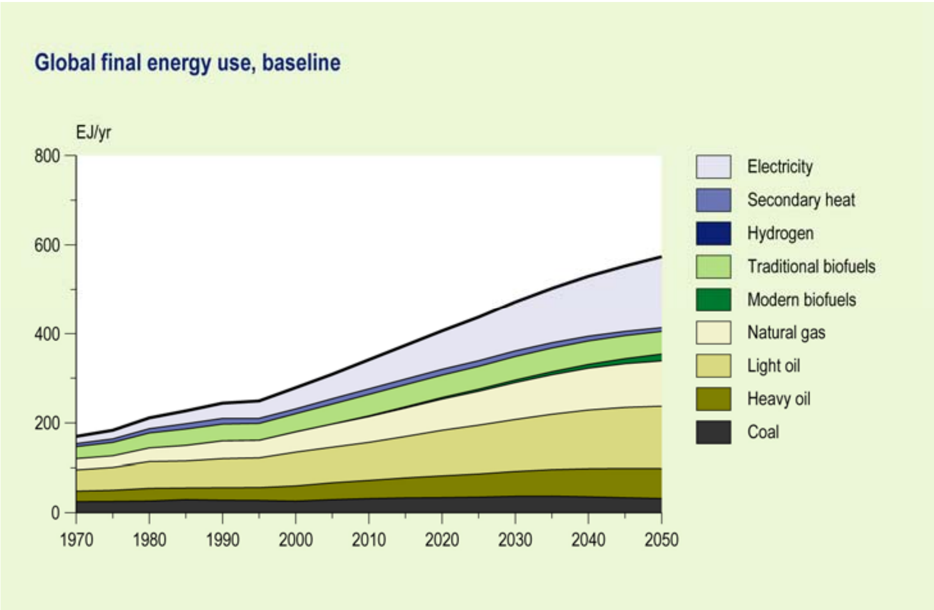


Figure 3.7 Final energy use by energy carrier, baseline

In the power sector, the main trend of the past decade is replacement of coal as the dominant fuel by natural gas, driven by the low investment costs, high efficiency and favourable environmental performance of combined cycle plants. Exceptions are regions with ample access to relatively low-cost coal and limited access to natural gas supplies, such as China and South Asia. As a result of the assumed continuation of high oil and gas prices, coal becomes the fuel of choice in practically all regions. The growing share in electricity generation plus the modest increase in final consumption imply that total coal use increases by 2.1% per year on average. Oil consumption, strongly driven by the transport market, grows by just over 1% per year. The continued high price of oil induces introduction of alternative transport fuels, mainly produced from bio-energy. Natural gas use grows by 2.3% per year between 2000 and 2030. Non-fossil power generation increases slightly, but on aggregate fossil fuels retain their high share (84% both in 2000 and 2030). Among the non-fossil resources, use of modern biofuels and renewables expands the most, together supplying 11% of global electricity in 2030.

3.2.4 Agricultural production and consumption

Up to 2030, it is projected that global agricultural production will need to increase by more than 50% in order to feed a population more than 27% larger and roughly 83% wealthier than today's. Although it is assumed that productivity of land will increase substantially, the global agricultural area will have to increase by roughly 10% to sustain this production (*figure 3.8*). After 2030, the growth in crop area slows down, mainly due to a reduced population growth.

In developing countries, agricultural production is growing four times faster than in OECD countries, due to faster economic and demographic change, and availability of new agricultural areas. In OECD countries, per capita consumption of agricultural products is almost stable, while it is projected to grow by 70% in developing countries to 2030. Trade, however, plays an important role for some countries and commodities. In general, countries with a high population growth have increasing imports and decreasing exports.

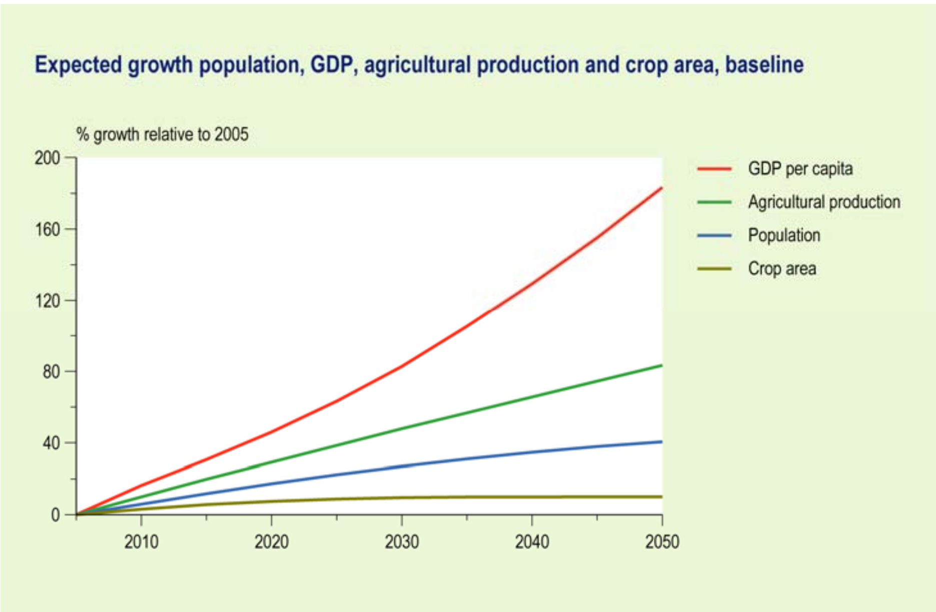


Figure 3.8 Growth of world population, GDP per capita, agricultural production and crop area; baseline

The largest part of the increase in agricultural production, as shown in detail in *figures 3.9 and 3.10*, can be explained by an increasing domestic demand.

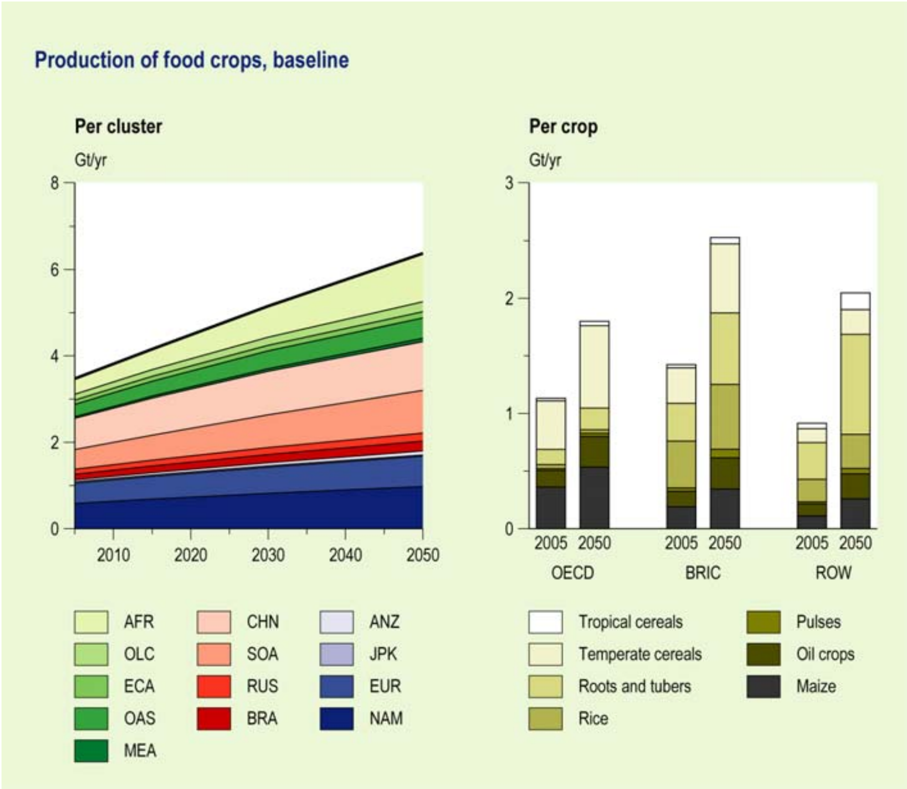


Figure 3.9 Production of food crops baseline

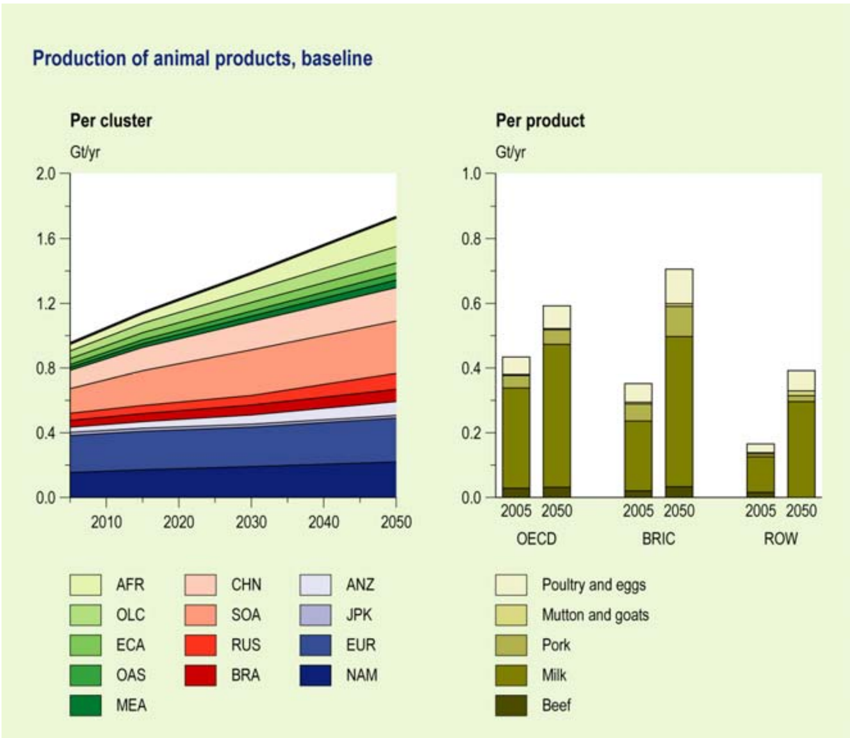


Figure 3.10 Production of animal products, 2005-2050, baseline

Oilseed production is projected to grow about 50% faster than overall average agricultural production to 2030. This growth is boosted not only by growing demand for vegetable oils for human consumption, but also for oilseed meal for feeding animals and for bio-diesel production. Oilseed trade is also projected to outstrip the trade in grain. The most important importer of oilseed is expected to continue to be China, which will double its imports from 2001 to 2030. The leading exporters are the United States and Brazil, with the United States almost tripling its oil seed exports by 2030.

3.2.5 Economic and social drivers of change in marine and coastal ecosystems

Marine products are used in developed economies as a luxury food and for subsistence in many coastal communities, but also as feed for aquaculture, pets and livestock. It is the relatively high prices for these products, combined with subsidies, that make aquaculture in coastal zones a feasible industry. The price of fish has increased in real terms while the price of red meat has dropped over the last 20 years. The result is that increasing scarcity, rather than causing a relaxation of pressure on the remaining remnants of the resource, acts to increase incentives to harvest the remaining individuals. On top of that, the, until recently, low price of fuel keeps fisheries in business. Within 10–15 years of starting to exploit a new fishing area, industrial fisheries tend to have seriously reduced the biomass of the resources. This process is often accelerated by encouragement from governments to diversify fisheries, often resulting in fleet overcapacity and a drive to exploit new or "unconventional" species. New technologies, while improving the safety of people working at sea, also allowed fishers to aim for specific places with high fish abundances, places that once were protected by the depths and vastness of the oceans. Much of the fish caught in the developing world (about 50% of the market value) is exported to countries in the developed world, which have thus been able to buffer against declines in fish availability and increases in prices. A benefit of globalization is the improved quality of fish that reaches the market, because most importing countries demand that exporting facilities meet safe food processing and handling standards. The associated benefits have been mainly to industrial countries, however. In developing countries, benefits have been limited MA(2005b).

3.3 The Baseline Scenario: Pressures

3.3.1 Introduction

In the DPSIR framework (see Chapter 2), the most important pressures on ecosystems and biodiversity are conversion of "pristine" ecosystem land cover to other forms of land use, climate change, air pollution and water use. These, and pressures on marine and coastal systems are discussed in this section.

3.3.2 Land use

The expected rise in agricultural productivity is not enough to meet the increasing demand. As a result, the global agricultural area will increase by roughly 10% to sustain this production (16% increase for food crops, 6% increase for grass and fodder, and 242% increase for biofuels). After 2030, the growth in crop area is slowing down, mainly due to a reduced population growth. Total land used is projected to increase in all regions except Japan and Korea. In South Asia, there could be additional loss of remaining forest areas (both tropical and temperate), savannah and scrubland. In Europe, much of the additional land for agriculture is expected to come from its eastern regions – a reversal of the trend during the past 15 years whereby land has been taken out of agriculture in these regions.

The increasing demand for agricultural products results both in an intensification of agriculture (more output per unit of land), and in an expansion of agriculture. *Table 3.2* presents the change in land used for agriculture between 2005 and 2030 as projected in the Baseline. *Figure 3.11* depicts the changes between 2000 and 2050. Total land used for agriculture, including crops, grass and energy crops, is projected to increase in all regions except Japan and Korea, mostly at the expense of remaining forest areas (both tropical and temperate), savannah and scrubland. In Europe, the increase is caused by an expansion of agricultural area in Turkey, while in West and Central Europe land continues to be taken out of production. After 2030, agricultural areas are roughly stable or decreasing in all regions except for Africa and Oceania.

Table 3.2: Change in land used for agriculture in 2030, baseline

North America	Europe	Japan Korea	Australia New Zealand	Brazil	Russia	South Asia	China	Middle East	South East Asia	Caucasus & Central Asia	Other Latin America	Africa	World
104	105	83	104	108	115	124	101	100	127	104	109	118	110

Note: Index 2005 = 100 ; if indexed at 2000=100 the world 2030 change would be 114.

The Baseline projects a considerable expansion of agricultural land in Africa, driven by population growth and relatively fast increases in food demand. A considerable part of that expansion is likely to occur in arid areas, contributing to the risk of desertification which happened already over the last few decades. The change shown for Europe is mostly in Turkey, where a significant expansion is projected in the Baseline. In Brazil, the small amount of agriculture that is in arid zones is gradually being phased out in favour of other, more profitable, areas. The results for Russia and South Asia are explained by a general expansion of agriculture, but because South Asia can only expand into arid zones, the environmental impact is greater there.

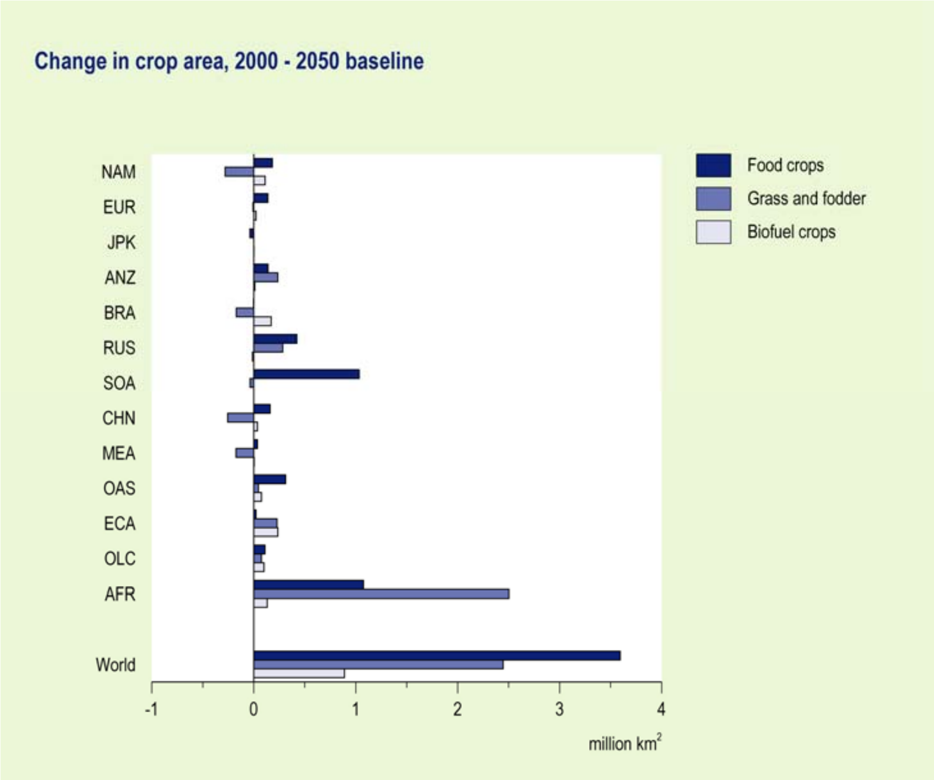


Figure 3.11 Change in crop area, 2005-2050, baseline

Another important environmental effect of global land-use change is the resulting CO_2 emission from biomass and soil stocks, following conversion of forests to cropland and grassland in (mostly) tropical regions. One of the currently promoted options is increasing the share of biofuels. Using mostly first generation crops, this option will lead to competition for land with agricultural crops and to further land conversion, as discussions at the IMF meeting in April 2008 illustrate. The role for biofuels in the baseline is limited. The projection takes a long-term perspective and only deals with second generation biofuels. In many regions, there is considerable potential for policies and market mechanisms to improve agriculture's efficiency of water use, making it environmentally sustainable. Of critical importance for land-use are the possibilities to continue the yield increase per hectare. The following Baseline assumptions are relevant for the development of land-use:

- There is a continued growth of trade, but it stabilizes relative to GDP (i.e. the proportion of goods and services that are traded internationally does not change). This is relevant for interpreting land-use projections, as the baseline does not show the effects of further liberalization of global trade. Under assumptions of tariff reform, total agricultural land use would increase in 2030 to almost 12%. There is considerable regional variation, such as increases in especially Brazil and parts of Southern Africa and decreases in especially those OECD countries with high tariffs. In a scenario study for the 2nd Global Biodiversity Outlook (CBD, 2007), global biodiversity decreased due to trade liberalisation, mainly as a result of shifting production to regions with lower production costs but with a lower agricultural productivity than in OECD countries.

- The trends for agricultural yields were largely adapted from the FAO Agricultural Outlook to 2030 (FAO, 2006) where macroeconomic prospects were combined with expert views. The increase in agricultural productivity is average, in comparison with other much used scenarios (*see figure 3.12*). The use of biofuels in the baseline scenario is relatively low and does not present an important additional pressure on land-use.

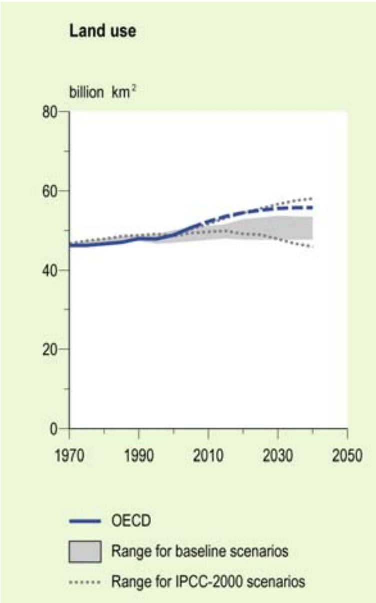


Fig. 3.12 Comparison of OECD baseline trends for land-use with several much used scenarios (grey area is for baseline scenarios without policy development).

The land use changes in the OECD Baseline scenario were calculated with the IMAGE model framework, specifically the LEITAP model and the IMAGE core model working together (see Box 3.1).

3.3.3 Climate change

Globally, carbon dioxide emissions from fossil fuel combustion increase under Baseline conditions from 7.3 GtC in 2000 to 12.5 GtC in 2030 and 14.7 GtC in 2050. Among the energy-related emissions, those from electric power generation and transport are the largest and also increase the most over the Outlook period. Per capita emissions in OECD countries remain much higher than for most non-OECD countries. Total global greenhouse gas emissions amount to 11.5 Gt C-equivalent in 2000 and are projected to be 17.5 Gt C-equivalent in 2030.Whereas emissions from OECD increase by nearly one-third (1.4 GtC) from 2000 to 2030, emissions from BRIC and Rest of the World nearly double over the same period and their share in the global emissions increases from 57% to 64%. These Baseline emissions would lead to a temperature increase of nearly 1.9 degrees Celsius above pre-industrial level by 2050. With higher temperatures, the hydrological cycle is also intensified as more water evaporates and on the whole more precipitation results. As with the temperature pattern, the effect is very unevenly distributed. In already water-stressed areas such as southern Europe and India, the negative impact on agriculture and human settlements can be substantial. Areas with substantial increases over already high levels in 2000 are more susceptible to run into water drainage or flooding problems. In general, all areas facing considerable changes in surplus will have to adapt to cope with these changes, including through adjustments in water management practices and/or infrastructure.

Box 3.1: The IMAGE framework of models: Land use and land cover (source: OECD 2008)

Agricultural land supply and use: LEITAP
The LEITAP model, named after the Agricultural Economics Institute (LEI) that developed and applies it, is an extended version of the GTAP model developed at Purdue University. A more detailed description of LEITAP is included in the background report to the *OECD Environmental Outlook* (Bakkes & Bosch, 2008); an example of a stand-alone application can be found in Francois *et al.* (2005).

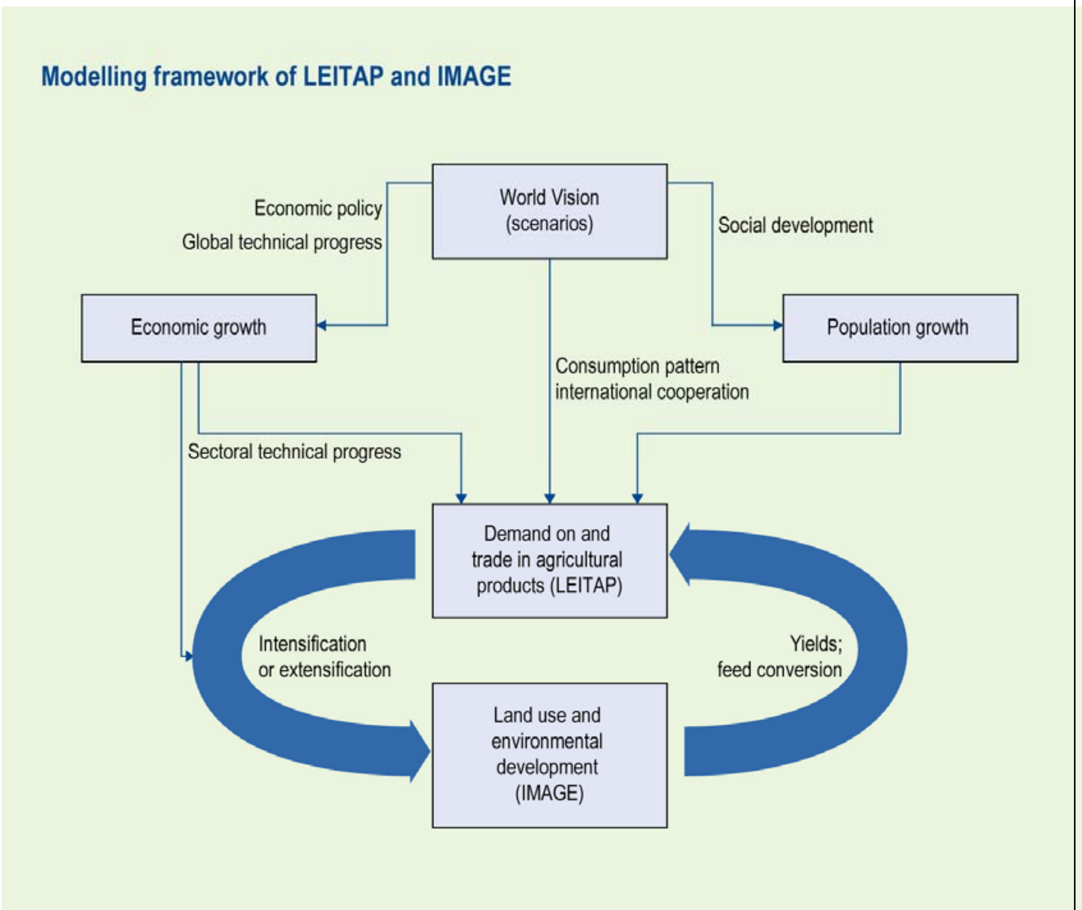
The base version of GTAP represents land allocation in a structure of constant elasticities of transformation, assuming that the various types of land use are imperfectly substitutable, but the substitutability is equal among all land use types. LEITAP extends the land use allocation structure by taking into account the fact that the degree of substitutability of types of land differs between types (Huang *et al.*, 2004). It uses the more detailed OECD's Policy Evaluation Model (OECD, 2003) structure. This structure reflects the fact that it is easier to shift land between producing crops like wheat, coarse grains and oilseeds, than between land uses like pasture, sugarcane or, even more so, horticulture. The values of the elasticities are taken from OECD (2003).

In the standard GTAP model the total land supply is exogenous. In LEITAP the total agricultural land supply is modelled using a land supply curve which specifies the relationship between land supply and a land rental rate in each region. Land supply to agriculture can be adjusted as a result of idling of agricultural land, conversion of non-agricultural land to agriculture, conversion of agricultural land to urban use and agricultural land abandonment. The concept of a land supply curve has been based on Abler (2003). The general idea underlying the land supply curve specification is that the most productive land is first taken into production. However, the potential for bringing additional land into agriculture is limited. If the gap between potentially available agricultural land and land used in the agricultural sector is large, the increase in demand for agricultural land will lead to land conversion to agricultural land and a modest increase in rental rates to compensate for the cost of bringing this land into production.

The land supply curve is derived using biophysical data from the IMAGE modelling framework, described below. In the IMAGE model, climate and soil conditions determine the crop productivity on a grid scale of 0.5 by 0.5 degrees longitude-latitude. This allows spatially heterogeneous information on land productivity to be fed into the agro-economic model with LEITAP. In practice, land use change projections are iterated between LEITAP and the IMAGE until a stable solution is reached — typically one iteration is enough. Land supply functions differ between region according to survey results on land type supply constraints.

Land use and land cover from an environmental point of view: IMAGE
The IMAGE model is geographically explicit in the description of land-use and land-cover change. The model distinguishes 14 natural and forest land-cover types and 6 man-made land-cover types. The land use model describes both crop and livestock systems on the basis of agricultural demand, demand for food and feed crops, animal products and energy crops. A crop module based on the FAO agro-ecological zones approach (FAO, 1978-1981) computes the spatially explicit yields of the different crop groups and the grass, and the areas used for their production, as determined by climate and soil quality. Where expansion of agricultural land is required, a rule-based "suitability map" determines the grid cells selected (on the basis of the grid cell's potential crop yield, its proximity to

other agricultural areas and to water bodies). An initial land-use map for 1970 is incorporated on the basis of satellite observations combined with statistical information. For the period 1970-2000, the model is calibrated to be fully consistent with FAO statistics. From 2000 onwards, agricultural production is driven by the production of agricultural products as determined by LEITAP and demand for bio-energy crops from the TIMER model. Changes in natural vegetation cover are simulated in IMAGE 2.4 on the basis of a modified version of the BIOME natural vegetation model (BIOME, Prentice, 1992). This model computes changes in potential vegetation for 14 biome types on the basis of climate characteristics. The potential vegetation is the equilibrium vegetation that should eventually develop under a given climate (Bouwman et al., 2006).



Modelling of change in agricultural land use

3.3.4 The nitrogen cycle

With the assumed increase in fertilizer use efficiency, most industrialized countries and developing countries with a current surplus (India, China) show a decrease of total Nitrogen (N)-inputs per hectare of agricultural land, while many developing countries with a current deficit show an increase. However, due to expanding agricultural areas this increase is often small. Gradually the N-inputs in the form of fertilizers, animal manure and biological N-fixation have increased in most developing countries and will continue to do so in the coming three decades. Hence, agricultural systems with N-deficits gradually change into systems with N-surpluses, leading to growing losses of reactive N to the environment. At the same time, there is an increasing efficiency of the agricultural system as a whole. It depends on the relative importance of each of these developments (intensification, increasing efficiency) whether the loss of reactive N will increase or decrease.

Although the livestock production in OECD decreases somewhat between 2000 and 2030 (and associated manure production even more by higher efficiency), fertilizer use increases as a consequence of the strongly increasing crop production for all crops, and the assumption that the fertilizer use efficiency is the same as that assumed in the FAO-Agriculture Towards 2030 study and follow-on work (FAO, 2006). The overall result is a slightly decreasing (3% less than in 2000) total ammonia emission in the Baseline. However, the ammonia emission per hectare is constant (or a minimal increase), due to the fact that the agricultural area shrinks somewhat (also a minimal change) by assumed productivity growth. For ammonia volatilization the assumption is that manure is incorporated in arable land, and broadcast in grassland. For stables, there are no additional emission reduction techniques included in the calculation.

Typical of non-OECD regions, the improvements in treatment of sewage are not enough to keep up with the increased access to sanitation and connection to sewerage. This problem is foreseeable for the Baseline but also in the case of acceleration of environmental policies. At the same time, an even larger load of nutrients originates from agriculture. As a result, for the regions Other Asia and Africa, a marked deterioration of the nutrient load on aquatic systems is projected precisely under the conditions of a global environmental policy package.

On the basis of the Baseline projections for agricultural production, deposition from the air and urban sewage, the global quantity of reactive nitrogen exported by rivers to coastal marine systems will increase by 4% in the coming three decades. While the nitrogen export by rivers will decrease by about 5% in OECD countries, an 11% increase is projected for the BRIC countries and 2% in the Rest of the World. This is a continuation of the trend observed in the past decades. There are, however, large differences between regions. For example, fast increases in nitrogen loads will occur according to the Baseline in India and Middle East, with a somewhat slower increase in China.

3.3.5 Pressures which are not included in the GLOBIO model.

In the modelling exercise to assess changes in Biodiversity factors such as air pollution and water use are not included (yet). In the cases, discussed in chapters 4, 5 and 6, the quality of ecosystems, ecosystem services and the economic value may however be affected by these pressures. A short summary of the baseline scenario results is therefore given here.

Air pollution
In the Baseline the global totals of emission of sulphur dioxide and nitrogen oxides remain almost unchanged between now and 2030 (*Figure 3.13*). However, the

regional contributions to the global total change drastically over this period, decreasing in OECD countries,-reflecting the progress in abating air pollution-, stabilizing in the BRIC countries and increasing in the rest of the world where the institutional capacity or the financial resources to control air pollution are still insufficient. Compared with the global projection by IIASA (Cofala et al., 2005) the OECD Baseline features larger emissions in the base year as well as in the future, reflecting a less optimistic view on industrial emissions outside OECD countries. The development over time is very similar. Both projections are lower than those of the IPCC (2000), reflecting newer insights in the most plausible development of emissions sulphur and nitrogen oxides under Baseline conditions.

Key uncertainties include the future use of coal worldwide, quantity as well as technology; use or non-use of existing abatement equipment in power plants in China; and industrial emissions for example from metallurgy in Russia. The focus of the OECD environmental outlook regarding air pollution is on the future air quality on over 3000 urban agglomerations worldwide. It analyses the associated impacts on population health, in conjunction with urbanisation and ageing. This line of analysis is not included in this COPI study, but the contributions of ecosystems in improving air quality are (see Chapter 5).

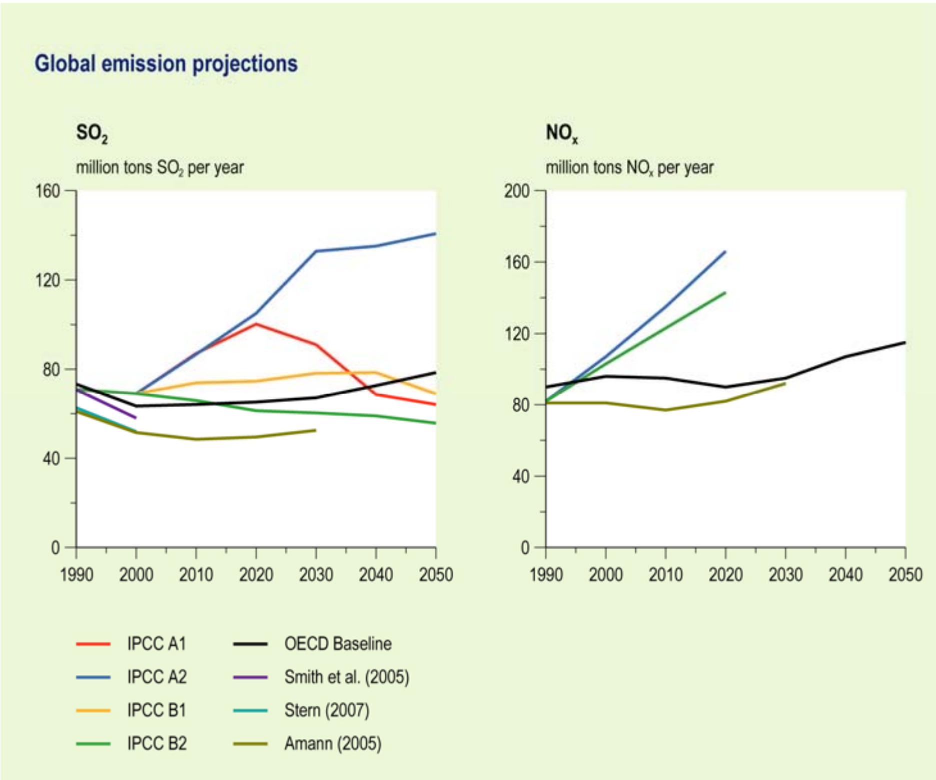


Figure 3.13 Global baseline emissions of sulphur dioxide and nitrogen oxides

Water issues

The Baseline simulation for water demand reveals a considerable increase of about 26% for overall water withdrawals between 2005 and 2030 (see *Table 3.3*). In almost all regions overall water demand increases, except in Canada and Japan (decrease of water withdrawals of -6% and -11% respectively). Especially in Central and South America, in Western Africa, Ukraine and in many parts in the South East Asia water, demand increases by more than 40%.

Table 3.3 Water use, baseline

	2005	2030	change 2000-2005
	km³		%
North America	639	679	1.1
OECD Europe	484	588	8
OECD Asia	61	75	8
OECD Pacific	34	37	3
Brazil	39	99	10
Russia & Caucasus	153	187	17
South Asia	1283	1713	-0.3
China region	689	1460	5
Middle East	236	342	5
Other Asia	163	382	14
Eastern Europe & Central Asia	134	155	4
Other Latin America & Caribbean	121	214	4
Africa	192	343	1.4
World	**4230**	**6275**	**3.5**

OECD Environmental Outlook modelling suite, final output from IMAGE cluster (WaterGAP)

In Indonesia and Western Africa water use doubles, however with medium or low contribution to the global demand. In contrast, in the two countries with the largest overall water use, namely India and China, water use increases less (18% and 49%, respectively). This is in both cases due to a larger water demand in the electricity and manufacturing sector, with smaller increases in the domestic sector and a decrease in water use for irrigation. Consistent with the expectation in the Comprehensive Assessment on Water Management (Molden, 2007), it is assumed that irrigated area does not expand much. The room for change in irrigation globally is in efficiency of water use in existing systems rather than in expanding irrigated areas. Hence under the no-new policies Baseline, the total amount of water withdrawn for irrigation does not change, up to 2030. At the same time, water use in the electricity and manufacturing sectors increases considerably. The increase in total water demand together with the envisaged growth of the population in affected areas will increase the number of people living under water stress (see *figure 3.14*).

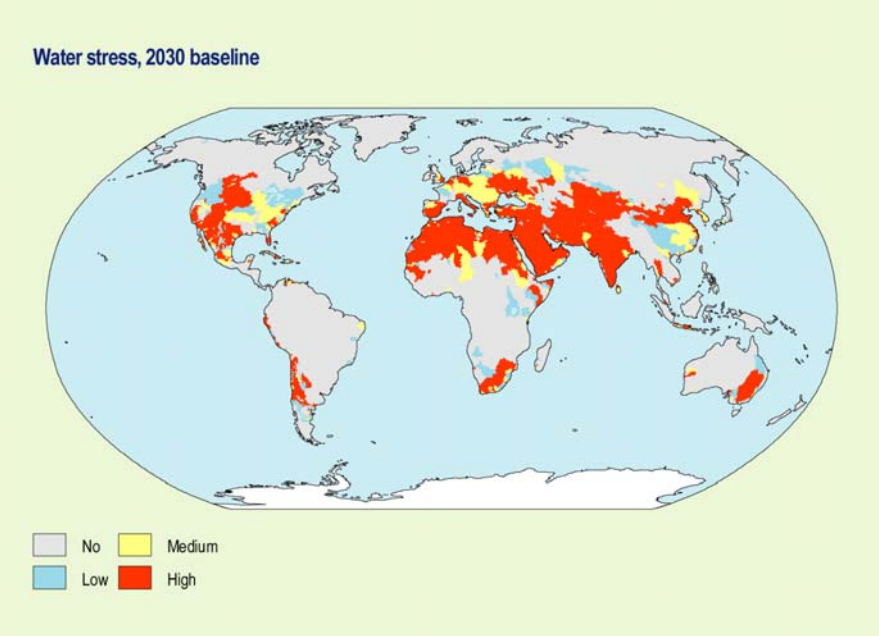


Figure 3.14 Water stress areas in 2030, baseline

3.3.6 Pressures on the marine and coastal ecosystems

Climate change is an important pressure in marine and coastal systems. Change in climate and weather influences oceanic processes. Changes in currents may result in changes in population abundance and distribution for many marine species. Habitat changes in coastal systems are a major cause of fisheries declines. Some coastal habitats have been converted to mangroves for coastal aquaculture ponds or cage culture of high valued species such as shrimp, salmon, or tuna. Such conversions affect wild-capture fisheries, which use these coastal habitats for part of their life cycle. Other factors of importance are invasive species, pollution, and disease. Moreover, persistent and widespread misconceptions about the ability of marine fish populations to withstand and recover from fishing continue to undermine initiatives to address the root causes of these problems (MA, 2005b)

3.4 The Baseline scenario: policy landscape

3.4.1 Introduction

Policy elements influencing biodiversity play an important role in the Baseline scenario. The Baseline builds on the current state-of-play assuming that no new policies are adopted in direct relation to biodiversity, including extra enforcing of existing policies. Moreover, as all scenarios do, the Baseline deals with a general and highly stylised picture of the current situation and foreseeable trends, and it does not make explicit links with individual policies or policy instruments. In other words, the Baseline has not been developed with a reference to any specific policy element but it is rather based on more generic considerations of the policy and non-policy related attributes and their foreseeable effects on land and resources use. Nevertheless, for orienting "inaction" in a policy context, this section first sketches the landscape of relevant policies. Then, it places a few markers pointing out - approximately – the position of the Baseline.

The policy "landscape", influencing current and future trends in biodiversity and ecosystem services, can be broadly considered to consist of two types of elements: (1) policies (including legislative instruments) that are specifically aimed at supporting the conservation and maintenance of biodiversity, and (2) policies with adverse impacts on biodiversity and ecosystems (see *figure 3.15*). In general, the observed trends in biodiversity and ecosystem services are a result of the interplay between these "pro and against" biodiversity elements of the policy landscape, combined with a number of non-policy dynamics affecting the land- and resources use, such as population growth and environmental factors.

The policies with negative biodiversity impacts form one of the main reasons behind the current loss of biodiversity and related services. They include different sector policies that stimulate unsustainable use of land and natural resources, resulting in increased pressure on biodiversity and related ecosystem services. In addition, the lack of pro-biodiversity policies and legislative instruments, including limited effectiveness and implementation in securing the conservation and sustainable use of biodiversity is also an important cause of loss.

There is not always a sharp distinction between – on the one hand - development in policies with a peripheral connection to biodiversity and – on the other hand - outright uncertainties. Therefore, this section includes comments on the latter as well.

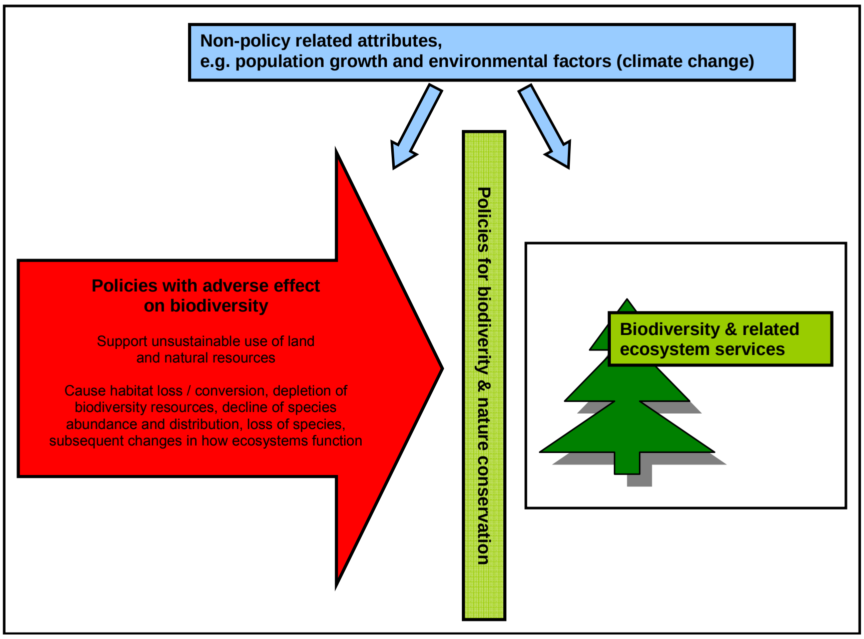


Figure 3.15 Policy and other attributes influencing trends in biodiversity and ecosystem services

The *Tables 3.4 and 3.5* identify the most relevant policy sectors, with specific policy and legislative elements and instruments, which influence the trends in biodiversity and ecosystem services supply. *Table 3.4* presents an overview of the key international, EU and national instruments currently in place to support the conservation and maintenance of biodiversity whereas *Table 3.5* outlines the major policy sectors with known negative effects on biodiversity. The latter table also summarises the main pressures these policies create on biodiversity.

3.4.2 Policy landscape affecting trends in biodiversity and ecosystem services: Pro-biodiversity policies

The existing pro-biodiversity policies (*Table 3.4)* differ as regards their implementation "power" and subsequent effectiveness. In general, the most effective biodiversity policies are the ones supported by legally enforceable instruments. These include, in Europe, the national and EU nature conservation policies that are supported by legislative frameworks for the establishment of *protected areas*. However, the majority of the existing national and regional "pro-biodiversity" policies in the world lack legal force, in particular those policies aiming at protecting biodiversity and ecosystem services outside protect areas.

Even when such instruments exist, e.g. the legal instruments supporting the sustainable use of biodiversity in the context of agricultural and fisheries policies, the political will and resources for their implementation and enforcement seem inadequate. Consequently, their actual positive contribution to biodiversity conservation is at present limited and to a large extent blocked by policy elements that continue to support unsustainable use of natural resources. Additionally, the existing instruments might fail to address the actual current biodiversity related threats within the sectors. For example, the environmental measures within the EU Common Agricultural Policy (CAP) are mainly directed to decrease agricultural intensification and they fall short on addressing the increasing problem of land abandonment

A number of international pro-biodiversity instruments, such as conventions and agreements, exist. Several of these are legally binding in terms of international law. However, in order to take effect, international law needs to be adopted in national and regional level legislations. Thus, the real value of international biodiversity related agreements depends on creating enough political impetus for their effective uptake, which is at present limited. Some international agreements have, however, created more concrete and enforceable international mechanisms for their implementation. For example, the WTO Agreements are supported by the Dispute Settlement Body that has legislative powers to ensure the proper implementation of the WTO trade rules. Similarly, the Kyoto Protocol functions as a concrete mechanism for the implementation of the UN Framework Convention on Climate Change. These types of mechanisms are absent in the current international biodiversity policy framework, thus it appears rather toothless in the face of existing policies supporting unsustainable use of land and natural resources.

In addition to issues related to enforceability, the availability of financial resources is often a bottleneck for implementation of "pro-biodiversity" policies. Conservation of biodiversity and ecosystems still generally looses out to financing policies focusing on short-term economic growth. Securing adequate financing can be identified as one of the main factors jeopardising the effective implementation and management of the current national and regional protected area networks, particularly in the developing world.

Table 3.4 Overview of international, EU and national policies (e.g. legislative and policy instruments) with positive contribution to the conservation and sustainable use of biodiversity (Note: includes examples of main policy elements; it is not an exhaustive list)

International	EU	National
Biodiversity & nature conservation policy	Biodiversity & nature conservation policy (see (1) in section 3.4.4.)	Biodiversity & nature conservation policy
International binding agreements • **UN Convention on Biological Diversity (CBD)** • **Cartagena Protocol on Bio safety** • **Ramsar Convention** • **Convention on the Conservation of Migratory Species of Wild Animals (CMS)** • **Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)** • **International Plant Protection Convention (IPPC)** • **Convention on the Conservation of European Wildlife and Natural Habitats (the Bern convention)** International non-binding agreements • **Pan-European Biological and Landscape Diversity Strategy (PEBLDS)** • **Political resolutions on biodiversity (2004 Kyiv Resolution on Biodiversity; 2007 G8 Potsdam Initiative on Biological Diversity)** • **Biodiversity related action plans, Codes of conduct and best practise etc. by organisations such as UNEP, IUCN etc.**	Legislative instruments • **Habitats & Birds Directives (e.g. official Guidance Documents for implementation)** • **EU Wildlife Trade Regulations** Policy instruments • **EU biodiversity policy and the 2006 Biodiversity Action Plan** • **Different non-binding Community Guidelines for the implementation of Habitats and Birds Directives and other elements of the EU biodiversity policy**	Legislative instruments • **National legislation for biodiversity and nature protection, e.g. in the EU national implementation of Habitats & Birds Directives** Policy instruments • **National biodiversity policies, Action Plans and guidance documents**
Biodiversity elements within other policies	Biodiversity elements within other policies	Biodiversity elements within other policies
International binding agreements • **UN Framework Convention on Climate Change**	**EU environmental policy** **<u>Legislative instruments</u>** • **Environmental Liability Directive** • **EIA and SEA Directives**	**Legislative and policy instruments for sustainable use and conservation of**

International	EU	National
Biodiversity & nature conservation policy	Biodiversity & nature conservation policy (see (1) in section 3.4.4.)	Biodiversity & nature conservation policy
(UNFCCC) • **UN Convention on the Law of the Sea** • **Convention on the Protection of the Marine Environment of the Baltic (HELCOM)** • **Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)** International non-binding agreements • **Political resolutions with included biodiversity as pecys, e.g. the 2002 UN Johannesburg Plan of Implementation on sustainable development** • **Action plans, Codes of conduct and best practise with biodiversity relevance etc. by authoritative organisations such as FAO UNEP, IUCN, International Council for the Exploration of the Sea (ICES)**	• **Water Framework Directive** • **Directive on the assessment and management of flood risks** • **EU Marine Strategy Directive *(to be adopted)*** **Policy instruments** • **EU Soil Thematic Strategy** • **EU Marine Thematic Strategy and Maritime Policy (*under development*)** • **Thematic Strategy on the Sustainable Use of Natural Resources** EU Common Agricultural Policy (CAP) **Legislative instruments** • **Cross-compliance Regulation** • **Financial support under European Agricultural Fund for Rural Development (EAFRD) to agri-environment measures** • **Regulation on organic production and labelling of organic products** **Policy instruments** • **EU Forest Action Plan** **EU Common Fisheries Policy (CFP)** **Legislative instruments** • **Provisions for conservation of fish stocks and marine ecosystems within the CFP Regulation** • **Financial support under European Fisheries Fund (EFF) to aqua-environment measures** • **Regulation on Using Alien and Locally Absent Species in Aquaculture** **Policy instruments** • **Action plan for the eradication of illegal, unreported and unregulated fishing (IUU)** **EU Cohesion Policy and regional development** **Legislative instruments** • **Financial support under European Structural and Cohesion Funds for conservation and sustainable use of biodiversity** **EU climate change and energy policy** **Policy instruments** • **EU policy for Climate Change adaptation *(under development, green paper 2007)*** **EU policies on development cooperation and external assistance** **Legislative instruments**	**biodiversity integrated into national sectoral policies:** • **environmental policies** • **agricultural policy** • **forestry policy** • **fisheries policy** • **regional development policy** • **climate change and energy policy** • **transport policy** • **policies regulating land-use and land-use planning** • **policies for development cooperation and external assistance** **In the EU, this includes national level implementation of relevant EU provisions – with the exception on land use planning as this falls under the full competence of the Member States.**

International	EU	National
Biodiversity & nature conservation policy	Biodiversity & nature conservation policy (see (1) in section 3.4.4.)	Biodiversity & nature conservation policy
	• **Financial support under the EU Development Cooperation Instrument (DCI), European Neighbourhood and Partnership Instrument (ENPI) and European Development Fund (EDF) for conservation and sustainable use of biodiversity** **Policy instruments** • **Thematic Programme for EU 2007-2013 External Action on Environment and Sustainable Management of Natural Resources (inc. energy)**	
Policy instruments not specifically addressing biodiversity but with potential to do so	Policy instruments not specifically addressing biodiversity but with potential to do so	Policy instruments not specifically addressing biodiversity but with potential to do so
International binding agreements • **United Nations Convention to Combat Desertification (UNCCD)** • **European Landscape Convention** International non-binding agreements • **UN Millennium Development Goals (MDGs)** • **Different regional agreements for sustainable development within river basins, mountain regions etc.**	Legislative instruments • **EU Regulations for animal and plant health (re: invasive alien species)** **Note: Additionally, all above mentioned sector EU legislative instruments could be used to protect biodiversity in more pro-active manner** Policy instruments • **EU Integrated Coastal Zone Management (ICZM) strategy** • **EU Sustainable Development Strategy** • **EU policies for chemicals and waste** • **Instruments Arhus Convention** • **Enterprise and industrial policies**	**All national legislative and policy instruments providing for environmental sustainability and sustainable development.** **Environmental education, e.g. awareness rising on the value of ecosystem services, could play an important role in changing unsustainable consumption patterns.**

3.4.3 Policy sectors with known negative effects on biodiversity

The list of policy sectors with known negative effects on biodiversity (*Table 3.5*) is long, including policies on agriculture, fisheries, trade, energy and climate change, transport and regional development. In general, these policies cause decline in biodiversity and ecosystem services by either failing to address or actively supporting unsustainable exploitation of natural resources.

Table 3.5 Overview of international, EU and national policies with negative effects on the conservation and sustainable use of biodiversity (Note: includes examples of main policy elements, thus it is not aimed to be an exhaustive list)

<table>
<tr><th>International</th><th>EU</th><th>National</th></tr>
<tr><td>High concern</td><td>High concern</td><td>High concern</td></tr>
<tr><td>Trade: WTO and regional trade agreements (see (2) in section 3.4.4.)
trade liberalisation increases unsustainable land-use practises in areas with high production and export potential, e.g. intensification of land-use and converting unused ecosystems into human activities
trade liberalisation causes extensive, small scale and biodiversity-friendly agriculture to die out in certain regions as the product cannot compete at the world market
trade liberalisation results in increased spread of invasive alien species
WTO agreement narrows the scope to introduce regional / national environmental standards for guaranteeing sustainability of imports</td><td>Climate change and energy policy (see (3) in section 3.4.4.)
The EU biofuels targets require increase in a) biofuels production in the EU and b) imports outside the EU. This can cause rapid land-use changes with negative effects on biodiversity both within and outside the EU.
Commission 2008 proposals for an EU policy package on climate and energy
Common Agricultural Policy (CAP) (see (4) in section 3.4.4.)
CAP direct aid to agricultural production (Pillar 1) continues to support intensive production oriented agriculture. This can increase water shortage (via irrigation) and the use of pesticides and fertilisers
The level of EU support to Pillar 1 continues to be significantly higher than to Pillar II (agri-environment measures)
Environmental measures within CAP are mainly directed to decrease agricultural intensification and they fall short on addressing the increasing problem of land abandonment
Common Fisheries Policy (CFP) (see (5) in section 3.4.4.)
CFP continues to inadequately address unsustainable exploitation of fisheries resources and destructive fishing practices (e.g. failures in implementation)
Fishing Agreements with third countries continue to support exhaustion of resources by EU vessels outside the EU leading more generally to unsustainable use of natural resources in these countries, e.g. increased use of bush meat
Cohesion Policy and regional development</td><td>Similar to EU, national policies / legislation contributing to unsustainable use of natural resources in the following sectors:
Land-use and land-use planning
Use of water resources
Energy (and climate change)
Agriculture, forestry and fisheries
Biotechnology and GMOs
Policies for industries, e.g. extractive industries
Tourism
Bi-lateral trade agreements between countries can cause similar effects than global trade liberalization.</td></tr>
</table>

International	EU	National
High concern	High concern	High concern
	• **Regardless of increasing potential for supporting sustainable development (e.g. biodiversity conservation), the support to regional development continues, to a large extent, to be focused on development of growth, jobs, industries and infrastructure with limited biodiversity considerations.** **Transport policy** • **Considering potential impacts on biodiversity and ecosystem services have a limited role in the EU transport policy** **Policies for extractive industries** • **Existing EU policies and legislation for extractive industries (e.g. EIA and mining Waste Directives) fall short in their implementation**	
Moderate / indirect concern	**Moderate / indirect concern**	**Moderate / indirect concern**
Investment policies, e.g. international and regional investment agreements • **International investment agreements, particularly in developing countries, often introduce low requirements for environmental standards and liability etc. to foreign investors. This means that possible negative effects of foreign investors' activities, such as environmental impacts of extractive industries, can be hard to control at national level.**	**EU budget (see (6) in section 3.4.4.)** • **The decline in the EU overall and Member State species budgets increases competition for financial support between different sectors. It is likely that this will decrease available resources for environment. For example, general cuts in the Community budget will reduce the financing for environment within CAP and CFP. These cuts are likely to take place first in agri / aqua – environment measures.** **Lisbon Strategy for Growth and Jobs** • **Political discussion on growth and development of jobs in the EU attention tend to lack the full consideration of the aspects of environmental sustainability** **EU internal trade** • **Free intra-EU trade makes it difficult to control the spread of invasive alien species within the EU** **Policies and legislation for biotechnology and GMOs** • **Adopting liberal legislation and policies on GMOs resulting in the spread of GMOs could pose threats to biodiversity**	**National policies and legislation regarding:** • **Investments** • **Security**

International	EU	National
High concern	High concern	High concern
	EU Development Policy and External Assistance • **Despite of increased integration of environmental (e.g. biodiversity) related aspects into EU development cooperation and external assistance at the policy level the EU financed activities continue to have adverse effect on biodiversity in the third countries.**	

There is a general lack of effective mechanisms to try to limit and control the pressures on biodiversity caused by increased and intensified use of land and resources. For example, national and regional legislative instruments to specifically address these pressures are scarce, particularly in the developing world, and they are fully lacking at the global level. Additionally, the implementation and enforcement of the existing instruments is often inadequate due to lack of financial resources. Failures in enforcement have been identified among the main reasons why the EU Common Fisheries Policy (CFP) continues to inadequately address unsustainable exploitation of fisheries resources and destructive fishing practices. Furthermore, several sector policies, both at national and regional level, still provide substantive incentives to support short-term economic growth at the expense of long-term environmental sustainability and maintenance of biodiversity. These include, for example, subsidies for agricultural production. By subsidising the production and exports of a number of agricultural products several countries have distorted the international markets and contributed to global overproduction. Additionally, a number of the supported products, such as sugar beet and sugar cane, need to be widely irrigated, with negative environmental effects, to ensure consistent quality and productivity.

The scale at which biodiversity relevant policies are adopted ranges from global to regional and national. Similarly, their impacts on biodiversity and related ecosystem services can take place at different scales. Naturally, the national and regional policies play an important direct role in defining the trends in biodiversity within the scope of their geographic jurisdiction. In addition, national and regional policies also often have an indirect effect on biodiversity and ecosystem services outside their actual geographic scope (so called external effects). For example, the EU biofuels targets adopted as a part of the Community's climate change and energy policy are foreseen to have major impacts on biodiversity, in- and outside Europe.

The national and regional trade policies can also influence global trends in biodiversity. In particular, provisions for trade in agriculture and fisheries (e.g. favourable treatments or protective tariffs) can have a significant effect on land-use patterns in a wide range of exporting and importing countries. For example, international free trade policies and bilateral trade agreements, combined with export oriented national policies, can cause countries to focus on exporting natural resources at the expense of securing sustainable supply of resources at national and regional level. Also, the EU Fishing Agreements with third countries continue to support exhaustion of resources by EU vessels outside the EU. This is known to lead to a wider unsustainable use of natural resources in these countries, e.g. increased use of bush meat.

Box 3.2: The special case of the global marine system

Subsidies

Financial subsidies are one of the most important drivers of over-fishing. Cheap-fuel subsidies can keep fleets operating even when fish are scarce. Without such subsidies, many of these fisheries would cease to be economically viable. Globally, the extent of the subsidies to the fisheries industry has been estimated from $20 billion to over $50 billion annually, the latter roughly equivalent to the landed value of the catch. The subsidies given to fisheries vary between countries. For instance, in 1997 Canada provided over $198 million in unemployment benefits to its fishing sector; the United States gave $66 million in tax exemptions, and the European Union provided subsidies of $155 million to obtain access to other countries fishing grounds (MA, 2005b). Each of these has the effect of either reducing the cost of fishing or increasing the net revenues, and hence they lead to more fishing than would have been the case without the subsidies.

Illegal Fishing

The profits of fisheries that operate outside of national and international laws and conventions can be very high. In some areas there is a lack of surveillance, enforcement, and monitoring due to high operational costs. In other areas corruption and cheating are tolerated due to the economic conditions or social obligations within a country.

Effectiveness of International Instruments

In 1982, the United Nations Convention on the Law of the Sea was initiated, to become an international instrument for wise use of the oceans: it espouses the right and need for coastal nations to monitor and manage their fish stocks. However, UNCLOS has not been very successful, as will be described in chapters 4, 5 and 6. It is even considered to have increased over-fishing problems, as it gave coastal nations the ability to declare a 200-mile EEZ. By many national governments this was seen an opportunity to expand their fishing industries. A few industrial countries managed to achieve some of the expected benefits by testing and adopting new management measures (such as limited entry and fishing rights), most others simply failed to realize them. Furthermore, the UNCLOS requires that coastal nations without sufficient fishing capacity are allowed to make their EEZ resources available to other nations. The reimbursements are, as is usually the case with exports of raw resources, less than the potential market value of the resource.

There is no integrated approach to managing ocean use. Marine protected areas (MPA) with no-take reserves at their core may re-establish the natural structures that have enabled earlier fisheries to maintain themselves, but they are slow in being established and hard to enforce.

While more than 100 fisheries access agreements (multilateral and bilateral) are currently used to manage access to marine resources, few are monitored or evaluated for their effectiveness, equitable access, and sharing of economic benefits. The European Union has initiated a monitoring program for the EU's Common Fisheries Policy, and other regional fisheries bodies are considering monitoring programs, but none have been developed to date.

The observed global trends in biodiversity and ecosystem services supply are, to a large extent, a sum of different policy outcomes as outlined above. In short, the continued loss of biodiversity projected by the Baseline scenario provides a strong indication that the biodiversity policy landscape continues to be dominated by policies sustaining unsustainable use of land and natural resources with negative effects on biodiversity. Even though policies supporting conservation and sustainable use of biodiversity exist they tend to lack enforceability and suffer from ineffective implementation.

The Baseline marked out in a landscape of policies and uncertainties
A dominating uncertainty is the rate of increase in economic activities. From the discussion of key variants to the economic Baseline (OECD, 2008 and Bakkes & Bosch, 2008) it is clear that the baseline is conservative. In particular, if the period around the year 2000 had been given more weight in constructing the baseline, as opposed to the 1980-2000 period, GDP per capita levels in countries like Brazil, Russia India and China would have been projected much higher. Historic trends are not the only ingredient for the economic baseline, but they constitute an important point of choice.

Although the modelling for this study is more nuanced than assuming a fixed relation between GDP and pressures on biodiversity, it should be noted that the uncertainty in the baseline leans to the side of more pressures on biodiversity. This by itself makes it more probable that the COPI assessment in this study errs on the side of underestimation, rather than overestimation.

(1) Regarding biodiversity policies such as Natura 2000, the implicit assumption in the Baseline is that its implementation will not substantially change current trends.
(2) As mentioned earlier in this chapter, regarding trade in agricultural products, the assumption in the Baseline is that there will be no major changes in the spirit of a new Doha round.
(3) Regarding climate change mitigation, three policy elements should be mentioned.
  (1) the Baseline assumes no post-Kyoto regime other than the policies in place and instrumented by 2005. For the EU, this means that the Commission's early 2008 package of proposals on energy and climate change policies is not included in the Baseline. Obviously, the proposals are for new policy – in contrast to the Baseline, which projects a 'no new policies' future. The existing trading scheme for emission credits (ETS) is included.
  (2) on biofuels the Baseline takes a long-term view and only considers second generation, woody, biofuels.
  (3) on the fuel mix worldwide, the Baseline is calibrated to the World Energy Outlook 2006 (IEA, 2006). This implies the assumption that domestic energy demand in Russia will be largely met with natural gas. However, current policy in Russia is to reserve natural gas for export. Together with the expected privatisation of the electricity sector, this makes a strong increase in the use of coal likely. On this point of coal use in Russia, too, the Baseline is conservative in terms of future pressures on the environment.

The time horizon of 2050 (2030 for some themes) has the effect of limiting the cumulative of climate change on biodiversity that is taken into account. This, too, has the effect of making the COPI estimate conservative. Explicit adaptation policies are not included in the baseline.

(4) An important assumption in the baseline is that agricultural productivity, in terms of yield per unit of agricultural area, can continue to improve over the coming decades. (See Figure 3.3 and Chapter 4.) This is in line with productivity trends of Agriculture Towards 2030 (FAO, 2006). Among other things, this would require the declining trend in worldwide investments in agriculture-related research and development to be at least halted. Implicitly, the baseline assumes this will happen. An additional important assumption is that there will be enough water to realize the productivity increases. The Comprehensive Assessment on Water Use in Agriculture (Molden, 2007) finds that this will be feasible but that it will require novel and wide-ranging new policy approaches that go beyond engineering. Thus, on these two important areas just outside the environmental domain – but consequential to it – the Baseline implicitly assumes new policies. They would have to happen in particular outside the current OECD countries. Moreover on agriculture and land use, the baseline includes no policies aimed at decoupling the increase of meat consumption from the increase of disposable income worldwide. Finally, the no new policies assumption is that the further evolution of the Common Agricultural Policy will not significantly alter the level of agricultural production support.

(5) The Baseline assumes that the EU Common Fisheries Policy, as well as equivalent policies in other world regions, remains in place and continues to be implemented as it is now.

(6) Regarding EU enlargement, the Baseline is agnostic. Policy implications such as a possible dilution of the budget are 'below the radar' of the worldwide assessment that the Baseline has been designed for. Developments in neighbouring countries relevant in this respect (Turkey, Ukraine region) have been modelled independently of the EU, using the 'no new policies' rule of the Baseline.

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4 Changes in biodiversity

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Summary

By the year 2000, about 73% of the original global biodiversity on land was left. The largest declines have occurred in the temperate and tropical grasslands and forests, the biomes where human civilizations developed first. There is a projected further biodiversity loss on land of about 11% worldwide between 2000 and 2050. The global annual rate of loss increased dramatically in the twentieth century, especially in Europe, in comparison to previous centuries. The expected loss rate for Europe seems to decrease but does not halt, while the global average still increases. By 2050, for the world as a whole, biodiversity is lost corresponding with an area of 1.5 times the USA changing from entirely natural to asphalt. With these loss rates, the global and European 2010 targets will not be met, not in 2010, and not in 2050. The number and extent of protected areas have been increasing rapidly worldwide in recent decades; they now cover almost 12% of global land area. However, the biomes represented in that coverage are uneven and global figures mask significant regional disparities.

Fishing pressure has been such in the past century that the biomass of larger high-value fish and those caught incidentally has been reduced to 10% or less of the level that existed before industrial fishing started. The loss of biomass and fragmented habitats has led to local extinctions. Those scenarios that used current trends or increased effort whether for commercial or recreational fisheries all indicated collapses in stocks and ecosystems; they differed only in their rates of decline and mankind is increasingly relying on fish that originate from the lower part of marine food webs. Different scenarios for depletion of fish stocks between year 2007 and 2047 all produce negative global mean values, indicating a further depletion of the marine biodiversity. There has been a substantial loss of estuaries and associated wetlands globally. Over the last 25 years, 3.6 million hectares of mangroves, about 20 percent of the total extent found in 1980, have disappeared worldwide In 1999, it was estimated that approximately 27% of the world's known reefs had been badly degraded or destroyed in the last few decades. While conversion to agricultural land was the major factor in historic biodiversity loss, the major increase between 2000 and 2050 in the respective contributors to the biodiversity loss are to found in the expansion of infrastructure and climate change.

4.1 Introduction

The COPI analysis is aimed at an estimate of the economic consequences of biodiversity loss. In this Chapter we present a qualitative and quantitative assessment of the expected future changes in biodiversity in ecosystems around the world, both terrestrial and marine. The assessment is based on three sources: (1) the projected changes in mean species abundance calculated with the GLOBIO model, based on the OECD Baseline scenario calculations about the land use changes and other pressures (Chapter 3), (2) scenario studies with the EcoOcean model and (3) a wide variety of case studies, many already extensively reviewed in the MA project (MA, 2005b) and selectively summarised here, alongside a number of more recent examples. The assessment provides an essential input to the analysis of subsequent changes in ecosystem service levels and economic value to society (see the next chapters).

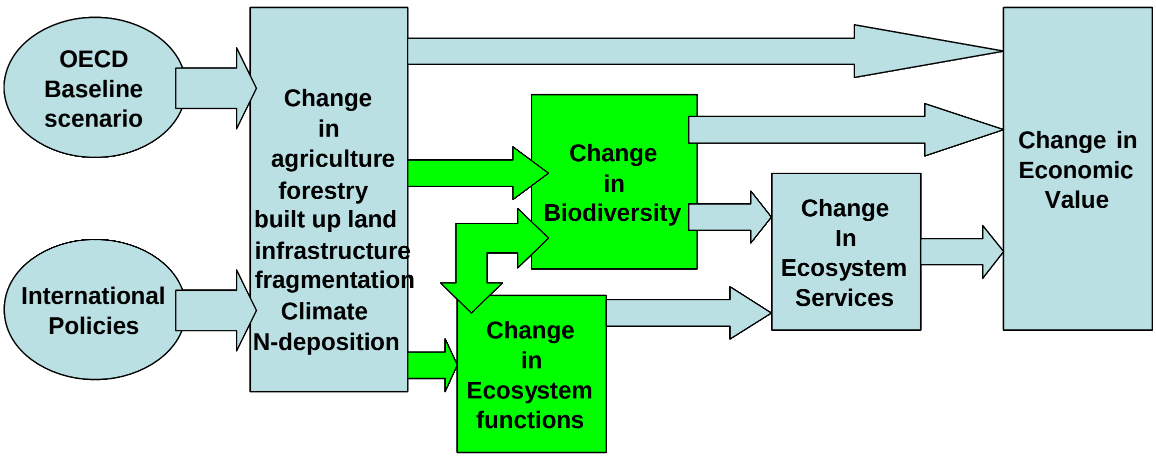


Figure 4.1 Chapter 4 in the conceptual model of the COPI-analysis

The information presented in the global assessments of the past decade, e.g. Global Environment Outlook-3 (2002) and GEO-4 (2007), the Millennium Ecosystem Assessment (MA, 2005a), the Global Biodiversity Outlook 2 (CBD, 2006; Ten Brink et al., 2007) and the OECD Environmental Outlook (2008), has made clear that the rates of loss of biodiversity have accelerated dramatically over the past century. Current rates of species extinction are at least 2 orders of magnitude above background rates and are expected to rise to at least 3 orders above background rates while 20% of all species in those groups that have been comprehensively assessed are believed to be threatened with extinction in the near future (MA, 2005b). Even among species not threatened with extinction, the past 20–40 years have seen substantial declines in population size or the extent of range in most groups monitored. Rates of biodiversity decline vary. Some species and species groups are more vulnerable to change than others. Some generalist species are expanding their ranges, either naturally or as invasive aliens, whereas many ecological specialists are in decline.

The drivers of loss are changing: invasive species and overexploitation were the predominant causes in historic times, while habitat conversion, especially from natural systems to agricultural use, is the most significant driver currently. Climate change is expected to develop into a major threat in the near future. Interactions within ecological communities mean that changes in the abundance of one species will often have effects through the community. It is also quite clear that ecosystems show both gradual changes, when perceived in the time frame of humans, but at the same time respond non-linearly to external changes, with threshold-based dramatic collapses. Changes are presented at the global level, by world regions, by biome and landscape types and at the species level. The changes are partly calculated with the IMAGE – GLOBIO model framework (for terrestrial systems; see Box 3.1 and Box 4.1 respectively) and the EcoOcean model (for the marine biomes; see Box 4.5), and partly derived from extrapolation of historic trends in case studies at various geographical levels. The changes are expressed in a number of CBD 2010-indicators, some of which are used in the models (ecosystem extent and species abundance).

4.2 Indicators of biodiversity change

4.2.1 Biodiversity measures and indicators

Biodiversity as defined by the Convention on Biological Diversity encompasses the diversity of genes, species and ecosystems. Given this complexity, biodiversity dynamics can only be described by a set of complementary indices (see *table 2.1* in Chapter 2). Several focal areas and indicators have been identified and accepted for measuring the progress towards the 2010 CBD target '*to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth'*. Well known indicators for the status and trends in terrestrial biodiversity are the Red List Index (IUCN), the Living planet index (WWF and UNEP-WCMC), the coverage of Protected Areas (UNEP-WCMC) and the Ecological Footprint (Global Footprint Network and WWF). Each of the indicators has strengths and weaknesses, as summarized in *figure 4.2*.

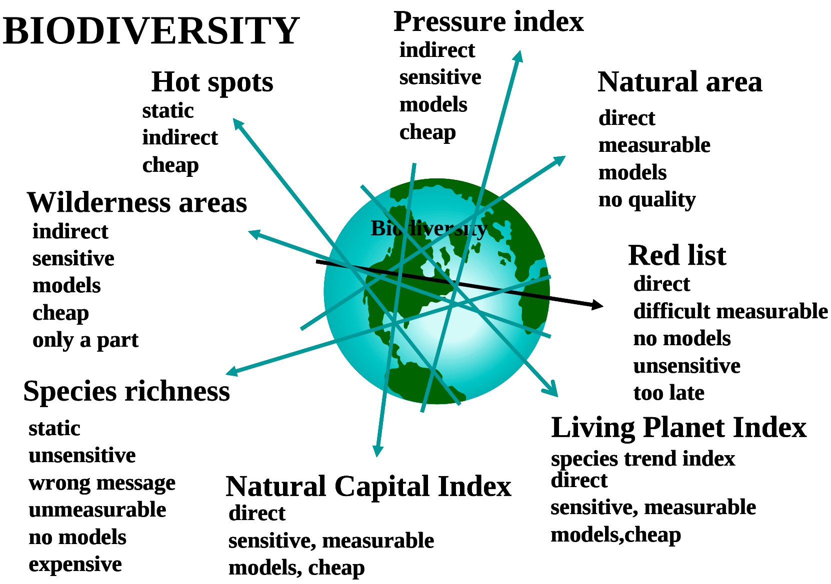


Figure 4.2 An overview of aggregated biodiversity indicators. B. ten Brink, 2000, 2006

In decision VII/30 the Conference of the Parties of the CBD in 2004 adopted a framework to assess and communicate progress towards the 2010 target at the global scale. The framework includes seven focal areas, each of which encompasses a number of indicators for assessing progress towards, and communicating, the 2010 target at the global level. In total, 22 indicators were indentified by the Conference of the Parties (see Chapter 2, *table 2.1*). These indicators are in the process of being developed at the global scale by a wide range of organizations, including UN agencies, research institutes and universities, and non-governmental organisations, brought together by the 2010 Biodiversity Indicators Partnership project. The EEA is developing a set of indicators derived from the CBD set, to monitor progress in Europe (EEA, 2007). Several of the CBD biodiversity indicators have also been included as indicators under MDG Goal 7 (ensuring environmental sustainability; *Table 4.1*). Proportion of land covered by forest, proportion of land in protected areas (terrestrial and marine), proportion of threatened species (the Red List Index) and proportion of fish stocks managed sustainably are all now official MDG indicators of biodiversity and sustainable use of environmental resources.

Table 4.1 Biodiversity in the Millennium Development Goals (MDGs)

Goal 7: Ensure environmental sustainability (biodiversity related aspects only)	
Target 7.A: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources	7.1 Proportion of land area covered by forest 7.2 CO_2 emissions, total, per capita and per $1 GDP (PPP) 7.3 Consumption of ozone-depleting substances 7.4 Proportion of fish stocks within safe biological limits 7.5 Proportion of total water resources used
Target 7.B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss	7.6 Proportion of terrestrial and marine areas protected 7.7 Proportion of species threatened with extinction

4.2.2 The Mean Species Abundance (MSA) indicator

In the COPI study, a model framework and biodiversity indicator were used for assessment of terrestrial biodiversity dynamics which are able to reflect the impacts of the most important direct and indirect drivers: the extent of biomes and ecosystems, trends in abundance and distribution of species, protected areas, nitrogen deposition, climate change and fragmentation. The biodiversity indicator chosen for use in the COPI study is the Mean Species Abundance (MSA), as used in the GLOBIO model (*Box 4.1*), and the IMAGE framework (see Chapter 3, *Box 3.1*). This measure of mean species abundance (MSA) is similar to the Biodiversity Intactness Index (Scholes and Biggs, 2005) and is a composite of CBD's 2010-indicator 'the abundance and distribution of a selected set of species' (*table 2.1*). The numerical values of the MSA in the COPI study represent the biodiversity impacts of the drivers and pressures in the OECD Baseline Scenario.

The loss of biodiversity we are facing in modern times is the –generally unintentional- by-product of increasing human activities all over the world. 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. Extinction is just the last step in a long degradation process. Countless local extinctions ("extirpations") precede a potentially final global extinction. 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; Scholes and Biggs, 2005; MA, 2005b). Decreasing populations are as much a signal of biodiversity loss as rapidly expanding species populations, which may sometimes even become plagues in terms of invasions and infestations. F*igure 4.3* showing this process of changing abundance (indexed) of the original species from left to right. Until recently, it was difficult to measure the process of biodiversity loss. "Species richness" appeared to be an insufficient indicator. First, it is hard to monitor the number of species in an area, but more important it may sometimes increase as original species are gradually replaced by new human-favoured species. Consequently the Convention on Biological Diversity (VII/30) has chosen a limited set of indicators to track this degradation process, including the "change in abundance of selected species".

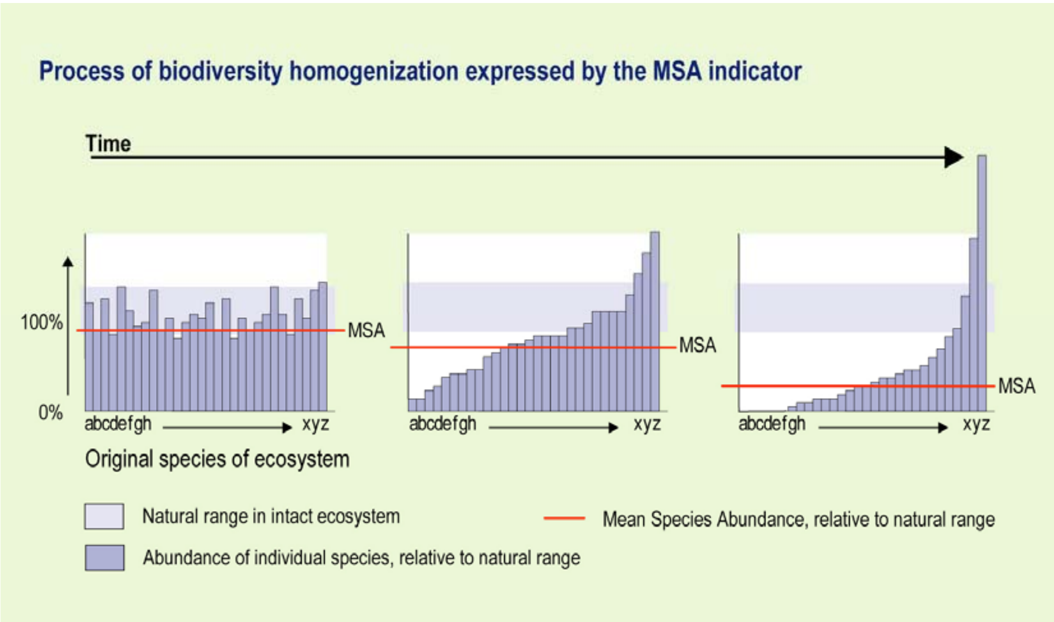
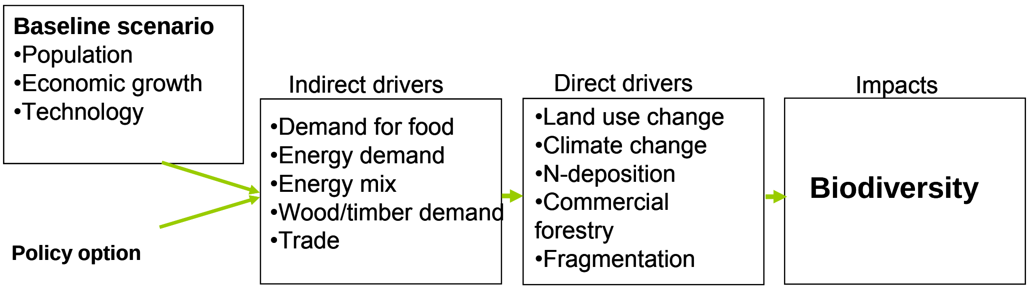


Figure 4.3 Species dynamics during the homogenisation process, and the response in the MSA biodiversity indicator.

This indicator has the advantage that it measures the key process, is universally applicable, and can be measured and modelled with relative ease. In the GLOBIO/MSA framework biodiversity loss is calculated in terms of the *mean species abundance of the original species (MSA) compared to the natural or low-impacted state*. This baseline 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 similar to the natural or low-impacted 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. The range of MSA values and the corresponding land-use and impact levels are visualised for grassland and forest systems in *Box 4.2* 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).

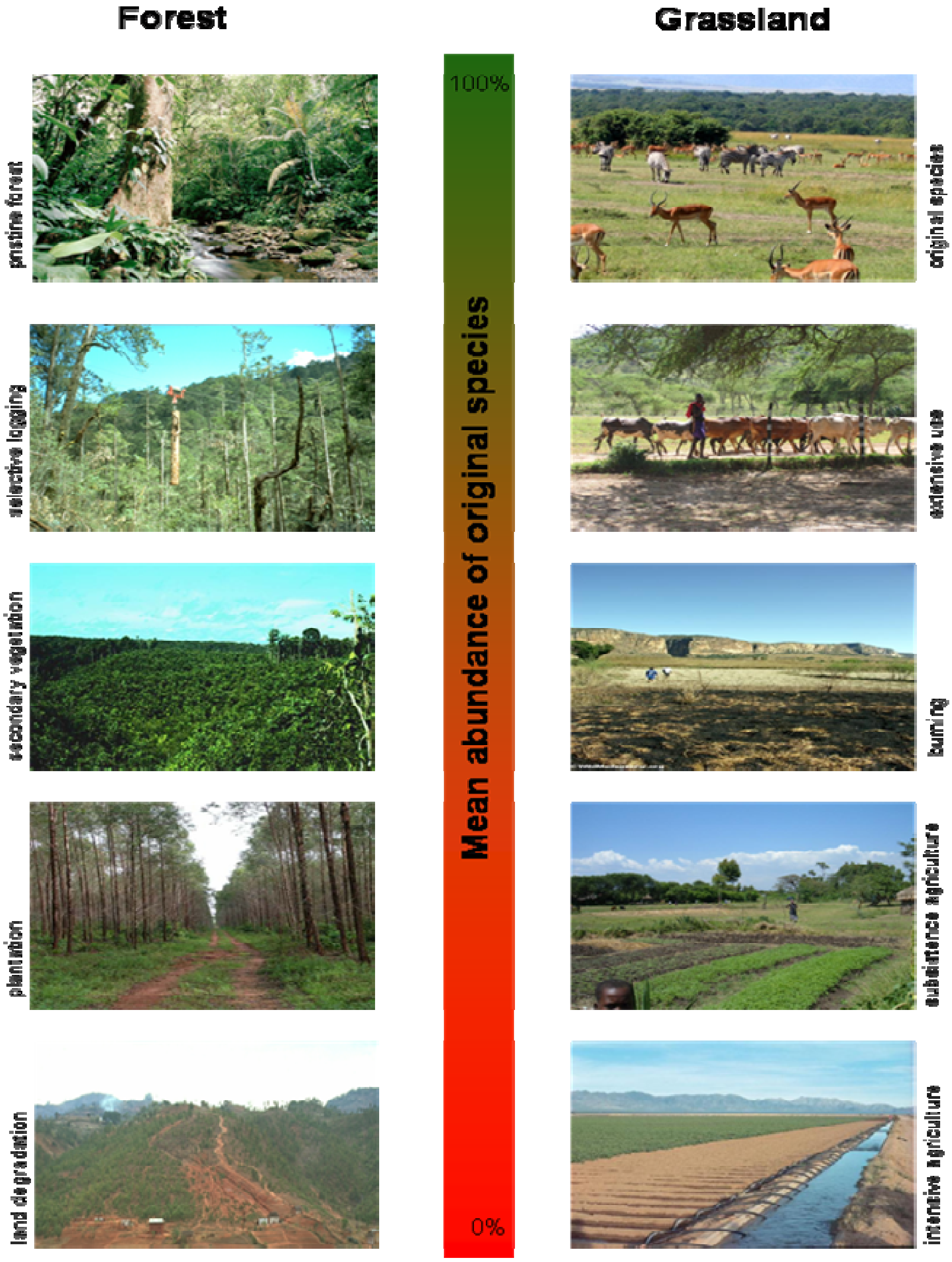
Box 4.1: GLOBIO: The Global Biodiversity model

The GLOBIO 3 model (Alkemade et al., 2006) contains generalised cause-effect relationships between a selection of pressure factors and the mean species abundance (MSA). The core of GLOBIO 3 is a set of regression equations describing the impact on biodiversity of the degree of pressure using dose–response relationships. These relationships are derived from a database of observations of species responses to change, derived from more than 700 peer reviewed publications. The database includes separate measures of MSA, each in relation to different degrees of pressure exerted by various pressure factors or driving forces. The pressures considered in GLOBIO 3 include land-cover change (agriculture, forestry, built up area), land-use intensity, atmospheric nitrogen (N) deposition, infrastructure development, fragmentation and climate change. The current version of the GLOBIO model does not capture that biodiversity is typically lost quickly and regained or restored only slowly. Therefore the overall totals generally underestimate the amount of change.



Box 4.2: Visual impressions of mean species abundance scale

A photographic impression of the gradual changes in two ecosystem types (landscape level) from highly natural ecosystems (90-100% *mean abundance of the original species*) to highly cultivated or deteriorated ecosystems (around 10% mean abundance of the original species).



4.3 Change in terrestrial biodiversity

4.3.1 Global developments

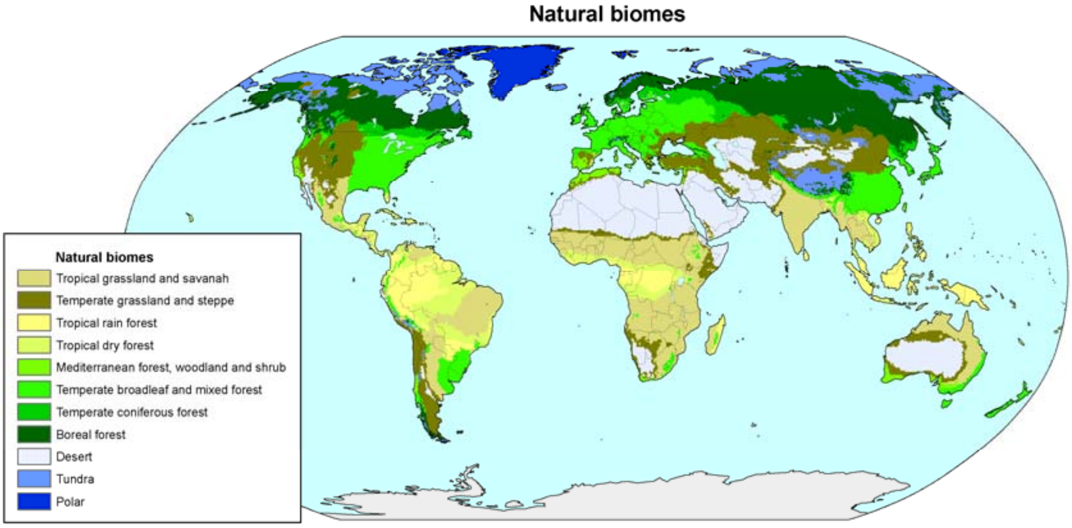


Figure 4.4 Geography of the major world biomes, as used in the IMAGE and GLOBIO model framework.

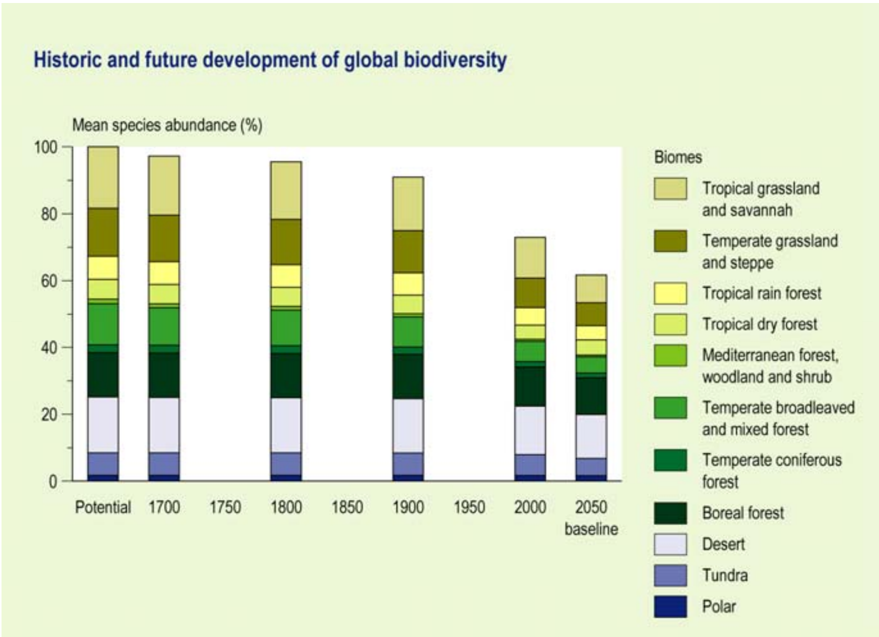


Figure 4.5 Global terrestrial biodiversity development by major biomes, from 1700 to 2050

Anthropogenic biodiversity loss in natural terrestrial biomes (see map in *figure 4.4*) started many centuries ago (see *figure 4.5*). By the year 2000, about 73% of the original global natural biodiversity was left. The strongest declines have occurred in the temperate and tropical grasslands and forests, the biomes where human civilizations developed first (McNeill & McNeill, 2003). Natural habitats were converted to cropland and pasture already more than 10,000 years ago in Southwest

Asia, 6,000 – 9,000 years ago in China and 4,000 – 6,000 years ago in Mexico and South America. The most intact biodiversity is therefore found in those biomes that are less suitable for human development, such as desert, tundra and polar areas.

The total biodiversity loss resulting from land conversion and other pressures between 2000 and 2050, representing the projections of the driving forces and environmental pressures as described in the OECD Baseline scenario is 11% points (73 to 62%). This corresponds with an area of 1,300 million ha (about 1.5 times the United States) which would loss its entire original biodiversity, for example changing from pristine to asphalt. The relative loss is greater when the desert, tundra and polar biomes are excluded from the equation: 12%-point in 50 years.

The global annual rate of loss increased dramatically in the twentieth century, especially in Europe, in comparison to previous centuries. The expected loss rate for Europe seems to decrease, while the global average still increases (see *figure 4.6*).

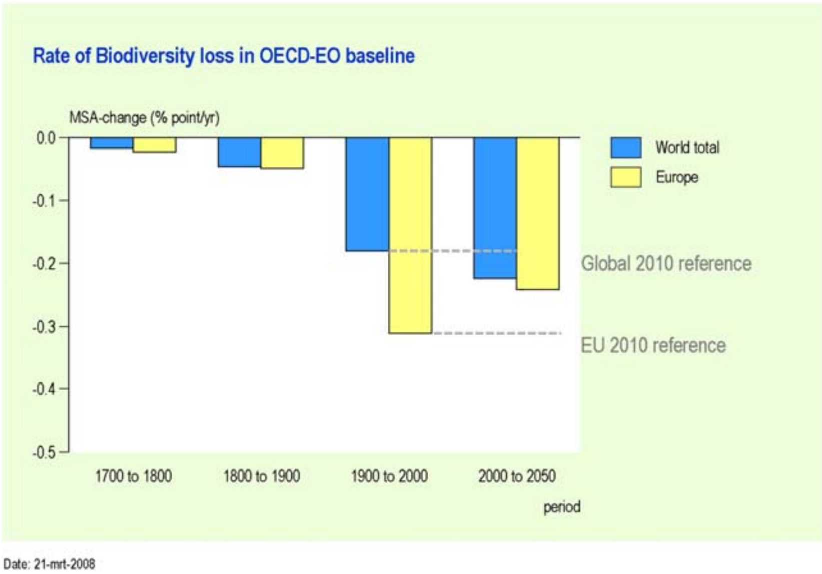


Fig 4.6 Rate of annual terrestrial biodiversity loss (MSA %-points) for different periods. (a change from 80% MSA to 40% MSA = absolute decrease of 40%-point and relative change of 50%.)

The role of agricultural land-use (crops and pastures) remains the largest of all the pressure factors, which is a logical consequence as the total crop area continues to grow in the Baseline scenario (see figure 4.7a). While conversion to agricultural land was the major factor in historic biodiversity loss, the major contributors to the *additional* biodiversity loss between 2000 and 2050 are expansion of infrastructure and climate change (*Figure 4.7b)*. The influence of nitrogen deposition and fragmentation are not expected to increase, even though these factors share similar indirect drivers as the other factors. But through the expansion of agriculture, less natural biome area is left where these stresses can exert their influence.

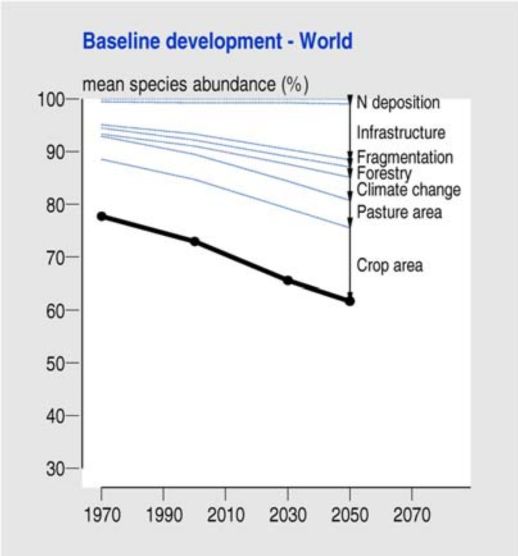


Figure 4.7a Contribution of different pressures to the global biodiversity loss between 2000 and 2050 in the OECD baseline.

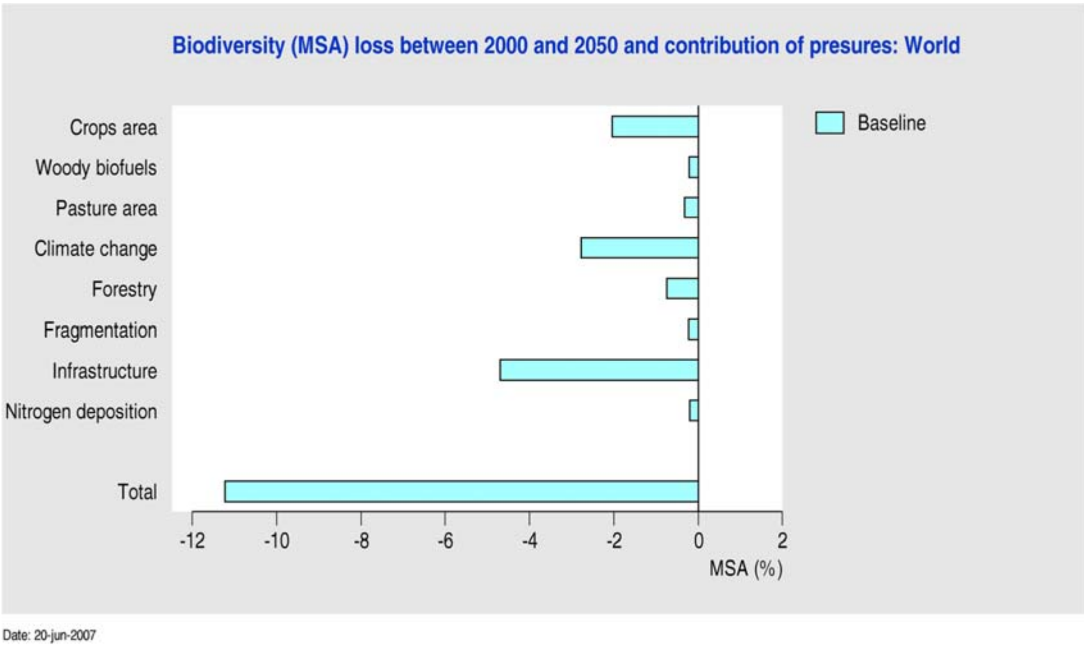


Figure 4.7b Contribution of different pressures to the global biodiversity loss between 2000 and 2050 in the OECD baseline.

4.3.2 Biodiversity change by world region

The results for the main groups of OECD-countries, transition economies (BRIC) and the developing countries (Rest-of-World) are generally similar to the global average. However, there are strong differences in biodiversity levels between regions within the groups (see maps in *figure 4.8*), both in the rate of decline and in the breakdown over the various stress factors (*figure 4.9*).

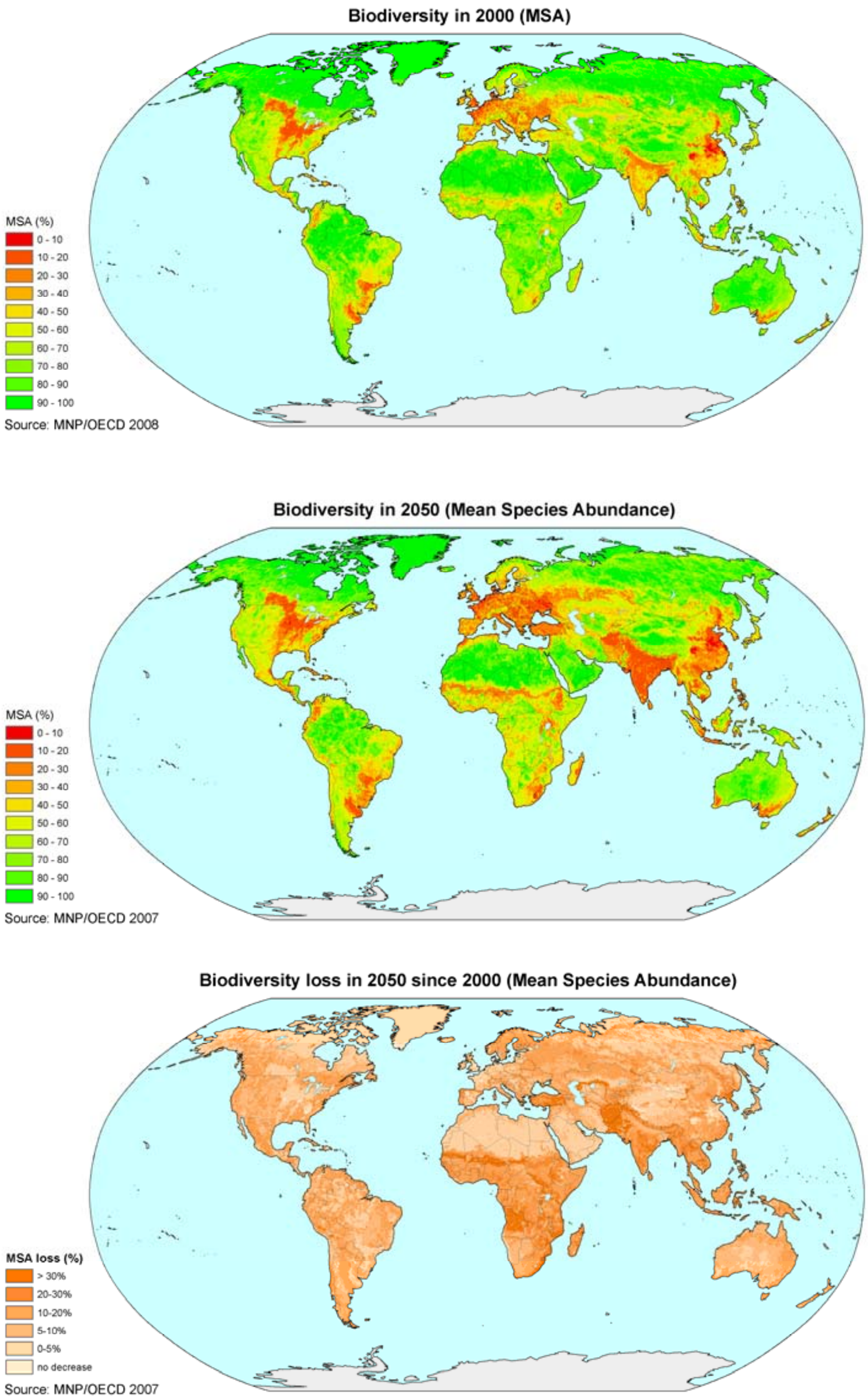


Figure 4.8 Global biodiversity (MSA) in 2000 and 2050 (top maps) and change in global biodiversity (bottom map), according to OECD Baseline development.

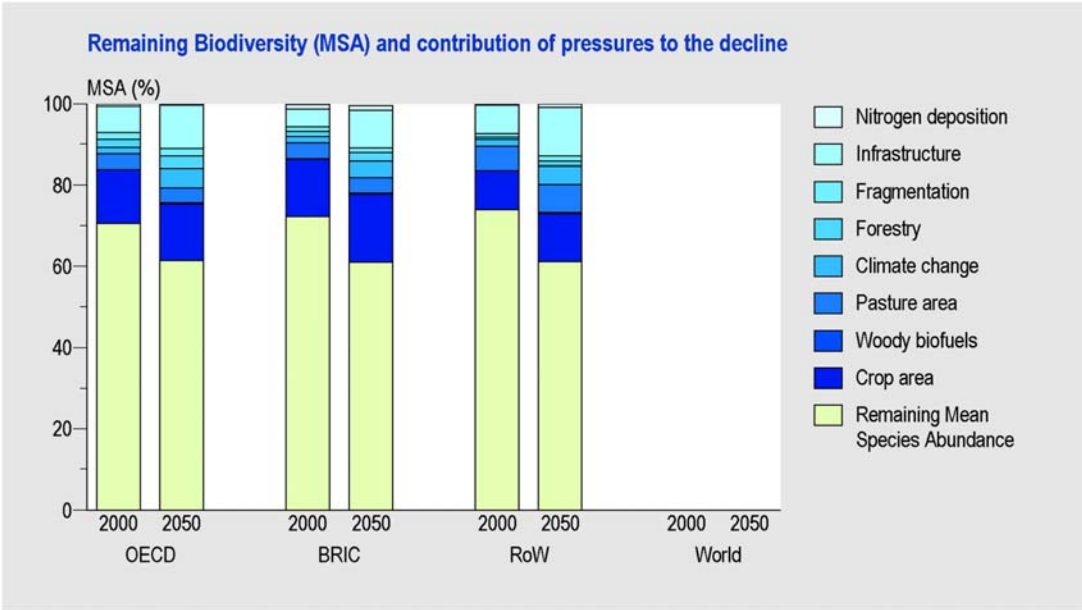


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Figure 4.9 Remaining biodiversity (MSA) in 2000 and 2050 and contribution of pressures to the loss, for the different country clusters of the OECD baseline.

The strongest increase in crop area can be seen in the BRIC group, whereas in the OECD group agricultural influence even declines from 2030 to 2050. Pastures are not expanding, so their impact stays more or less the same. Impacts of infrastructure development are considerable in all regions, which is the consequence of increasing economic and agricultural activities. Through the global effects of temperature rise, all groups show a similar and increasing climate change effect.

The OECD group

The lowest further loss is seen in the OECD group (- 9%-point). The overall biodiversity level in the OECD group is strongly influenced by the vast natural areas in USA, Canada and Oceania with relatively high biodiversity levels. By contrast, remaining biodiversity in the densely populated regions Japan and especially Europe is much lower. The further decline to 2050 for the OECD group is mostly due to infrastructure expansion (additional 4%-point loss) in the densely populated countries of this group and to global effects of climate change (additional 3%-point loss).

The BRIC group

The main causes for the further decline of 11%-point to 2050 in the BRIC group are agricultural expansion (additional 3%-point), expanding infrastructure (additional 5%-point) and climate change (additional 2,5%-point). The differences within the BRIC group are also large. The vast natural and sparsely populated areas in Russia and Brazil have a large influence on the total BRIC group biodiversity level. At the other extreme are the densely populated and strong developing countries in South Asia. These have the lowest biodiversity of the BRIC group, and the mean species abundance declines through further growth in already important agricultural activities.

The Rest-of-the-World group
The highest further loss is found in the Rest-of-the-World group (-13%-point). Again, large differences in both levels and trends are found between regions. The main cause for the further decline in the ROW-group to 2030 is the strongly expanding infrastructure (additional 5%-point) through economic development. In all regional clusters in Rest-of-World the influence of climate change on biodiversity increases (additional 3%-point). The last important cause is agricultural expansion (additional 2%-point). The Other Asia and East and Central Asia regions show the lowest biodiversity values, with large additional losses due in particular to strong expansion of infrastructure. Infrastructure development is also a significant factor on the vast African continent, which exerts a large influence on the total Rest-of-World group. This development is caused by growth in population and GDP, and natural resource exploitation. In the Middle East, original biodiversity levels remain relatively high, due to the widespread arid and desert biomes that are not easily converted to human activities. Agricultural expansion plays an important role in Other Asia and Africa.

4.3.3 Changes by Biome

The major changes in the different biomes can be described with land-use developments and changes in the total biodiversity of each biome. The total area of a biome[8] does not change in the 2000-2050 period (due to only slowly changing boundaries), but major shifts in land-use occur within each biome. This is mostly from natural and extensively used areas to intensive agricultural use. The total biodiversity in a biome (expressed by the biodiversity indicator MSA) is changing due to the land-use shifts and to changing environmental conditions.

Box 4.3: Historic changes in biomes and landscapes around the world *(adapted from the MA, 2005b)*

Forests
- Forest ecosystems are important refuges for terrestrial biodiversity, a central component of Earth's biogeochemical systems, and a source of ecosystem services essential for human well-being. Forests, particularly those in the tropics, provide habitat for 50% or more of the world's known terrestrial plant and animal species.
- In the last 300 years, global forest area has been reduced by approximately 40%. Forests have completely disappeared in 25 countries, and another 29 countries have lost more than 90% of their forest cover.

Dry-lands
- Depending on the level of aridity, dry-land biodiversity is relatively rich, still relatively secure, and is critical for the provision of dry-land services. Of 25 global "biodiversity hotspots" identified by

[8] By definition, a biome is an area with suitable conditions (climate, temperature, rainfall) for development of certain natural vegetation types, given undisturbed development. In the IMAGE model framework, biomes are modeled according to Prentice *et al.*, (1992).

Conservation International, 8 are in dry-lands. The proportion of dry-lands designated as protected areas is close to the global average, but the proportion of dry-land threatened species is lower than average. At least 30% of the world's cultivated plants originated in dry-lands and have progenitors and relatives in these areas.
- Transformation of rangelands to cultivated systems (approximately 15% of dry-land grasslands, the most valuable dry-land range, were converted between 1950 and 2000), in combination with inappropriate dry-land irrigation and cultivation practices has led to soil salination and erosion.

Polar
- Important changes include: the reduction of top predators in Antarctic marine food webs, increased shrub dominance in Arctic wetlands, which contributes to summer warming trends and alters forage available to caribou, changes in insect abundance that alter food availability to wetland birds, energy budgets of reindeer and caribou, or productivity of forests; increased abundance of snow geese, which are degrading Arctic wetlands; overgrazing by domestic reindeer in parts of Scandinavia, Russia, and sub-Antarctic islands; and a rapid increase in the occurrence and impact of invasive alien species, particularly in previously isolated sub-Antarctic islands.

Inland waters
- It is estimated that 50% of inland water habitats were lost during the twentieth century. Inland water habitats and species are in worse condition than those of forest, grassland, or coastal systems. Inland water systems encompass habitats such as lakes and rivers, marshes, swamps and floodplains, small streams, ponds, and cave waters. All inland aquatic habitats,-whether fresh, brackish, or saline—as well as inland seas are considered. More than 50% of inland waters (excluding lakes and rivers) have been lost in parts of North America, Europe, and Australia. In addition to the loss of inland water systems, degradation is widespread. The species biodiversity of inland waters is among the most threatened of all ecosystems.

Mountains
- Because of the compression of climatic life zones with altitude, and small-scale habitat diversity caused by different topo-climates, mountain regions are commonly more diverse than lowlands. They support about one quarter of terrestrial biodiversity, with nearly 50% of the world's biodiversity hot spots concentrated in mountains. 32% percent of protected areas are in mountains (9,345 mountain protected areas covering about 1.7 million square kilometres).

Land-use changes (in terms of ha)

The remaining part (in terms of ha) of each biome that still has a natural character is getting smaller for all biomes. Changes are strong in the savannah biome, where only 700 million ha of natural area will be left in 2050, compared to 900 million ha in 2000 (*figure 4.10a*). This leads to increases for intensive agriculture or grazing (*some managed forest is also found within the savannah biome, due to boundary effects and spatial mismatch between biome and actual land-use maps*). Extensive agriculture also disappears as agricultural productivity is expected to increase in the coming decades. Similar changes are projected for the grassland and steppe biome, with a large share for grazing and intensive agriculture. The vast areas with boreal forest still have a large share with relatively unaffected natural areas, but forestry and agricultural practices are developing here as well towards 2050. A similar development takes place in the tropical forests and woodlands.

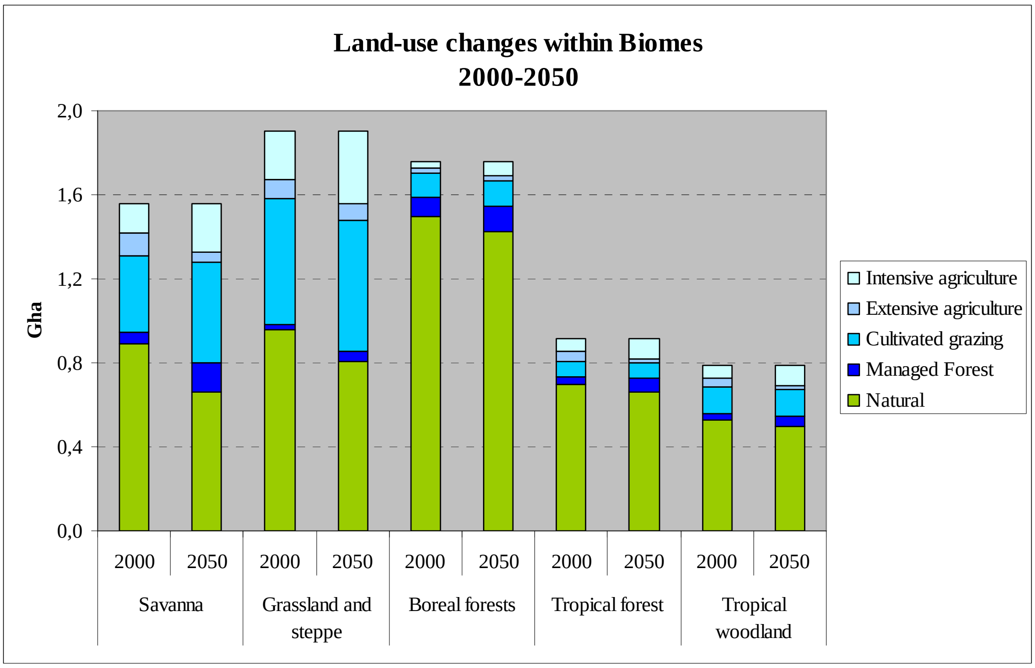

Figure 4.10a Land-use changes within the biomes (in Gha) between 2000 and 2050 (according to OECD Policy inaction scenario).

Biodiversity changes (in terms of MSA)

The future changes in biodiversity (in terms of MSA) between 2000 and 2050, both absolute and relative, are projected to be most dramatic in the Savannah Biome (270 million MSA-ha, and ca. 17% of original natural area in the biome; *figure 4.10b*). MSA-ha is the product of area and remaining % biodiversity (MSA %)[9]. The Grassland & Steppe biome (ca 220 million MSA-ha, 11%) and the Boreal Forest Biome (160 million MSA-ha, almost 9%) are hit hard as well. The tropical forest and woodland biomes together lose more than 200 million MSA-ha or ca 13% of their original biodiversity. Surprisingly at first sight, the desert biome also loses quite a lot of biodiversity, but that is mainly the result of its large area (just 8% relative loss). In the savannah, grassland and steppe biomes, the biodiversity had already dropped to about 70% of the pristine situation in 2000, and declines to about 50% by 2050. The decline is mostly due to the much smaller natural area, while grazing area expands. For the forested systems, the areas still natural make up a very large part of the remaining biome biodiversity. Only in tropical woodlands is some biodiversity present in grazed areas.

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[9] If 100 ha intact biodiversity (100% MSA) deteriorates in 100 ha of 40% MSA, then 100 MSA-ha changes into 40 MSA-ha (area x quality).

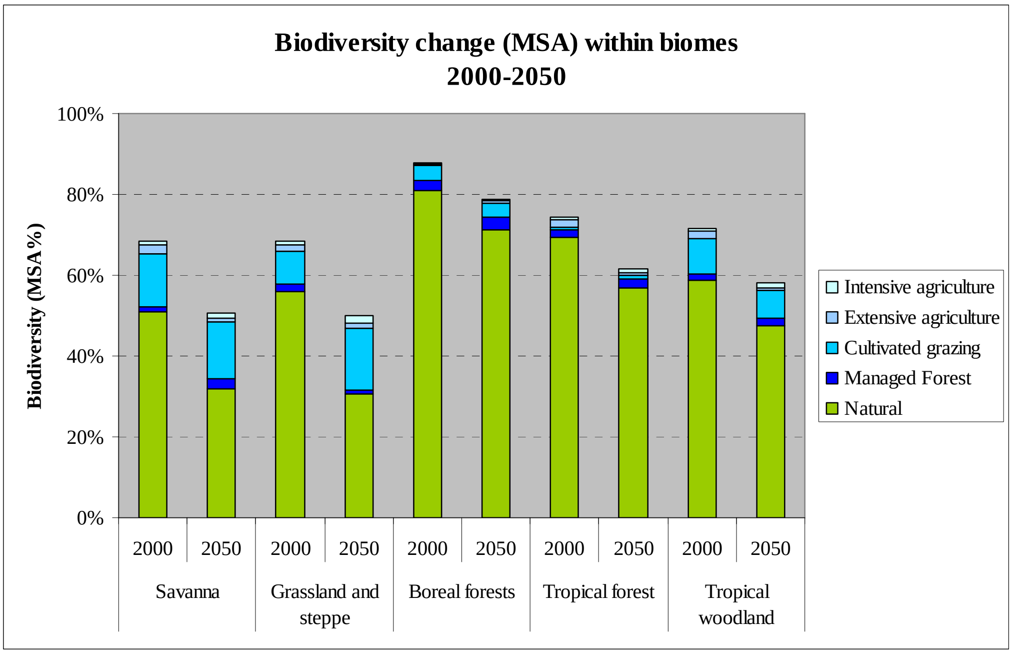
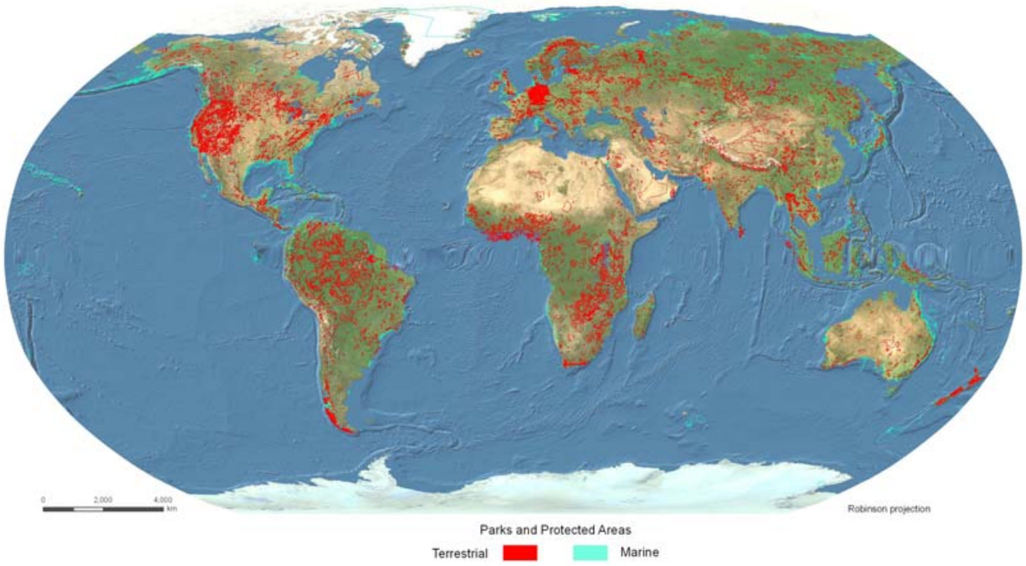


Figure 4.10b Biodiversity changes (in MSA% of the original biome) within biomes between 2000 and 2050 (according to OECD Policy inaction scenario).

4.4 Protected areas

The number and extent of protected areas have been increasing rapidly worldwide in recent decades; they now cover almost 12% of global land area. However, the biomes represented in that coverage are uneven. Marine areas are under-represented in all categories of protected areas. Protected areas represent the cornerstone of efforts to conserve biological diversity, and the CBD has set a target of conserving 10% of the earth's surface in formally protected areas. Currently some 19.3 million km^2 of terrestrial area and 2.4 million km^2 of marine area are protected, representing 12.9% of terrestrial area 9.8% of territorial waters (0.7% of total marine area) and 12.4% overall. This is an increase from 8.45% in 1990, and suggests that, globally, targets are beginning to be met (see *figure 4.11*).

However, global figures mask significant regional disparities. Moreover, not all biodiversity is included in protected area networks – some 20% of threatened species do not occur in any protected area, with birds and amphibians being particularly under-represented (Rodrigues *et al.*, 2004). Countries with the greatest proportion of un-protected species included China, India, Sri Lanka and Madagascar, the last being a conservation hotspot of threatened biodiversity. Nevertheless, improvements are underway. For example, the government of Madagascar has pledged to increase its protected area network from 2.9% in 2002 to 10% in 2010. By 2006 the Protected Areas network in Madagascar had been expanded to cover 6.3%, and recent priority-setting analyses are helping to identify where to establish a further 3.7% to ensure greatest inclusion of endemic biodiversity (Kremen *et al.*, 2008).



Source: Data extracted from the World Database on Protected Areas (WDPA), produced by UNEP-WCMC and the IUCN World Commission on Protected Areas working with governments and collaborating NGOs, January 2008.

Figure 4.11 Global distribution of Terrestrial and Marine Protected Areas. For display purposes, only protected areas with spatial (GIS) boundaries are shown.

Of course, protected areas are not a guarantee to maintain biodiversity unless they are managed effectively. Whilst degradation is usually less within protected areas than in surrounding unprotected zones, many protected areas are nothing more than 'paper parks', and many of the world's flagship protected areas, such as those inscribed on the UNESCO World Heritage List, are threatened by external pressures and lack of adequate protection. For example, all five of the natural World Heritage Sites in DRC are listed as 'in danger' by UNESCO due to the conflict in that region. In China, deforestation within Wolong Nature Reserve was higher than in surrounding areas, and appeared to increase after the Reserve was established, leading to a significant decline in the resident Giant Panda population (Liu *et al.*, 2001). Yet it is still the case that in general the ecosystem service benefits from protected areas outweigh the management costs by at least an order of magnitude (Balmford *et al.*, 2002).

4.5 Changes in marine biodiversity

4.5.1 Introduction

The Ocean biomes

In a similar way as on land, biomes can be distinguished in the marine part of Earth. A short orientation is presented in this section (adapted from MA, 2005b; see *figure 4.12*).

The *Coastal Boundary Zone biome* (10.5% of the world ocean) consists of the continental shelves (0–200 meters) and the adjacent slopes. This biome is the most significant source of marine fish landed globally, and it also bears many of the impacts of fishing on ecosystems and of other human activities.

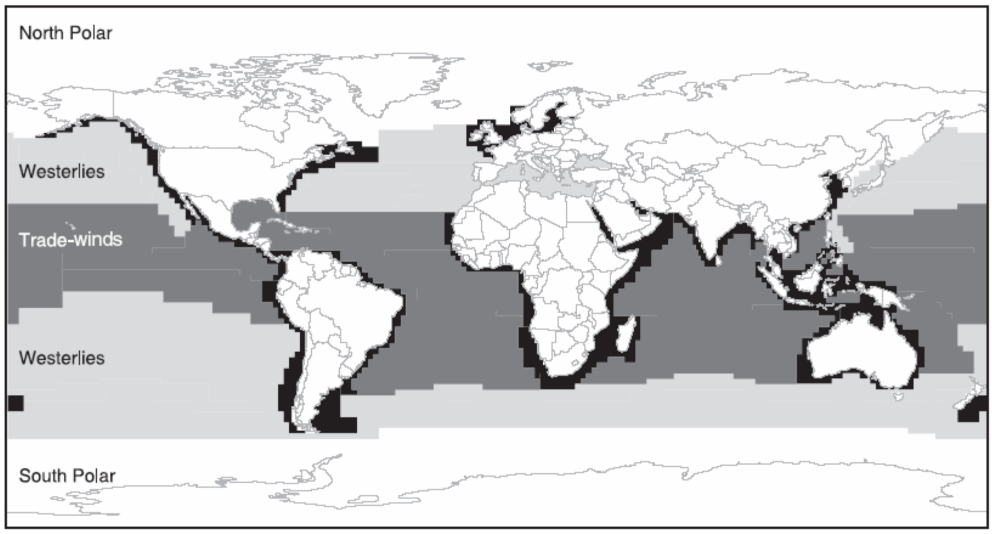


Figure 18.1. Classification of World's Oceans. Four "Biomes" were identified: Polar, Westerlies, Trade-winds, and Coastal Boundary (Longhurst et al. 1995; Longhurst 1998). The Coastal Boundary is indicated by a black border around each continent. Each of these Biomes is subdivided into Biogeochemical Provinces. The BGP of the Coastal Boundary Biome largely overlaps with LMEs identified by K. Sherman and coworkers (see Watson et al. 2003).

Figure 4.12 The Marine Biomes

The *Polar biome* (15% of the world ocean) accounts for 15% of global marine fish landings. Its vertical density structure is determined by low-salinity waters from spring melting of ice. The bulk of annual primary production occurs in ice-free waters during a short intense summer burst. However, primary production under lighted ice occurs over longer periods, especially in Antarctica.

In the *Westerlies biome* (35.7% of the world ocean), seasonal differences in the depth of the mixed layer result from seasonality in surface irradiation and wind stress, inducing strong seasonality of biological processes, including a spring bloom of phytoplankton. Overall, the Westerlies biome contributed 15% of the world's marine fisheries catch in 2001.The marine environment in this biome is relatively unaffected by human use other than fishing.

The *Trade-winds biome* (38.5% of the world ocean) lies between the northern and southern sub-tropical convergences, where a strong water density gradient hinders nutrient recycling between deep layers and upper surface layers. The resulting low levels of new primary production make these zones the marine equivalent of deserts. Therefore, fisheries in this biome rely mainly on especially tunas, capable of migrating over the long distances that separate isolated food patches. Overall, the trade-winds biome contributed 15% of the world's marine fisheries catch in 2001. One exception to the general low productivity of the trade-winds biome is around islands and seamounts, where physical processes such as localized upwelling allow for localized enrichment of the surface layer.

Like on land, mountain ranges in the oceans, seamounts, are areas with relatively high biodiversity. They are increasingly under pressure, both from the inhabited mountain tops (islands) and from long range fishing industries. The map in *figure 4.13* illustrates the location and share of the seamounts in Exclusive Economic Zones.

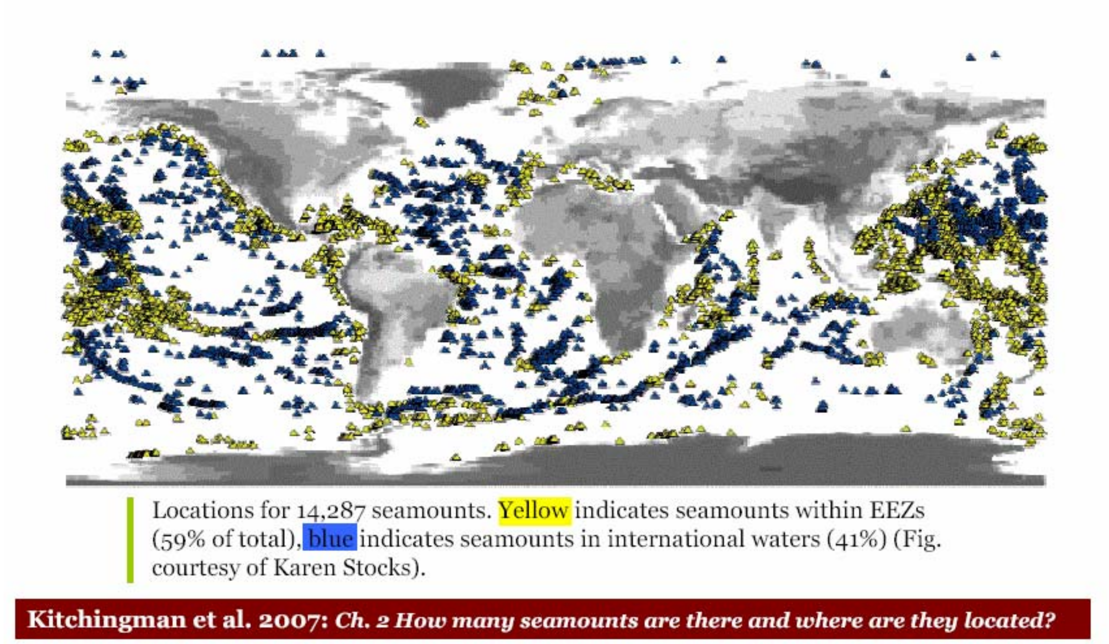


Figure 4.13 Seamounts around the world

4.5.2 Global trends in Marine biodiversity

Fishing pressure has been such in the past century that the biomass of larger high-value fish and those caught incidentally (the 'by-catch') has been reduced to 10% or less of the level that existed before industrial fishing started[10]. The loss of biomass and fragmented habitats have led to local extinctions. The percentage of stocks which are not yet completely exploited has declined steadily, while the proportion of stocks exploited beyond maximum sustainable yield levels has increased steadily[11] (see *figure 4.14*).

[10] Add reference
[11] Add reference

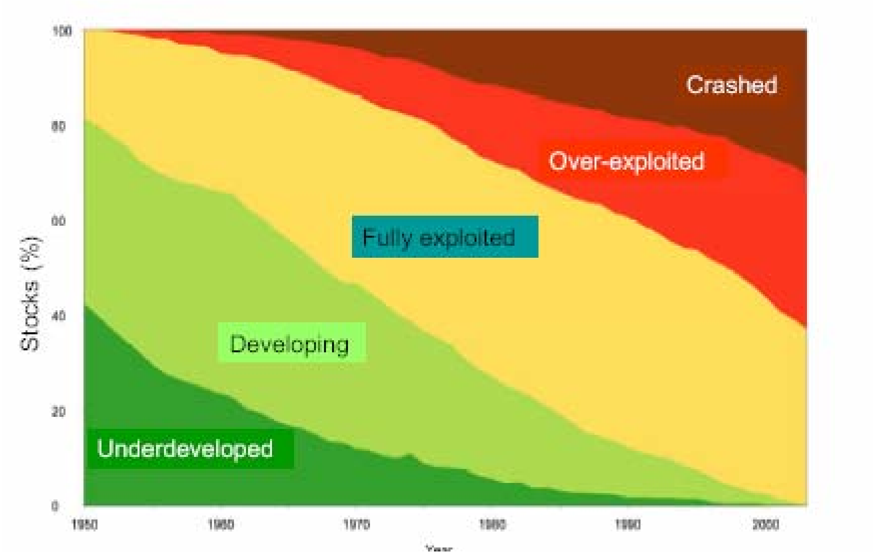


Figure 4.14 Changes in degree of exploitation of stocks of marine fish species (source: Alder, Trondheim/UN conference on Ecosystems and people, October 29- November 2, 2007; original source: Sea Around Us project, 2007)

Trophic level decline is the change through time in the composition of the catch from a mixture of "top predatory fish such as sharks, mid-trophic level fish such as cods and herrings, and a few lower trophic level animals such as shrimp" to a catch of "a few mid-trophic species such as whiting and haddock and many low-trophic species such as shrimp" (*see figure 4.15*). This change is a result of three phenomena:

- the expansion of fisheries from benthic coastal areas to the open ocean;
- the expansion of fisheries from the Northern Hemisphere (dominated by large shelves and bottom fish) to the Southern Hemisphere (dominated by upwelling systems and pelagic fish); and
- over-fishing, leading to a local replacement of depleted large predators by their prey.
- This change in catch composition is sometimes called "fishing down marine food webs."

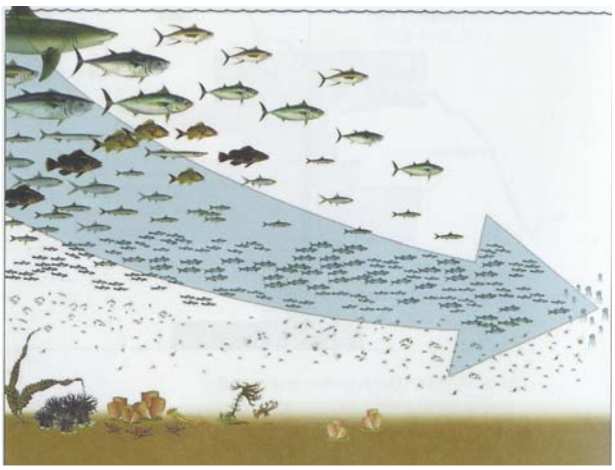


Figure 4.15 Fishing down the foodweb (source: Pauly et al., 1998.)

Figure 4.16 illustrates the actual decline in average trophic level in the catch for North Atlantic and coastal areas, which implies that we are increasingly relying on fish that originate from the lower part of marine food webs (MA, 2005b).

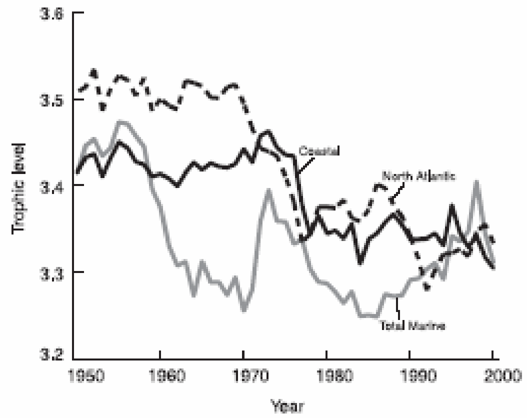


Figure 18.9. Changes in Trophic Level in North Atlantic and Coastal Areas at Less Than 200 Meters Depth, and Total Marine Landings, 1950–2000 (SAUP 2005)

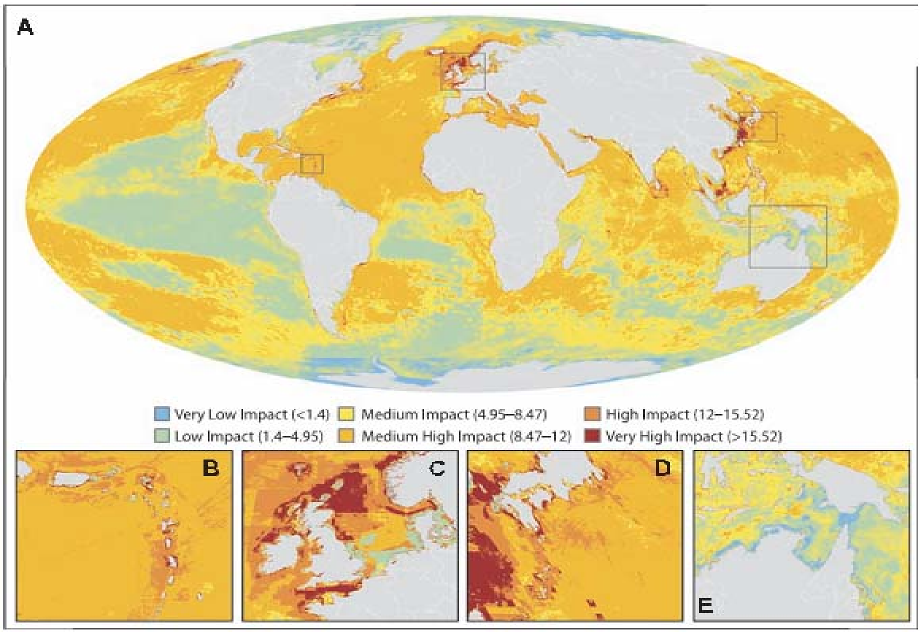
Figure 4.16 Changes in trophic level (source MA, 2005b)

Box 4.4: Case examples of trends in marine biodiversity (adapted from MA, 2005 b, Alder et al. 2007)

- Shark declines are believed to be occurring as a result of increased by-catch from pelagic long-line fisheries and direct exploitation for shark fins. Most recorded shark species have experienced a decline of more than 50% in the past 1990's. Sharks grow and reproduce slowly, so even if exploitation were stopped, recovery would be slow.
- Trends in Caribbean corals reveal that there has been a significant decline over the past three decades and although the decline has slowed, the trend persists. The average hard-coral cover on reefs has been reduced by 80%, from around 50% to 10% cover, in three decades. These data support the notion that coral reefs are globally threatened.
- The sudden switch in 1983 from coral to algal domination of Jamaican reef systems followed several centuries of overfishing of herbivores, which left the control of algal cover almost entirely to a single species of sea urchin, whose populations collapsed when exposed to a species-specific pathogen. As a result, the reefs shifted to a new low diversity, algal-dominated state with very limited capacity to support fisheries.
- The major stock collapses of the last few decades have been a surprise, even to those involved in monitoring and managing these stocks. One well known example is Newfoundland's northern cod. Almost the same scenario was re-enacted 10 years later, in 2001, in Iceland, which very nearly lost its cod stock in spite of the Icelandic government's commitment to sound fisheries management.

4.5.3 The current state of marine biodiversity

Figure 4.17 presents an image of the current, impacted, state of the biodiversity of the global marine system. The highest impact regions are the North Sea and North-eastern Atlantic, the North-western Atlantic coast and the coastal seas of South-East Asia, the areas with historically intensive fisheries.



Source: *Salman Hussein* presentation at the Workshop: ***The Economics of the Global Loss of Biological Diversity 5-6 March 2008, Brussels, Belgium***

Figure 4.17 The impact of human use of the oceanic biomes (source: National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara.)

4.5.4 Marine biodiversity futures

A global crisis in marine fisheries is included in the COPI analysis since the world's fisheries contributes to addressing food security as well as assisting in economic development for many countries, especially for developing coastal countries (Pauly *et al.*, 2005). The EcoOcean model (see *Box 4.5*) was developed as a tool to explore fisheries and marine policy options. The development of EcoOcean was in response to requests from three global assessment projects: the GEO4, which has a strong environment focus; the IAASTD, which has a strong focus on knowledge development and transfer and includes fisheries from a capture and aquaculture perspective; and the GLOBIO project (applied in the OECD Environmental Outlook 2008 study) which is exploring global changes in biodiversity. All three assessments are using scenarios. GEO4 is based on scenarios developed from GEO3 (UNEP, 2002) with weightings for optimization based on input from regional representatives of the GEO4 process. The IAASTD and OECD/GLOBIO are using variations around a baseline which is not necessarily a business as usual scenario, but using current trends that are modified by key drivers such as subsidies.

Box 4.5: The EcoOcean MODEL (adapted from Alder et al, 2007)

A stratified global model, EcoOcean, was developed for quantitatively assessing the future of fisheries under different scenarios. A series of 19 marine ecosystem models representing the 19 FAO (Food and Agriculture Organization of the United Nations) areas of the world's oceans and seas was constructed. The models account for the biomass of each functional group, their diet composition, consumption per unit of biomass, natural and fishing mortality, accumulation of biomass, net migration, and other mortality. The principle behind this modelling approach is that biomass and energy are conserved on a yearly basis, i.e. that future biomass can be estimated from current biomass plus change in biomass due to growth, recruitment, predation, fisheries, etc. (Walters et al., 1997).

The models were quantified using global datasets of catches, ex-vessel prices, biomass and distant water fleets from the Sea Around Us Project and the fleet statistics from the FAO from 1950 to 1998, the last year for which data are available. The model distinguishes 43 functional ecological groups that are common to the world's oceans. The groups were selected with special consideration for exploited fish species but include all major groups in the oceans. Fishing effort is the most important driver for the ecosystem model simulations. Five major fleet categories (demersal, distant water fleet, baitfish tuna (purse seine), tuna long-line and small pelagic) are used to distinguish different fishing effort based on historical information. For current purposes, the oceans should be considered as spatially-separated production systems.

The aggregated global model produces results within 10% of the reported total for any given year. This gave confidence that the models are providing plausible results for different scenarios. EcoOcean was developed using the most up-to-date and best available global data, and while it does simulate many of the processes that occur, it is however not a full representation of the world's oceans as it contains several sources of uncertainties. The development of EcoOcean also provided the opportunity to look at the future of marine biodiversity using a **depletion index** (*Box 4.6*) as a proxy for changes in species composition and abundance under the different scenarios.

Box 4.6: Indicators of Marine Biodiversity (adapted from Alder et al. 2007)

- A **biomass diversity index** can be used to synthesise information on the number of species or functional groups that compose the biomass of the ecosystem,. The biomass diversity index can be used to evaluate model behaviour, assuming that more stable ecosystems will tend to have a more even distribution of biomass across the functional groups.
- The **marine trophic index (MTI)** is calculated as the average trophic level of the catch and is used to describe how the fishery and the ecosystem may interact as a result of modelled policy measures (Pauly and Watson, 2005). The index is often used to evaluate the degree of "fishing down the food web" (Pauly et al., 1998). The MTI is one of the core indicators being used by the Convention on Biological Diversity.
- The indicator used in the scenario-analyses is the mean species abundance (MSA) of the original species belonging to an ecosystem, that is, the abundance of native wildlife in terrestrial systems. EcoOcean has been used to develop a marine equivalent to the MSA, the **depletion** index (DI) that is calculated as part of the overall assessment within EcoOcean. The **DI** was used to represent the different rates of decline of species that had been aggregated into functional groups. The DI was calculated from prior knowledge of the intrinsic vulnerability and the estimated changes in functional group biomasses. Intrinsic vulnerability to fishing of the 733 species of marine fishes with catch data available from the Sea Around Us Project database (www.seaaroundus.org) was included in the analysis.

The application of EcoOcean to GEO4 and the IAASTD resulted in plausible outcomes under the different policy scenarios, and the outcomes differed across geographic areas as well as across scenarios. In cases where effort increased, landings and therefore profits increased; however, any increase in landings was achieved by increases in groups that are not currently fished in large quantities. The groups that declined varied with each scenario and geographic area. In many cases increased landings resulted in declining marine trophic levels, and increased depletion risks. The fishing scenarios indicated that only those scenarios with significant reductions in effort and targeting fish at lower trophic levels would be effective in rebuilding depleted stocks and maintaining other stocks. Those scenarios that used current trends or increased effort whether for commercial or recreational fisheries all indicated collapses in stocks and ecosystems; they differed only in their rates of decline.

All GEO4 scenarios proposed an increase in effort, and as a consequence landings generally increased. Landings were increased by augmenting the proportion of secondary ground fish groups and the proportion of invertebrates. As a consequence, the marine trophic index (MTI) generally decreased in all oceans. The decline in MTI confirms that as demersal effort increased, landings increased, but usually at lower trophic levels. With the exception of the Mediterranean Sea and the Caribbean region, the biomass diversity index also decreased for the three main oceans. In the Mediterranean Sea and Caribbean region, the increase appears to be a result of the predation impact of a few top predators being lowered as their biomasses decrease, allowing for increase in dominance of lower trophic levels.

IAASTD Scenarios 1 and 2 proposed an increase in effort and, as a consequence, landings increased for the scenarios in the Atlantic and Pacific Ocean. For scenario 3, which emphasises ecosystem rebuilding, with a 2% annual effort increase over the last 25 years of the scenario, landings decreased for all areas for the first twenty years of the scenario run, while subsequently landings increased as effort increased. As a consequence, the marine trophic index (MTI) generally decreased in all oceans. An exception to this would be for scenario 4, where the 10% decrease in tuna longline and demersal fleet effort over the last 45 years of the scenario run resulted in a decrease in demersal and large tuna landings, and as a result the MTI increased or remained constant for all oceans.

Depletion index

By comparing the calculated DI of the ecosystems between year 2007 (present) and 2047 under different scenarios, we can predict changes in conservation status during this period (see *figure 4.18*. In all scenarios the global mean difference is negative, indicating a further depletion of the marine biodiversity.

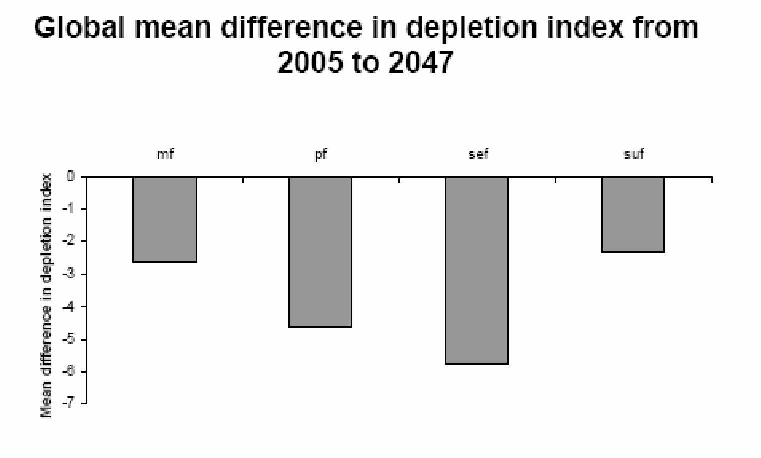


Figure 4.18 Global mean difference in Depletion index in the GEO4 scenarios (Alder et al., 2007)

Figures 4.19a and 4.19.b show the regional differences across the global marine ecosystem.

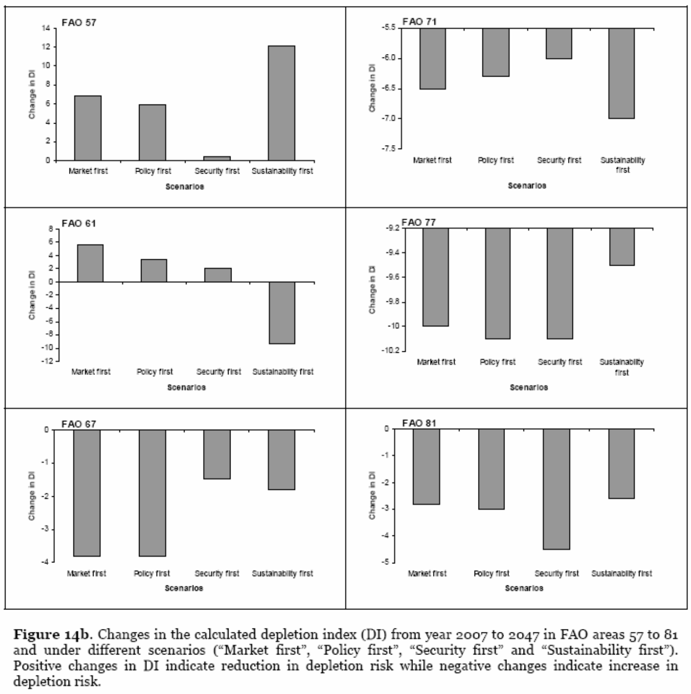


Figure 4.19a Depletion index in 6 FAO marine regions in 4 GEO4 scenarios (Alder et al., 2007) FAO 57=East Indian, 61=Northwest Pacific, 67=Northeast Pacific, 71=Northwest Oceanic, 77=California Current, 81=Southwest Pacific

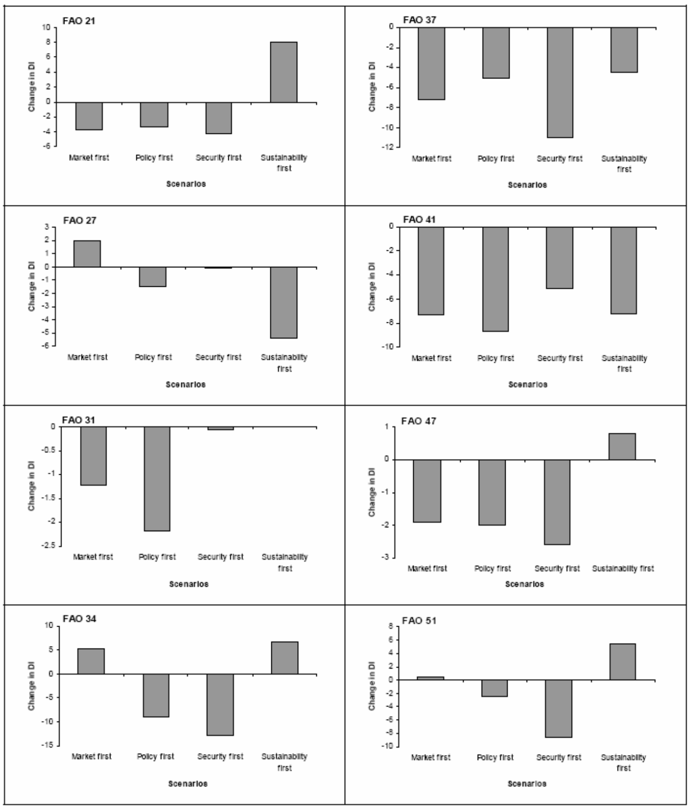


Figure 14a. Changes in the calculated depletion index (DI) from year 2007 to 2047 in FAO areas 21 to 51 and under different scenarios ("Market first", "Policy first", "Security first" and "Sustainability first"). Positive changes in DI indicate reduction in depletion risk while negative changes indicate increase in depletion risk.

Figure 4.19b Depletion index in 8 FAO marine regions in 4 GEO4 scenarios (Alder et al., 2007) FAO 21=Northwest Atlantic, 27=Northeast Atlantic, 31=Caribbean, 34=Northwest Africa, 37=Mediterranean, 41=Southwest Atlantic, 47=Southeast Atlantic, 51=West Indian

The graphs illustrate that only in the Sustainability First scenario in some FAO regions a positive development can be expected. In all other areas the future of marine biodiversity is very dismal.

4.6 Changes in coastal systems

4.6.1 Introduction

Coastal ecosystems are among the most productive ecosystems in the world. They include freshwater and brackish water wetlands, mangrove forests, estuaries, marshes, lagoons and salt ponds, rocky or muddy intertidal areas, beaches and dunes, coral reef systems, seagrass meadows, kelp forests, nearshore islands, semi-enclosed seas, and nearshore coastal waters of the continental shelves (see map in *figure 4.20*). They are highly dynamic, and are now undergoing more rapid change than at any time in their history. The changes are due to dredging of waterways, infilling of wetlands, and construction of ports, resorts, and housing developments, and biological, as has occurred with declines in abundances of marine organisms such as sea turtles, marine mammals, seabirds, fish, and marine invertebrates. Sediment transport and erosion deposition have been altered by land and freshwater use in watersheds. These impacts, together with chronic degradation resulting from land-based and marine pollution, have caused significant ecological changes and an overall decline in many ecosystem services (MA, 2005b).

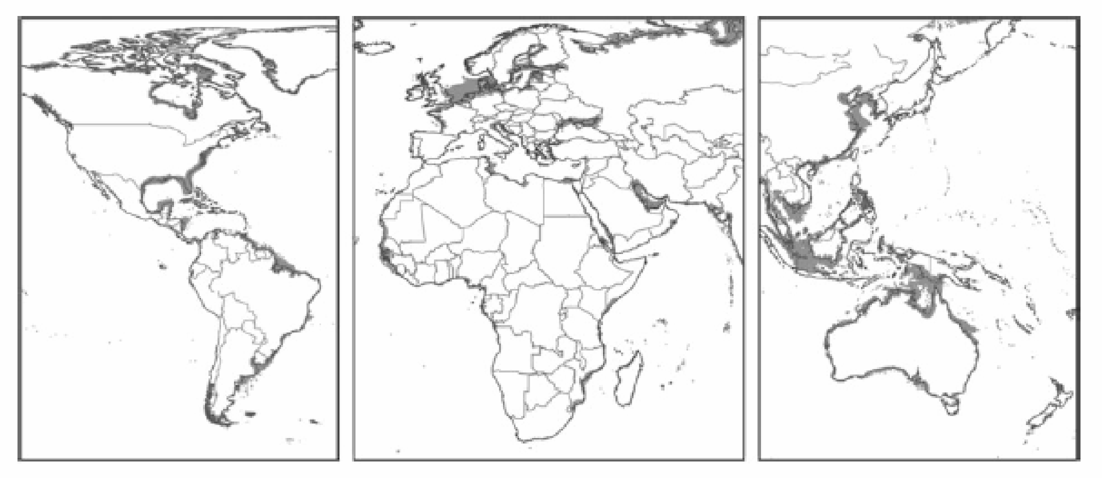


Figure 4.20 Costal ecosystems around the world

4.6.2 Trends in estuaries and salt marshes

Estuaries are areas where the fresh water of rivers meets the salt water of oceans. Worldwide, some 1,200 major estuaries have been identified and mapped, yielding a total area of approximately 500,000 square kilometers. The 1,200 largest estuaries, including lagoons and fiords, account for approximately 80% of the world's freshwater discharge (Alder 2003). There has been a substantial loss of estuaries and associated wetlands globally. In the United States over 50% of original estuarine and wetland areas have been substantially altered. In Australia, 50% of estuaries remain undamaged, away from current population centers.

Salt marshes and coastal peat swamps have also undergone massive change and destruction, whether they are within estuarine systems or along the coast. Salt marsh subsidence has occurred in part due to restricted sediment delivery from watersheds. Peat swamps in Southeast Asia have declined from 46–100% in countries monitoring changes. Since sea level is rising due to climate change as well as to land subsidence, and since freshwater diversion impedes delivery of sediments to estuarine systems, salt marshes will continue to be degraded and lost.

4.6.3 Trends in mangroves

Mangroves are trees and shrubs found in intertidal zones and estuarine margins that have adapted to living in saline water, either continually or during high tides. Mangroves grow under a wide amplitude of salinities, from almost fresh water to 2.5

times seawater strength; they may be classified into three major zones (Ewel et al. 1998): tide dominated fringing mangroves, river-dominated riverine mangroves, and interior basin mangroves.

About 15.2 million hectares of mangroves currently exist worldwide, with the largest extent found in Asia, followed by Africa and South America. The area of mangroves present in each country varies from a few hectares to more than 3 million, with close to half the global area found in just five countries: Indonesia, Australia, Brazil, Nigeria and Mexico. Many mangrove areas have become degraded worldwide, and habitat conversion of mangrove is widespread. Over the last 25 years, 3.6 million hectares of mangroves, about 20 percent of the total extent found in 1980, have disappeared worldwide. Estimates of the loss of mangroves from countries with available multiyear data show that 35% of mangrove forests have disappeared in the last two decades—at the rate of 2.1%, or more than 2,800 square kilometers, per year. In some countries, more than 80% of original mangrove cover has been lost due to deforestation.

Mangroves have been converted to allow for aquaculture and for agriculture, including grazing and stall feeding of cattle and camels. The leading human activities that contribute to mangrove loss are aquaculture (38% shrimp plus 14% fish), 26% forest use, and 11% freshwater diversion. Although alarming, the rate of net loss of mangroves is showing signs of slowing down. From about 185 000 ha lost annually in the 1980s (-1.03 percent per annum), it dropped to some 105 000 ha/year (-0.67 percent) during the 2000–2005 period. This may reflect an increased awareness of the value of mangrove ecosystems, which has led, in turn, to the preparation of new legislation, better protection and management and, in some countries, to an expansion of mangrove areas through active planting or natural regeneration (Global Forest Resources Assessment, 2005) Restoration has been successfully attempted in some places, but this has not kept pace with wholesale destruction in most areas.

4.6.4 Trends in intertidal habitats, deltas, beaches, and dunes

Rocky intertidal, nearshore mudflats, deltas, beaches, and dunes provide ecosystem services such as food, shoreline stabilization, maintenance of biodiversity (especially for migratory birds), and outdoor recreation. In the United States, the rocky intertidal zone has undergone major transformation in the last few decades: Similar trends have been observed elsewhere in the world. Along the Yellow Sea coast, China has lost around 37% of habitat in intertidal areas since 1950.

Intertidal mudflats and other soft-bottom coastal habitats play pivotal roles in ocean ecology, even though research and public interest have not historically focused on these habitats. Soft bottom coastal habitats are highly productive and can be extraordinarily diverse, with a species diversity that may rival that of tropical forests. Mudflats are critical habitat for migrating shorebirds and many marine organisms. Unfortunately, mudflats are commonly destroyed during port development or maintenance dredging, and coastal muds in many areas are highly contaminated by heavy metals, PCBs, and other persistent organic pollutants.

Coastal deltas are extremely important microcosms where many dynamic processes and human activity converge. Deltas, estuaries, and small islands are the coastal systems most vulnerable to climate change and sea level rise. Deltas are high population and human land use areas and are dynamic and highly vulnerable (e.g. New Orleans, The Netherlands, Bangla Desh).

Beaches and sandy shores also provide very important and economically valuable ecological services and are being altered worldwide. Sandy shores have undergone massive alteration due to coastal development, pollution, erosion, storms, alteration to freshwater hydrology, sand mining, groundwater use, and harvesting of organisms. Dune systems occur inland of the intertidal zone but are commonly found in conjunction with beaches and sandy shores. These habitats are often highly dynamic and mobile, changing their form in both the short and long term. Dunes support high species diversity in certain taxonomic groups, including endangered bird, plant, and invertebrate species. Encroachment in dune areas often results in shoreline destabilization, resulting in expensive and ongoing public works projects such as the building of breakwaters or seawalls and sand renourishment.

4.6.5 Trends in coral reefs and atolls

Coral reefs exhibit high species diversity and are valued for their provisioning, regulating, and cultural services. Reef-building corals occur in tropical coastal areas with suitable light conditions and high salinity and are particularly abundant where sediment loading and freshwater input is minimal. Reef formations occur as barrier reefs, atolls, fringing reefs, or patch reefs, and many islands in the Pacific Ocean, Indian Ocean, and Caribbean Sea have extensive reef systems occurring in a combination of these types. Coral reefs occur mainly in relatively nutrient-poor waters of the tropics, yet because nutrient cycling is very efficient on reefs and complex predator-prey interactions maintain diversity, productivity is high. However, with a high number of trophic levels the amount of primary productivity converted to higher levels is relatively low, and reef organisms are prone to overexploitation. The fine-tuned, complex nature of reefs makes them highly vulnerable to negative impacts from overuse and habitat degradation— when particular elements of this interconnected ecosystem are removed, negative feedbacks and cascading effects occur. Many coral reefs are transformed from productive, diverse biological communities into depauperate ones, along with similar cascading effects caused by technological, economic, and cultural phenomena. Coral reefs are at high risk from many kinds of human activity, including coastal construction that causes loss of habitat as well as changes in coastal processes that maintain reef life. In 1999, it was estimated that approximately 27% of the world's known reefs had been badly degraded or destroyed in the last few decades, although the latest estimates are of 20% of reefs destroyed and more than a further 20% badly degraded or under imminent risk of collapse.

Of all the world's ecosystems, coral reefs may be the most vulnerable to the effects of climate change. Although the mechanisms are not clear, warming seawater triggers coral bleaching, which sometimes causes coral mortality. Climate change also has other detrimental impacts on coral. For example, rising carbon dioxide levels change the pH of water, reducing calcium carbonate deposition (reef-building) by corals. Climate change also facilitates the spread of pathogens leading to the spread of coral diseases. It has been suggested that climate change will reduce the world's major coral reefs in exceedingly short time frames—one estimate suggests that all current coral reefs will disappear by 2040 due to warming sea temperatures, and it is not known whether the reefs that take their place will be able to provide the same level of services to humans and the biosphere.

4.7 Changes at the species level.

4.7.1 The Red List Indicator

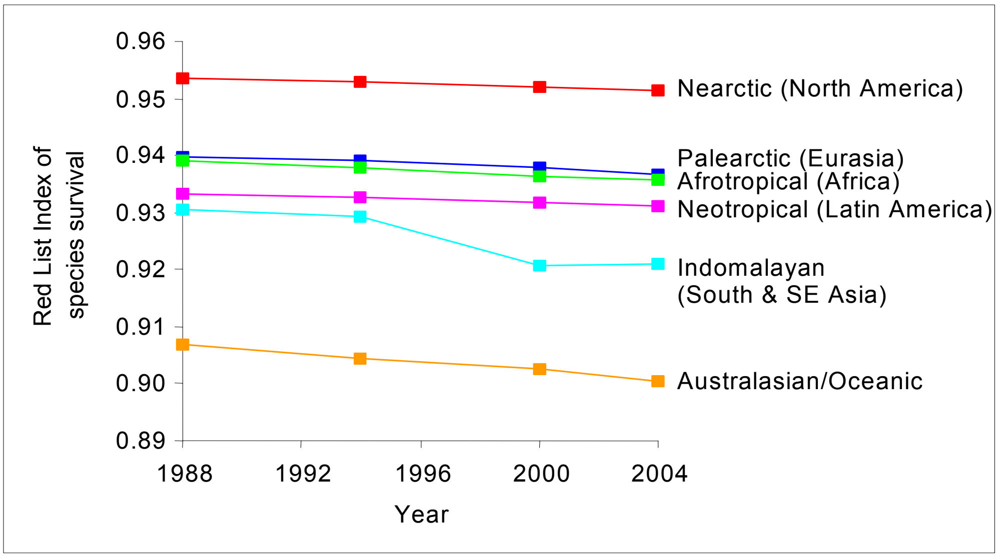


Figure 4.21 Changes in the Status of Species, as shown by the IUCN Red List Index for birds in different biogeographic realms (ecological regions) (approximate equivalent regional listings are provided in parentheses). The IUCN RLI tracks changes over time in the status of species. An IUCN RLI value of 1.0 equates to all species being categorised as Least Concern, and hence that none are expected to go extinct in the near future; a value of zero indicates that all species have gone Extinct (Butchart et al., 2007)

The changes in the "Status of Species" indicator, as shown through the IUCN Red List Index (RLI; *figure 4.21*), provides both a widely accepted indicator of changes in overall biodiversity, and an indicator with strong connections to the socio-economic context of the links between biodiversity and development. The focus on species is relevant for some ecosystem services, e.g. those species that are harvested for food, medicines and fibres, that are domesticated for agriculture, that play a role in regulating local and global environments, and that hold cultural and other societal benefits for rich and poor people alike. The IUCN RLI can be calculated for any set of species for which species threat status assessments have been carried out at least twice. To date, an IUCN RLI has been developed for all bird species for 1988–2004 and a preliminary IUCN RLI has been developed for all amphibian species for 1980–2004. These indices show ongoing deterioration in the status of birds and amphibians worldwide, even after improvements in the status of certain species as a result of conservation action have been taken into account. Regional and national trends in the status of species will be important in formulating conservation responses to biodiversity loss, and measuring the success of these responses at these sub-global scales.

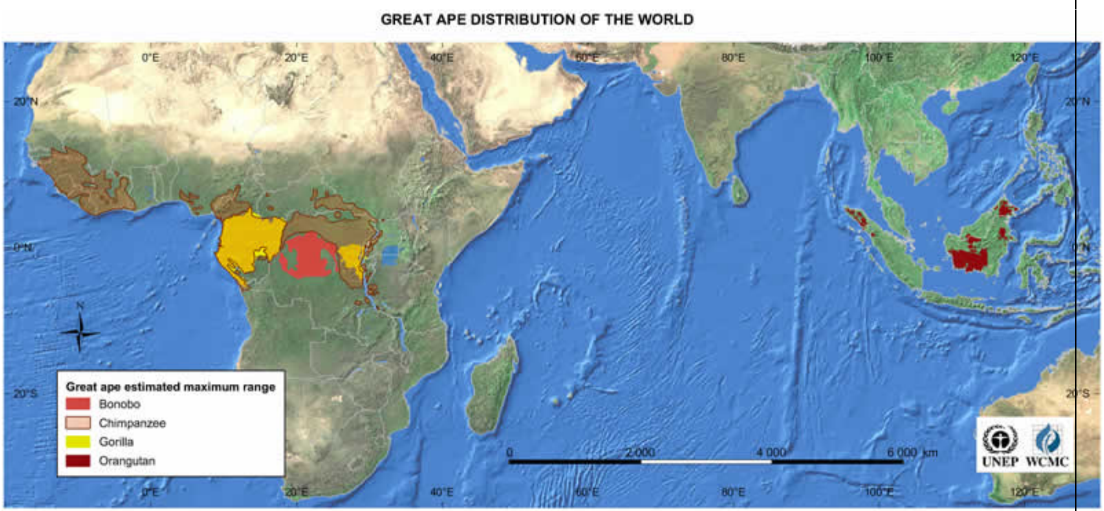
Birds in the Australasian/Oceanic region, for example, are showing a continual decline in the status of the species. The status of birds declined much faster in the Indo-Malayan realm than in other biogeographic realms during the 1990s. This was directly attributable to the increased rate of deforestation in the Sundaic lowlands during that period. When a graph line of the IUCN RLI is increasing, it means that the expected rate of species extinctions from that region is abating (i.e. the rate of biodiversity loss is decreasing), but this does not mean that biodiversity loss has stopped. To show that the global target of significantly reducing the rate of biodiversity loss has been met, an upwards trend is needed at the very least.

Data for calculating the IUCN RLI comes from the IUCN Red List of Threatened SpeciesTM (IUCN Red List, www.redlist.org). In 2006, the IUCN Red List contained 40,177 species, 16,119 of them threatened with extinction. Of the groups for which every species has been assessed globally, 12% of all birds are classified as threatened, 23% of mammals (see Box 4.5), 33% of amphibians, approximately 42% of turtles and tortoises, 25% of conifers and 52% of cycads. A set of quantitative criteria is applied to every species included in the IUCN Red List. These criteria place each species into one of seven categories on a continuum from “Extinct” to “Least Concern” (or into a “Data Deficient” category for species that are very poorly known). The movement of species up and down this continuum of Red List Categories over time is a measure of the extent to which their status is either improving or deteriorating. When these changes are measured for large number of species across taxa over a given time period, the index calculated reflects changes in the status of biodiversity overall.

The status of terrestrial vertebrates is relatively well documented, with roughly 76% of species assessed, but less is known about the status of biodiversity in marine and aquatic systems, or of species-rich groups like invertebrates, plants and fungi – which together comprise the overwhelming majority of the world’s species. These gaps in knowledge are being addressed by more species being assessed for the IUCN Red List every year. As more is documented about the status of species, the longer the world’s list of extinctions becomes. From known extinctions of birds, mammals and amphibians over the past 100 years, it is clear that the extinction rates of recent times exceed the natural rates of extinction determined from the fossil record by at least 2 to 4 orders of magnitude. Although most human-caused extinctions over the past several hundred years have taken place on oceanic islands, roughly half of extinctions over the past twenty years occurred on continents. The problem of continental extinctions is becoming much worse and as most terrestrial and aquatic species occur on continents they are facing growing threats to their survival and persistence.

Box 4.5: Great Apes – habitat destruction and population decline

The great apes are our closest living relatives yet are among the most endangered species on the planet. All are listed on the IUCN/SSC Red List as endangered or critically endangered, and all are in decline. A recent survey of *24* protected areas on both continents revealed that great apes were declining in *96%* of them due to habitat loss/degradation and hunting. As flagships for conservation in these regions, and generating significant tourism revenues as a result of their charisma and rarity, they are rightly a global conservation priority (Nellermann & Newton, 200?; Caldecott & Miles, 2005).



Source : Caldecott, J., Miles, L., eds (2005) World Atlas of Great Apes and their Conservation. Prepared at the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA.

Orangutans

There are *57,000* Orangutans remaining in Borneo, and only *7,300* in Sumatra. They have declined by *75%* and *93%*, respectively, since 1900, mostly as a result of habitat loss. In Borneo *55,000 km^2* of breeding habitat was lost between 1993 and 2002 through logging and forest fires, and the draining of peat swamp for rice cultivation destroys many more thousands of km^2 of prime Orangutan habitat. Subsistence agriculture was also reported to have affected *27%* of the land area of Kalimantan (Indonesian Borneo), *87%* of which was considered prime Orangutan habitat. Forests are increasingly being transformed into oil palm plantations, whilst fire has been responsible for massive forest loss. The fires of 1997/98 destroyed *95%* of lowland forest in Kutai National Park, and large numbers of Orangutans were killed by people fleeing the flames, or by smoke. As a result of the fires, *1/3* of Borneo's Orangutans may have been lost in one year alone. The situation for the critically endangered Sumatran Orangutan is even more dire. There has been a *61%* decline in forest area in Sumatra between 1985 and 1997. Even in the Leuser ecosystem, which is the best protected Sumatran Orangutan site and the heart of their present range, at least *1000 individuals per year* were being lost in the later 1990s. Very little forest below 1000m is expected to survive in either Sumatra or Kalimantan beyond 2010.

African Great Apes

Major threats are hunting, disease, and the massive upsurge in forest loss since the 1990s. most forests in the Congo Basin are under logging and mining concessions controlled by companies in the EU. By 2000 more than half of Gabon's forests had been allocated as logging concessions, whilst at the same time in Cameroon *76%* of forests were either logged or allocated to concessions. Analyses suggest that more than *70%* of African great ape habitat has already been affected by such development, and future scenarios suggest a continued loss of undisturbed habitat of *2% per year*. By 2030, it is predicted that less than *10%* of African great ape habitat will be free of disturbance. Mountain gorillas number only *a few hundred*, but the sub-species is stable in a handful of well-protected areas in the Albertine Rift area of central Africa. The surrounding Eastern Lowland Gorilla is much more numerous but of much greater immediate concern due to hunting and armed conflicts. This conflict has also begun to again threaten the Mountain Gorilla, with several individuals in the groups visited by tourists having been killed during 2007. Chimps are more numerous and more adaptable than Gorillas, and less sensitive, in the short term, to habitat disturbance due to their large home ranges. However they remain in decline. In Gabon the combined population of chimpanzees and gorillas declined by more than *50%* from 1983-2000 due to logging, hunting and the spread of Ebola virus. The latter resulted in *a 99% decline* in chimpanzees in Minkébé forest. In southern Sudan, chimpanzees were thriving in the 1960s but are now thought locally extinct. In some areas chimpanzee populations are stable, but overall trends are negative; current continental estimates range from *170,000-300,000*, down from a possible *1 million* in 1960. Chimpanzees will find it increasingly hard to survive as forests fragment in the face of expanding farming and settlement, and they come into contact with human diseases. Bonobos probably number fewer than *100,000* distributed patchily over a large area of the Congo basin. They are hunted for food in many areas particularly in times of conflict and food shortage. In more accessible areas numbers have declined by 25-75% during the late 1990s.

Major threats to species include habitat destruction, overexploitation, invasive alien species, disease, pollution and climate change. The IUCN RLIs for birds and amphibians show that habitat loss is a very important cause of decline in both groups, but that invasive species on islands are a greater threat to birds, while disease is more serious for amphibians. Early indications suggest that overexploitation in fisheries will prove to be the greatest cause of decline among marine fish species. It is anticipated that future assessments of a broader group of species are likely to demonstrate the growing impact of climate change. Most threatened terrestrial species occur in the tropical latitudes – particularly on islands and mountains. This uneven distribution of threatened species means that tropical developing countries have a comparatively large number of species at risk of extinction

4.7.2 Impacts of invasive alien species

Invasive alien species (IAS) have led and continue to lead to a wide range of ecological and socio-economic impacts including changes in species composition and dynamics, habitat characteristics, provisioning of ecosystem services (e.g. provision of food, water retention and regulation of erosion and forest fires). Invasive alien species also have negative impacts on health and cause damage to infrastructure (see for an overview Van der Weijden et al., 2007).

IAS, together with habitat destruction, have been a major cause of extinction of native species throughout the world in the past few hundred years. For example the introduction of the Nile perch (Lates nilotica) into lake Victoria in 1954 resulted in the extinction of over 200 endemic species of fish. In China's Dianchi Lake, the number of native species fell from 25 to 8 over a 20 year period that coincided with the introduction of 30 alien species of fish McNeely et al (2001). The Indian mongoose, introduced to Fiji, West Inies, Mauritius and Hawaii to control rats has led to the extinction of several endemic species of birds, reptiles and amphibians (McNeely et. al., 2001).

Additionally, it has been suggested that 80% of endangered species worldwide could suffer losses due to competition with or predation by IAS (Pimentel *et. al.*, 2005). For example, the grey squirrel (*Sciurus carolinensis*), the Asian lady beetle (*Harmonia axyridis*) and the Argentine ant (*Linepithema humile*) are known to out-compete and displace native species in several parts of the world. The European Mink (*Mustela lutreola*) - one of the only two endemic carnivores in Europe - is at risk of extinction from competition with the America mink (*M. vison*). In addition to threatening native species, the introduction of IAS between continents, regions and nations has often had significant impacts on the structure and functioning of the recipient ecosystems. For example, the invasion of alien shrubs and trees in the South-African native fynbos ecosystem and the consequent increase in vegetation biomass has resulted in a significant decrease of the overall water supply in the area.

IAS are also increasingly seen as a threat to ecosystem services and negatively affecting economic development and human well-being. For example, a number of human health problems, e.g. allergies and skin damage, are caused by IAS. The economic effects are related to the negative impacts of IAS on various human activities, such as hindering navigation by blocking waterways, and causing damage to forestry and crops (see Box 4.6).

Furthermore, increasing pressures on ecosystems, caused mainly by destruction of habitats, spread of IAS, over-exploitation and pollution, are weakening ecosystem resilience and ability to adapt to new conditions. The ability to adapt to climate change is weakening with biodiversity loss, and there is also a continuously declining capacity for providing ecosystem services. Box 4.6 presents the list of ecological problems IAS are known to cause.

Box 4.6: List of negative ecological impacts of invasive alien species (*see also Annex III*

- **Competing with other organisms** (e.g. plants like Japanese knotweed - *Fallopia japonica* or the Giant hogweed - *Hercleum mantegazzianum*) and change habitat structure
- **Predating** on native organisms (e.g. the fish Nile perch - *Lates niloticus* causing the extinction or near-extinction of several hundred native species in Africa)
- **Hybridising** with a related species or varieties, such as the North American grass *Spartina alterniflora* which hybridized with the European *Spartina maritima* and produced the very invasive hybrid *Spartina anglica*, which has radically changed coastal mudflat habitats in Great Britain, Denmark and Germany
- **Causing extinction** of native species, e.g. displacement of native species is known for the invasive multicoloured Asian ladybeetle (by intra-guild predation) and the Argentine ant (superior competitiveness)
- Being **toxic** (toxic algae blooms caused by alien phytoplankton such as *Chattonella verruculosa* and *Alexandrium* species)
- Being a reservoir for **parasites** or a **vector** for pathogens (rainbow trout which is a host for the salmon parasite *Gyrodactylus salaris* , signal crayfish which is a carrier and host of the crayfish plague)
- **Disrupting pollination** (e.g. *Impatiens glandulifera*. The alien plant competes for pollinators such as bumblebees with the native riverbank species, and so reduces seed set in these other plants)
- **Altering energy and nutrient flows**, as well as physical factors in habitats and ecosystems (freshwater plants like the Canadian waterweed (*Elodea canadensis*) and the Nuttall's waterweed (*Elodea nuttallii*)

- **Altering the local food web**, e.g. alien plants alter nutrient availability (e.g. nitrogen-fixing *Robinia pseudacacia*, *Lupinus polyphyllus*)
- **Altering the composition and functioning of habitats and ecosystems**. E.g. alien tree (Snichona pubescens) covering originally treeless highland of Santa Cruz island, Galapagos.

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5 Changes in ecosystem services

Leon Braat, Chris Klok, Matt Walpole, Marianne Kettunen, Niele Peralta-Bezerra and Patrick ten Brink

Summary

Ecosystem services constitute the physical link between ecological systems and human economies. With conversions of natural ecosystems to other forms of land use, such as cropland, pasture land or urban land, or by unsustainable fishing the oceans, or converting coastal mangrove to shrimp farms, the total flow of services in a region is altered. The changes often bring short-term economic benefits but longer-term costs. Maximization of provisioning services such as food, fish and timber has caused the loss of area with intact ecosystems and biodiversity and thus with the capability of these systems to provide regulating services such as climate and flood control, and air and water purification. With the loss of biodiversity at gene, species and system levels of 30 - 50% in the last few centuries, much potentially relevant information for future human welfare has already been lost.

Losses of services are related to biodiversity loss either proportionally (regulating and information services) or have a maximum at low to medium use intensities (provisioning and recreation services). It is essential to take account of the *net change* in services, as some benefits may increase while others get lost. Increasing one particular local service with private benefits generally leads to losses of the regional or global services with public benefits. It is also important to assess the *net benefits* of changes, as many human interventions require additional energy subsidies.

Losses of ecosystem services have social and economic consequences. It is estimated that *1 billion people* worldwide are dependent on fish as their sole or main source of animal protein, while fish provided more than *2.6 billion people* with at least *20 percent of their average per capita animal protein intake*. The expected demise of ocean fisheries will therefore have severe consequences. Water scarcity is a globally significant and accelerating condition for *1–2 billion people* worldwide, leading to problems with food production, human health, and economic development. The impacts of invasive alien species on are global and of headline importance affecting the flow of ecosystem services to several beneficiaries.

5.1 Introduction

The COPI analysis is aimed at an estimate of the economic consequences of biodiversity loss. In this chapter we present a qualitative and quantitative assessment of the expected future changes in ecosystems services of the world. The assessment is based on two types of sources: (1) the projected changes in land use and biodiversity, together with projections regarding the future demand for ecosystem services based on the OECD Baseline demographic and economic data and the expected influence of international conservation and sustainable use policies , and (2) a wide variety of case studies, many already reviewed in the Millennium Ecosystem Assessment (MA), and selectively summarised here, and a number of more recent cases (see *figure 5.1*). The assessment provides an essential input to the analysis of subsequent changes in economic value to society (see the next chapters).

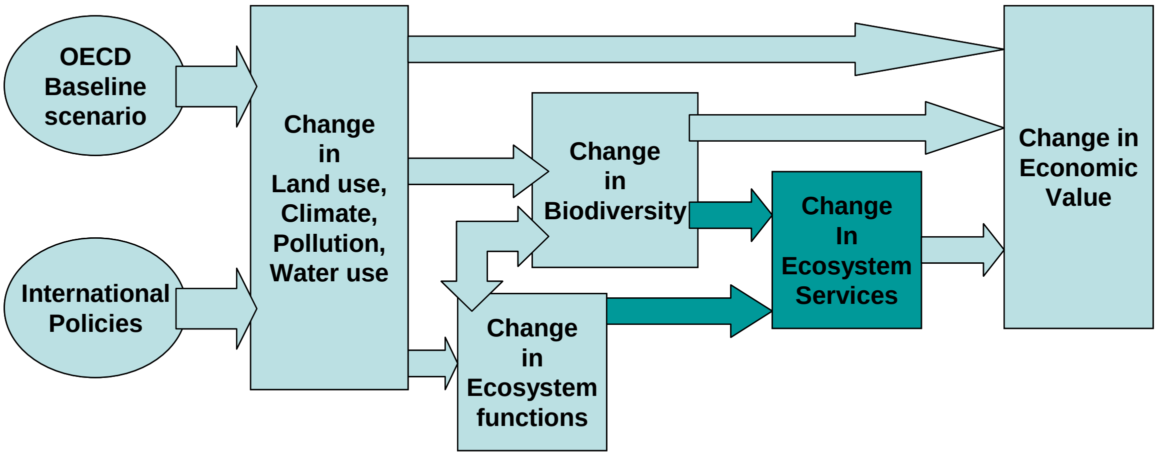


Figure 5.1 Chapter 5 in the conceptual model of the COPI analysis

The concept of ecosystem services in its modern form has been extensively discussed in the various reports of the Millennium Ecosystem Assessment. Earlier studies referred to the flow of goods and services from ecosystems to human systems as functions of nature (Braat, 1979, 1992; De Groot, 1992). An overview is presented in *figure 5.2* and *table 5.1*, taken from the MA (2005a). The MA has provided the basis for the analysis of ecosystem services work within the COPI study. There are of course different classifications possible of goods and services. A critical review and alternative classification is presented in Rodrigues et al. (2008), which is part of the Review of the Economics of the loss of Biodiversity.

Definitions (MA, 2005a; p.3) and conceptual implications

"Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits.

Human well-being has multiple constituents, including basis material for a good life, freedom of choice and action, health, good social relations, and security. Well-being is at the opposite end of a continuum from poverty, which has been defined as a "pronounced deprivation in well-being". The constituents of well-being, as experienced and perceived by people, are situation-dependent, reflecting local geography, culture, and ecological circumstances."

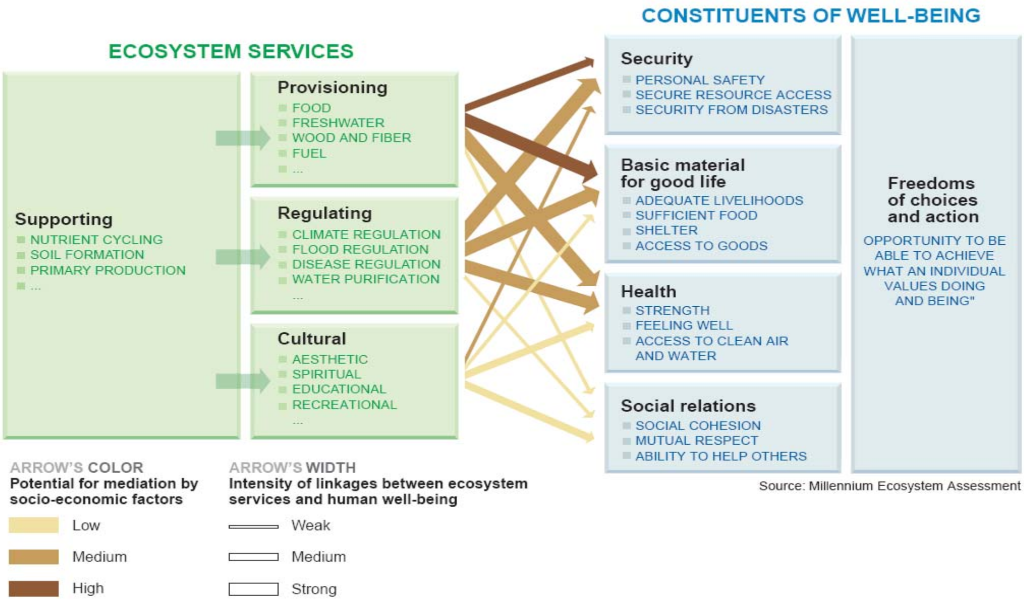


Figure 5.2 The Millennium Ecosystem Assessment Framework

The categories "human use" and "enhanced / degraded" in *table 5.1* do not apply for "supporting services" since, by definition, these services are not directly used by people (MA, 2005, p.25). A clear and useful distinction has been introduced between the internal dynamics within ecosystems (ecosystem functioning or supporting services), and the useable (potential) and used (actual) goods and services of ecosystems (provisioning, regulating, and cultural services). The potential and actual levels of ecosystems services are affected with the changes in ecosystem processes within ecosystems, as a consequence of, for example:

- climate change – e.g. a temperature change can lead to coral bleaching (see Chapter 4);
- the extraction of plant and animal specimens – e.g. loss of a keystone species will change the species dynamics of the ecosystem;
- change of nutrients flows – e.g. increase of nitrogen in soils from air pollution changes the balance among plant species on a given piece of land;
- change in water availability- e.g. rainfall patterns change or water abstraction, diversion of salination have major impacts on provision of agricultural produce or primary productivity of wetland habitats
- the input of toxic substances – e.g. heavy metal poisoning with effects on reproduction.

With conversions of original (pristine) ecosystems (called Natural Land Cover in the land use classification of the GLOBIO model), to other forms of land use (cropland, pasture land, urban land) or marine system use (e.g. mangrove to shrimp farming), the total flow of services in a region is altered. With the MA framework the possibility has been launched to have a common measure of loss of contributions to human well-being from ecosystems around the world. However, traditional ways of measuring and mapping productivity of different land use types need now to be amended, to include the contribution of ecosystems in terms of materials made available and work done, as compared to the input of materials and work from human sources.

Table 5.1 Ecosystems services (MA, 2005a) and dynamics

MA, 2005, P.21-25	ECOSYSTEM SERVICE	HUMAN USE	ENHANCED OR DEGRADED
PROVISIONING SERVICES			
1.1	FOOD-CROPS	↑	↑
1.2	FOOD-LIVESTOCK	↑	↑
1.3	FOOD-CAPTURE FISHERIES	↓	↓
1.4	FOOD-AQUACULTURE	↑	↑
1.5	FOOD-WILD PLANT / ANIMAL PRODUCTS	NA	↓
2.1	FIBER-TIMBER	↑	↑↓
2.2	FIBER-COTTON, HEMP, SILK	↑↓	↑↓
2.3	FIBER-WOOD FUEL	↑↓	↓
3	GENETIC RESOURCES	↑	↓
4	BIOCHEM'S, NATUR. MEDICINES & PHARMA' S	↑	↓
5	FRESH WATER	↑	↓
REGULATING SERVICES			
6	AIR QUALITY REGULATION	↑	↓
7.1	CLIMATE REGULATION -GLOBAL	↑	↑
7.2	CLIMATE REGULATION-REGIONAL & LOCAL	↑	↓
8	WATER REGULATION	↑	↑↓
9	EROSION REGULATION	↑	↓
10	WATER PURIFICATION & WASTE TREATMENT	↑	↓
11	DISEASE REGULATION	↑	↑↓
12	PEST REGULATION	↑	↓
13	POLLINATION	↑	↓
14	NATURAL HAZARD REGULATION	↑	↓
CULTURAL SERVICES			
15	CULTURAL DIVERSITY	NA	NA
16	SPIRITUAL & RELIGIOUS VALUES	↑	↑
17	KNOWLEDGE SYSTEMS	NA	NA
18	EDUCATIONAL VALUES	NA	NA
19	INSPIRATION	NA	NA
20	AESTHETIC VALUES	↑	↓
21	SOCIAL RELATIONS	NA	NA
22	SENSE OF PLACE	NA	NA
23	CULTURAL HERITAGE VALUES	NA	NA
24	RECREATION & TOURISM	↑	↑↓
SUPPORTING SERVICES			
25	SOIL FORMATION	NI	NI
26	PHOTOSYNTHESIS	NI	NI
27	PRIMARY PRODUCTION	NI	NI
28	NUTRIENT CYCLING	NI	NI
29	WATER CYCLING	NI	NI

↑	Increasing (human use) or Enhanced (Enhanced/Degraded)
↓	Decreasing (human use) or Degraded (Enhanced/Degraded)
↑↓	Mixed (trend 50 years up and down, regional differences)
NA	Not Assessed
NI	Not Included in analysis; not directly used by humans

This would seem quite possible, but requires a convergence of methodologies which has only just started. In the COPI study we therefore have used a number of assumptions, which necessarily simplify the complexities in producing the ecosystem services, but nonetheless produce a logical and traceable set of data as an intermediate step in the assessment of the economics of biodiversity loss.

So, ecosystem services are considered to stem from ecosystem functions within the natural environment, recognising that these are still provided in varying amounts when the original land cover in a biome is modified by humans (see *figure 5.1*). Furthermore, outputs from converted land or marine systems will likely have an economic value that includes more energy, matter and information than provided by the remaining parts of the original ecosystem, because these values also include human input(s), e.g. labour, fertiliser (see *figure 5.3*). So, if food or timber are provided by introduced or domesticated species but otherwise depend on the same processes as in natural (i.e. non-converted) ecosystems, they need to be considered, e.g. replacing deer with cattle may generate similar services in similar ways. To consider the loss of deer meat and ignore the gain in cattle meat would not make sense. Note that ecosystem services can be mimicked to a large extent and be provided **artificially** (e.g. water purification by water purification technologies, rather than via ecosystems), usually with some kind of fossil fuel-based technology.

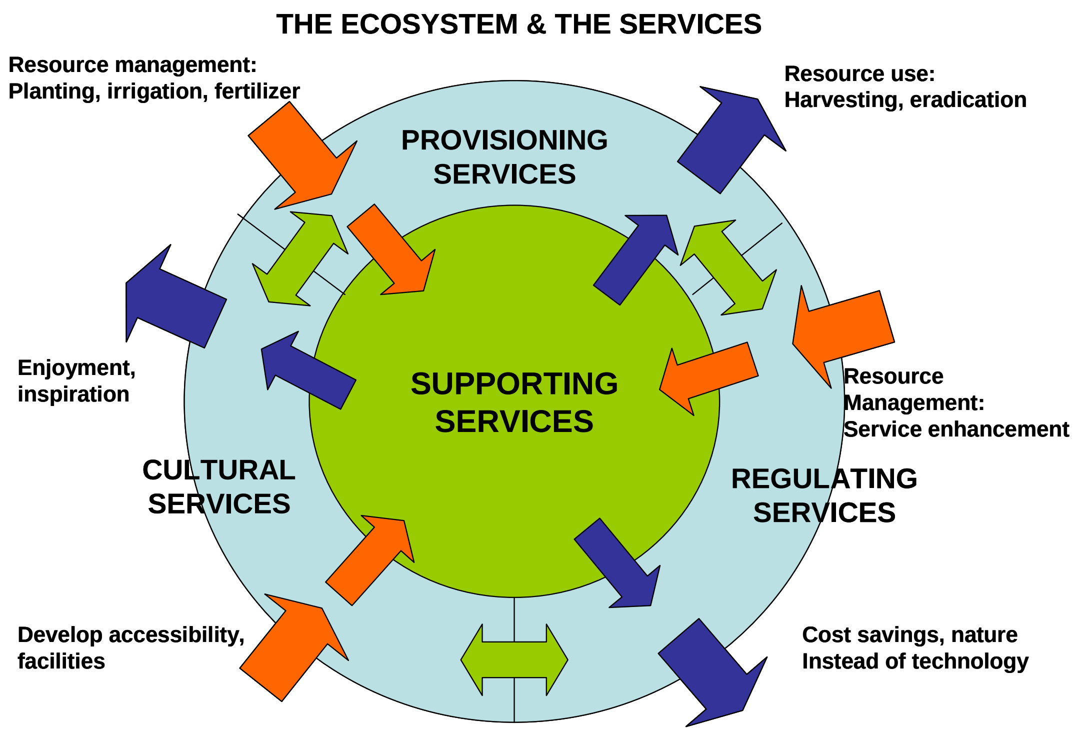


Figure 5.3 The ecosystem services relationships, including investments (red arrows), competition (green arrows) and benefits (blue arrows)

When estimating the change in services, a COPI assessment needs to take account of the ***net change.*** One would need to look at the ecosystem service contribution to e.g. cattle meat, and ensure net of other inputs – else the picture of the benefit will be skewed. Similarly one needs to look at the ecosystem services over the long term, as this helps provide a clearer picture of true changes in benefits and losses of services (short term economic gains at the cost of long term ecological degradation). If net values cannot be obtained yet, then the gross values should be used only with a clear warning about aforementioned issues. In the current COPI assessment the so called "leverage" effect - i.e. the existence of one Ecosystem Service to allow a series of other non-ecosystem service related values to be created – is not included. Also, services should in principle be valued whether they are commercialised or not. Where they are commercialised they are easier to value, where not there is a need to estimate non-market values. It is important to avoid an imbalance by having many data on the commercialised and few or none on non-commercialised services as this might lead to misleading messages.

5.2 The mechanisms behind changes in ecosystem services.

5.2.1 Provisioning services

When natural ecosystems are converted to produce food, timber, fresh water or other material contributions to human well-being, the essential changes are:

- When only components of the ecosystems are removed, like in a hunter – gatherer economy, functioning is not noticeably affected. This is probably still only occurring in remote areas such as Eskimo territory and some Tropical rainforest and Savannah native tribes in Africa, South-America, South-East Asia and Australia.
- Where over-exploitation has been the common pattern, in hunting and fishing it has lead to local or regional extinctions of e.g. predator species (wolf, bear in Europe) and game species (many large mammals in North-America), and the total eradication of virgin forests in many areas around the world. Capture fisheries and conversion of tropical rainforest to Palm oil plantations are the present day examples.
- In early agriculture, the structure of the ecosystem is altered. Wild species are replaced by domesticated species (plants and animals), in early societies in Europe and some areas in developing countries still at a limited scale, compared to the surrounding wild ecosystems. The remaining ecosystem services contributing to the production are: biomass production through contributions from the local soils and hydrological systems. The original biodiversity has disappeared to a large extent, a different set of species appears and in extensive agriculture some kind of sustainability may be achieved, with susceptibility to environmental fluctuations. In intensive agriculture and plantation forestry, biodiversity drops to very low levels, and the ecosystem only contributes some basic soil functions and may become the habitat of some human-adapted species.
- When most of the productive processes of the original system have been replaced by "artificial" processes, the last contribution of the original ecosystem is the

provision of the basic genetic program to produce biomass (a range from greenhouse vegetables, and bio-industry to water cultures). Biodiversity is only relevant at the genetic level.

5.2.2 Regulating services

Mankind has been quite successful in manipulating ecosystem productive processes to provide consumers with food and fiber etc., but it has been much less so in manipulating and mimicking the regulating processes of the world's ecosystems. A major reason is that *all of these services are the result of complex large scale interactions between physical forces and the biological processes driven by them, but mitigating, modulating and abating them, when intact.* The generic relationships between ecosystem functioning, biodiversity and ecosystem service levels in this group are:

(1) alteration of ecosystem composition and structure (simplification, removal of key species) leads to rapid decline of regulatory capacities, as many of these depend directly on the availability of ecosystem structure and biological activity which captures, stores and releases water, nutrients, and soil structure. Services such as pollination, pest and disease regulation depend on the presence of particular "controlling" species, which often have very narrow niches. Decline of biodiversity, as measured in the MSA (see chapter 3), is assumed to lead to a proportional decline of the service.

(2) Decreasing the extent of natural ecosystems, aside from per hectare changes in structure and composition leads also to serious losses of the "abiotic" regulating services, at least proportional, and most likely also for the biotic services.

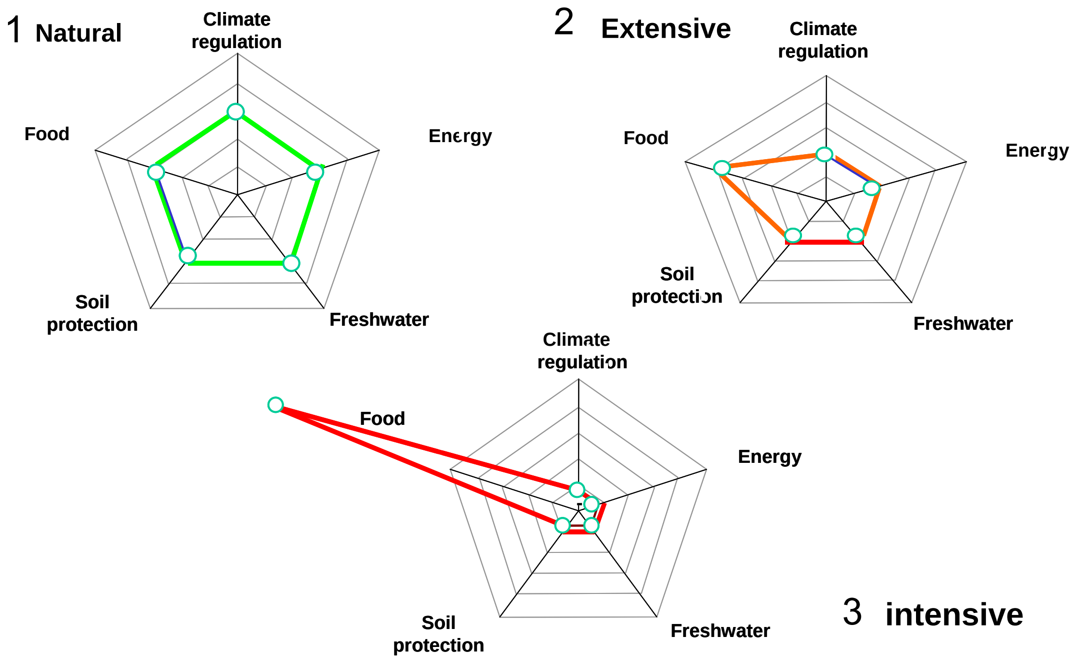
5.2.3 Cultural services

Two categories are distinguished based on the way ecosystems contribute:

(1) The recreation and tourism service is defined in terms of physically enjoying the ecosystem, its structure and its components (animal, plant species, streams) with or without extracting parts of the system. However, to accommodate people to consume the service, access has to be created, so a percentage of the area is converted to urban land use. A range of types of recreation can be distinguished based on dependency on "high, intact species richness" or "total system naturalness". At the high end for example scuba diving & snorkling on coral reefs, at the low end, a picnic in a city park. Service levels are therefore considered to decrease proportionally faster than biodiversity at the high end of the range and proportionally slower at the low end.

(2) Other cultural services are less attached to particular quantities, but sometime very much to particular qualities of ecosystems. Their service levels are, for lack of better knowledge currently assumed to respond proportionally to changes in biodiversity (MSA, including area and quality aspects).

Figure 5.4 illustrates the relationships between different ecosystem services in a different way than *figures 5.2 and 5.3*. In diagram 1, the service levels in a natural ecosystem are depicted to be in some kind of balance, fitting the capability of the particular ecosystem. In the second diagram, the system has been converted to extensive use for *food* production, thereby decreasing the potential and actual service levels of the other provisioning (energy, freshwater), regulating (climate) and supporting services (soil protection). In Diagram[3], representing an intensive food production system, the other services have been reduced to very low levels.



Source: Ben ten Brink (MNP ***2008)****.*

Figure 5.4 The consequences for ecosystem service levels of maximising food production

Next to these generalised characterizations of the functional relationships between biodiversity, ecosystem processes and ecosystem services a great amount of information is available in specific case studies. Before introducing a simple model, a few of these cases are reviewed. Very little work has been done so far on the quantification of the functional relationships between biodiversity features such as mean species abundance, species richness, extinction risks etc and specific ecosystem services.

The above characterisations are based on the ecological textbooks and the mass of qualitative case material published through the MA (2005b). Together with the cases inserted in Boxes in this chapter *a set of simplified functional relationships for groups of ecosystem services have been developed* in the COPI project to allow a bridge between the calculated future changes in areas (per type of land use) with associated changes in total biodiversity (because of the different biodiversity levels per land use type), and the wide variety of monetization case studies and estimates of economic benefits of the use of ecosystems (see *figure 5.5*). Summarising the literature and example discussed above, the following reasoning underlies the shape of the curves. Obviously, these are generalised curves. Specific situation will have specific versions of these generalised curves.

Box 5.1: Biodiversity and ecosystem services (MA, 2005b)

- **Species composition is often more important than the number of species in affecting ecosystem processes**. Conserving or restoring the composition of communities, rather than simply maximizing species numbers, is critical to maintaining ecosystem services.
- **The properties of species are more important than species number in influencing climate regulation.** Climate regulation is influenced by species properties via ecosystem level effects on sequestration of carbon, fire regime, and water and energy exchange. The traits of dominant plant species, such as size and leaf area, and the spatial arrangement of landscape units are a key element in determining the success of mitigation practices such as afforestation, reforestation, slowed-down deforestation, and biofuels plantations.
- **The nominal or functional extinction of local populations can have dramatic consequences in terms of regulating and supporting ecosystem services.** Before becoming extinct, species become rare and their ranges contract. Therefore their influence on ecosystem processes decreases, even if local populations persist for a long time, well before the species becomes globally extinct.
- **Preserving interactions among species is critical for maintaining long term production of food and fiber on land and in the sea.** The production of food and fiber depends on the ability of the organisms involved to successfully complete their life cycles. For most plant species, this requires interactions with pollinators, seed disseminators, herbivores, or symbionts. Therefore, land use practices that disrupt these interactions will have a negative impact on these ecosystem services.
- **The diversity of landscape units also influences ecosystem services.** The spatial arrangement of habitat loss, in addition to its amount, determines the effects of habitat loss on ecosystem services. Fragmentation of habitat has disproportionately large effects on ecosystem services.

Provisioning (P): There is no provisioning service, by definition, in a pristine ecosystem. With increasing intensity of use and conversion of the structure, species composition and thus functioning of the original natural area, MSA decreases (from 1 to 0) and the benefit flow (EV; ecosystem service value) increases. Adding labour, fertiliser, irrigation, pest control etc. will raise the gross benefits, and possibly the net. At some point, the remaining ecosystem will be reduced to a substrate for production of biomass. The final state is defined as approaching zero value, having been built on and covered by concrete or asphalt.

Regulating (R): Most of the information from case studies on the regulating services distinguished in the MA points at a complex relationship between the "intact" ecosystem and the service levels. As systems are converted, their regulating service potential, and actual performance drops more or less proportionally with the decrease of MSA along the range of land use types.

Cultural – recreation (Cr): A crucial feature in the valuation of the recreational services of ecosystems is accessibility. The graph therefore displays an increase from low value at inaccessible pristine systems to high values in accessible light use systems and a subsequent drop to degrade systems. This is of course very much generalised, as the biodiversity aspect counts, not the openness of landscapes, the cultural-historical value or amenities.

Cultural – Information (Ci): Most of the other cultural ecosystem services and their values are a function of the information content which is considered to decrease with the degree of conversion.

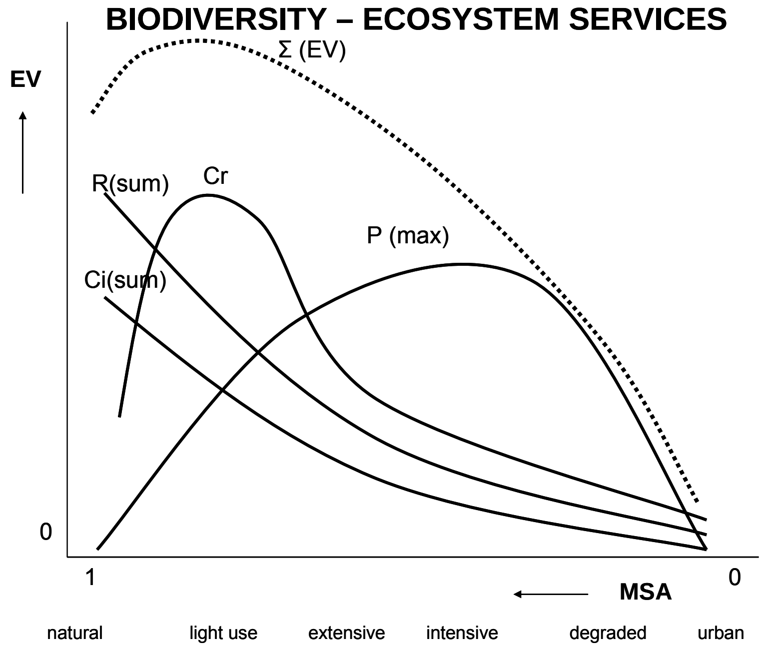


Figure 5.5 Generalised functional relationships between ecosystem service level and degree of land use intensity (decreasing MSA values)

The graphs have been used to develop multiplication factors (index) to be combined with the MSA factors (remaining biodiversity per land use type). These indices are presented in *Table 5.2*. These ecosystem service indices are used in the COPI spreadsheet to support benefit transfers from case studies with monetized ecosystem services. All areas in the world are classified to be in a particular biome and land use type (see Chapter 4 and the x-axis in figure 5.5). A particular type of land use is characterised with the set of indices. The biome-land use type(s) in the case studies analysed is determined and the monetary values are transferred to the areas with the same or similar type. Of course, this procedure has a considerable margin of uncertainty, but within the scope of the study, a reasonable estimate can thus be produced.
The relationships between ecosystem service levels, for the 4 groups of services, and changes in land area, within biome-land use units, have been assumed to be more or less linearly proportional. This is well documented for most land-based provisioning services. For services based on intact ecosystems with natural populations of plant and animal species, there is a so called species-area relationship, which implies a slow decrease of service level for with decreasing area, until some threshold is approached (minimum area). The species populations then collapse. However, as the COPI study

does not deal with regional or local changes, these effects have been ignored, although we are aware of their existence at the smaller geographical scales.

Table 5.2 Table of value –factors of ecosystem services (clusters) per land use type

COPI Category		natural areas			Bare natural	forest managed	Cultivated and managed areas				Artificial surfaces
		Pristine (historic)	Natural	Light forest			grazing area	woody biofuels	Extensive Ag	Intensive Ag	
General*	MSA	1	0.9	0.7	0.9	0.5	0.7	0.5	0.3	0.1	0.05
P*: Provisioning	Importance (gross)	-	*	**	*	***	**	***	****	*****	-
	Index	0	0.2	0.5	0.05	0.7	0.5	0.7	0.8	1	0
R*: Regulating	Importance	*****	*****	****	*	***	****	***	***	*	*
	Index= F*(msa)	1	0.9	0.7	0.05	0.5	0.7	0.5	0.3	0.1	0.05
C1*: Recreation	Importance	-	*****	*****	**	***	****	*	***	*	* (- to ***)
	Index	0	1	1	0.5	0.6	0.8	0.15	0.5	0.1	0.1
C2*: Info (spiritual, education)	Importance	*****	*****	****	*	***	****	**	***	*	*
	Index= F*(msa)	1	0.9	0.7	0.5	0.5	0.7	0.2	0.3	0.1	0.05

* These are broad relationships; for COPI valuation, where data exists that is more precise (eg for carbon storage), this will be used. The numbers here are back-up ratios to help fill gaps

The indices have been valuable in helping address the gaps, and future testing and fine tuning would be valuable to help clarify the relationships between Land use types and MSA levels of ecosystem services.

5.3 Ecosystem services, land cover and land use

5.3.1 Introduction

In this section the state and trends of ecosystem services as described in the MA report State and Trends (MA, 2005b) are summarised. With overview tables indicating the relative importance of a particular land cover – land use type for the ecosystem service types distinguished by the MA and a summary of qualitative and quantitative descriptions of trends per ecosystem service a basis for economic value assessment is presented. In later sections, the expected changes in service levels will be introduced as the basis for the assessment of economic loss of biodiversity. The selection of services is based on the original MA list, shown in *table 5.1*. The "X" es indicate the importance of the land use type, relative to other types, for the provision of each of the services distinguished.

5.3.2 State and trends in the levels of Provisioning Services

Food

- Global food production has increased by *168%* over the past 42 years. The production of cereals has increased by about *130%*, but is now growing more slowly. Nevertheless, an estimated *852 million people* were undernourished in 2000–02, up *37 million* from the period 1997–99. Of this total, nearly *96%* live in developing countries. Sub-Saharan Africa is the region with the largest share of undernourished people.
- Total fish consumption has declined somewhat in industrial countries, while it has increased to *200%* in the developing world since 1973. For the world as a whole, increases in the volume of fish consumed are made possible by aquaculture, which in 2002 is estimated to have contributed *27%* of all fish harvested and *40%* of the total amount of fish products consumed as food.
- In addition to fish, wild plants and animals are important sources of nutrition in some diets, and some wild foods have significant economic value. In most cases, however, wild foods are excluded from economic analysis of natural resource systems as well as official statistics, so the full extent of their importance is improperly understood.

Table 5.3 Overview of relative importance of Provisioning ecosystem services in the GLOBIO land use classes and water systems

Biome types and land co	Provisioning services									
Biome types and land cover types	1.1 Food-crops	1.2 Food-livestock	1.3 Food-capture fisheries	1.4 Food-aquaculture	1.5 Food-wild plant /animal products	2.1/2.3 Fiber-timber/wood fuel	2.2 Fiber-cotton, hemp, silk	3. Genetic Resources	4. Biochemicals, natural medicines, pharmaceuticals	5. Fresh water
natural areas		X	X		XXX	XX	X	XXX	XXX	XXX
bare natural										
forest managed		XX			XX	XXX		XX	XX	XX
extensive agriculture	XX	X					XX	XX	XX	X
intensive agriculture	XXX						XXX	X		
woody biofuels						XXX				
grazing area		XXX			X			X	X	
Artificial surfaces										
Ice										XXX
Hot desert					X			X	X	
Inland Waters			XX	X	XX			XXX	XXX	XXX
Coastal areas			XXX	XX	XXX			XXX	XXX	
Marine			XXX		XX			XXX	XXX	

Timber

- Global timber harvest has increased by *60%* in the last four decades and will continue to grow in the near future, but at a slower rate. In 2000, plantations were *5%* of the global forest cover, but they provided some *35%* of harvested roundwood, an amount anticipated to increase to *44%* by 2020. The most rapid expansion will occur in the mid-latitudes, where yields are higher and production costs lower.

- The global value of timber harvested in 2000 was around $400,000 million, and around *25%* of that entered into world trade, representing some *3%* of total merchandise trade. In constant dollar terms, global exports increased by a *factor of 25* between 1961 and 2000.
- Five countries—the United States, Germany, Japan, the United Kingdom, and Italy—imported more than *50%* of world imports in 2000, while Canada, the United States, Sweden, Finland, and Germany accounted for more than half of exports. During the past decade, China has increased its imports of logs and wood products by more than *50%*.
- Up to *15%* of global timber trade involves illegal activities, and the annual economic toll is around *$10,000 million*.
- The global forestry sector annually provides subsistence and wage employment of *60 million work years*, with *80%* taking place in the developing world.

Renewable Energy

- Fuel wood is the primary source of energy for heating and cooking for some *2.6 billion people*, and *55%* of global wood consumption is for fuel wood. An estimated *1.6 million deaths* and *39 million disability-adjusted life years* are attributed to indoor smoke pollution, with women and children most affected.
- Renewable energy technologies are being rapidly developed throughout the world, but examples of full commercial exploitation are still fairly modest.

Fibre

- Global cotton production has doubled and silk production has *tripled* since 1961, accompanied by major regional shifts in production areas. Production of other agricultural fibres such as wool, flax, hemp, jute, and sisal has declined.
- There are still instances where species are threatened with extinction due to the trade in hides, fur, or wool, in spite of international efforts to halt poaching and trade.

Fresh water

- Forest and mountain ecosystems serve as source areas for the largest amounts of renewable freshwater supply—*57% and 28%* of total runoff, respectively. These ecosystems each provide renewable water supplies to at least 4 billion people, or two thirds of the global population. Cultivated and urban ecosystems generate only *16% and 0.2%,* respectively, of global runoff, but because of their close proximity to human settlements, they serve *4–5 billion people.*
- Between *5%* and possibly *25%* of global freshwater use exceeds long-term accessible supply. Much of this water is used for irrigation with irretrievable losses in water-scarce regions. All continents record overuse. In the relatively dry Middle East and North Africa, non-sustainable use is exacerbated, with current rates of freshwater use equivalent to *115%* of total renewable runoff. In addition, possibly *1/3* of all withdrawals come from non-renewable sources, a condition driven mainly by irrigation demand.

- Global freshwater use is estimated to expand *10%* from 2000 to 2010, down from a per decade rate of about *20%* between 1960 and 2000. Contemporary water withdrawal is approximately *3,600 cubic kilometres* per year globally or *25%* of the continental runoff to which the majority of the population has access during the year. If dedicated instream uses for navigation, waste processing, and habitat management are considered, humans then use and regulate over 40% of renewable accessible supplies.
- Because the distribution of fresh water is uneven in space and time, more than *1 billion people* live under hydrologic conditions that generate no appreciable supply of renewable fresh water. An additional *4 billion (65% of world population*) is served by only *50%* of total annual renewable runoff in dry to only moderately wet conditions, with concomitant pressure on that resource base. Only about *15%* live with relative water abundance.
- Water scarcity is a globally significant and accelerating condition for *1–2 billion people* worldwide, leading to problems with food production, human health, and economic development. Rates of increase in water use relative to accessible supply—from 1960 to present averaged nearly *20% per decade* globally. The annual burden of disease from inadequate water, sanitation, and hygiene totals *1.7 million deaths* and the loss of at least *50 million healthy life years*.

Bio-prospecting

- Bio-prospecting is the exploration of biodiversity for new biological resources of social and economic value. There are between 5 million and 30 million species on Earth, each one containing many thousands of genes. However, fewer than 2 million species have been described, and knowledge of the global distribution of species is limited. History reveals that less than *1%* of species have provided the basic resources for the development of all civilizations thus far, so it is reasonable to expect that the application of new technologies to the exploration of the currently unidentified and overwhelming majority of species will yield many more benefits for humanity.

5.3.3 State and trends in Regulating services

Nutrient cycling

- In pre-industrial times, the annual flux of nitrogen from the atmosphere to the land and aquatic ecosystems was *90–130 teragrams (million tons) per year*. This was more or less balanced by a reverse "denitrification" flux. Production and use of synthetic nitrogen fertilizer, expanded planting of nitrogen- fixing crops, and the deposition of nitrogen-containing air pollutants have together created an additional flux of about *200 teragrams a year,* only part of which is denitrified.
- Phosphorus is also accumulating in ecosystems at a rate of *10.5–15.5 teragrams per year*, which compares with the preindustrial rate of *1–6 teragrams* of phosphorus a year, mainly as a result of the use of mined P in agriculture.
- Sulphur emissions have been progressively reduced in Europe and North America but not yet in the emerging industrial areas of the world: China, India, South Africa, and the southern parts of South America.

In contrast to the issues associated with nutrient oversupply, there remain large parts of Earth, notably in Africa and Latin America, where harvesting without nutrient replacement has led to a depletion of soil fertility, with serious consequences for human nutrition and the environment.

Table 5.4 Overview of relative importance of Regulating ecosystem services in the GLOBIO land use classes and water systems

Biome types and land co	Regulating services								
Biome types and land cover types	6. Air quality maintenance	7.1/2 Climate regulation global /regional	8. Water regulation	9.Erosion regulation	10. Water purification & waste treatment	11. Disease regulation	12. Pest regulation	13. Pollination	14. Natural hazards regulation
natural areas	XXX	XXX	XXX	XXX	X	XXX	XXX	XXX	XXX
bare natural									
forest managed	XXX	XX	XX	XX	X	X	X	XX	XX
extensive agriculture	X	XX	X	X		X	X	XX	XX
intensive agriculture									
woody biofuels	XX	XXX	X	XX					X
grazing area	X	X	X	X	X	X	X	XX	XX
Artificial surfaces									
Ice	X	XXX	XX						
Hot desert									
Inland Waters	XXX	XXX	XXX		XXX	X	XXX		
Coastal areas	XXX	XXX	XXX		XXX	X	XXX		
Marine	XXX	XXX	XXX		XXX	X	XXX		

Climate and air quality

Ecosystems provides atmospheric 'services': warming, cooling, water recycling and regional rainfall patterns, atmospheric cleansing, pollution sources and nutrient redistribution. Ecosystems are currently a net sink for carbon dioxide and tropospheric ozone, while they remain a net source of methane and nitrous oxide. Ecosystems influence the main anthropogenic greenhouse gases in several ways:

- Carbon dioxide—Pre-industrial concentration, *280 ppm*; concentration in 2000, *370 ppm*. About *40%* of the emissions over the last two centuries and about 20% of the CO_2 emissions during the 1990s originated from changes in land use and land management, primarily deforestation. Terrestrial ecosystems have been a sink for about a third of cumulative historical emissions and a third of the 1990s total (energy plus land use) emissions. Ecosystems were on average a net source of CO_2 during the nineteenth and early twentieth century and became a net sink sometime around the middle of the last century.
- Methane—Preindustrial concentration, *700 ppb*; concentration in late 1990s, *1750 ppb*. Natural processes in wetland ecosystems account for *25–30%* of current CH4 emissions, and about *30%* of emissions are due to agriculture (ruminant animals and rice paddies).

- Nitrous oxide—Preindustrial concentration, *270 ppb*; concentration in late 1990s, *314 ppb*. Ecosystem sources account for about *90%* of current N2O emissions, with *35%* of emissions from agricultural systems, primarily driven by fertilizer use.
- Tropospheric ozone—Preindustrial, *25 Dobson Units*; late 1990s, *34 DU*. Several gases emitted by ecosystems, primarily due to biomass burning, act as precursors for tropospheric ozone. Dry deposition in ecosystems accounts for about half the tropospheric ozone sink. The net global effect of ecosystems is a sink for tropospheric ozone.

Land cover changes between 1750 and the present have increased the reflectivity of solar radiation (albedo) of the land surface, partially offsetting the warming effect of associated CO_2 emissions:

- Deforestation and desertification in the tropics and sub-tropics leads to a reduction in regional rainfall. The biophysical effects of ecosystem changes on climate depend on geographical location and season.
- Deforestation in seasonally snow-covered regions leads to regional cooling during the snow season due to an increase in surface albedo and leads to warming during summer due to reduction in evapotranspiration. Large-scale tropical deforestation (hundreds of kilometres) reduces regional rainfall, primarily due to decreased evapotranspiration.
- Desertification in tropical and sub-tropical drylands leads to decrease in regional rainfall due to reduced evapotranspiration and increased surface albedo.

The self-cleansing ability of the atmosphere is fundamental to the removal of many pollutants and is affected by ecosystem sources and sinks of various gases. Removal of pollutants involves chemical reactions with the hydroxyl radical. OH concentration and hence atmospheric cleansing capacity has declined since preindustrial times but probably not by more than *10%*. The net contribution of ecosystem changes to this decline is currently unknown. The reactions are complex, but generally emissions of NOx and hydrocarbons from biomass burning increase tropospheric ozone and OH concentrations, and emissions of CH4 and carbon monoxide from wetlands, agricultural practices, and biomass burning decrease OH concentration.

Disease control

Intact ecosystems play an important role in regulating the transmission of infectious diseases.

- Natural systems with intact structure and characteristics generally resist the introduction of invasive human and animal pathogens brought by human migration and settlement. This seems to be the case for cholera, kala-azar, and schistosomiasis, which have not become established in the Amazonian forest ecosystem.
- Dams and irrigation canals provide ideal habitat for snails that serve as the intermediate reservoir host species for schistosomiasis; irrigated rice fields increase the extent of mosquito breeding areas, leading to greater transmission of mosquito-borne malaria, lymphatic filariasis, Japanese encephalitis, and Rift Valley fever.

- Deforestation alters malaria risk and uncontrolled urbanization of forest areas has been associated with mosquito borne viruses (arboviruses) in the Amazon, and lymphatic filariasis in Africa.
- Habitat fragmentation, with subsequent biodiversity loss, increases the prevalence of the bacteria that causes Lyme disease in North America in ticks.
- Overcrowded and mixed livestock practices, as well as trade in bush meat, can facilitate interspecies host transfer of disease agents, leading to dangerous novel pathogens, such as SARS and new strains of influenza.

Extreme events
Quantification is rare but available studies on extreme events, their impacts on human well-being, and the roles of ecosystem services do in mitigation and alleviation of the impacts allow several qualitative assertions to be made (see also sections on coastal systems):
- Many measures of human vulnerability show a general increase, due to growing poverty, mainly in developing countries.
- Impacts of natural hazards are increasing in many regions around the world. Annual economic losses from extreme events increased tenfold from the 1950s to 1990s. From 1992 to 2001, floods were the most frequent natural disaster (*43% of the 2,257 disasters*), and floods killed *96,507 people* and affected more than *1.2 billion people* over the decade. A large number of damaging river floods occurred in Europe in the last decade. Material flood damage recorded in Europe in 2002 was higher than in any previous year.
- Interactions of modern human activities with ecosystems have contributed to increasing human vulnerability and to the impact of extreme events on human well-being.

5.3.4 State and trends in Cultural services

Human cultures, knowledge systems, religions, heritage values, social interactions, and the linked amenity services (such as aesthetic enjoyment, recreation, artistic and spiritual fulfilment, and intellectual development) have always been influenced and shaped by the nature of the ecosystem and ecosystem conditions in which culture is based.

At the same time, humankind has always influenced and shaped its environment. Rapid loss of culturally valued ecosystems and landscapes lead to social disruptions and societal marginalization, now occurring in many parts of the world.
Our understanding of the tangible benefits derived from traditional ecological knowledge, such as medicinal plants and local species of food, is relatively well developed. However, our knowledge of the linkages between ecological processes and social processes, and their tangible and intangible benefits (such as spiritual and religious values), and of the influence on sustainable natural resource management at the landscape level needs to be strengthened.

Table 5.5 Overview of relative importance of Cultural ecosystem services in the GLOBIO land use classes and water systems

	Cultural s.		Supporting	
BIOME TYPES AND LAND COVER	15-23 Cultural & Nature Information values	24. Recreation and ecotourism	25/28/29. Soil formation/ nutrient & water cycling	26/27. Photsynthesis & Primary Production
natural areas	XXX	XXX	XXX	XX
bare natural				
forest managed	XX	XX	XX	XXX
extensive agriculture	XXX	X	XX	XX
intensive agriculture	X		X	XXX
woody biofuels			X	XXX
grazing area	XXX	X	X	XX
Artificial surfaces				
Ice	X	X		
Hot desert	X	X	X	X
Inland Waters	XXX	XXX	XXX	XX
Coastal areas	XXX	XXX	XXX	XXX
Marine	XXX	XXX	XX	XXX

5.4 Trends in services in terrestrial biomes and landscapes

5.4.1 Introduction

The data in this overview of developments in the levels of various ecosystem services are from the MA (2005b) report on State and Trends and a number of other sources. The focus is on quantitative data.

5.4.2 The land biomes

Forests

Forests annually provide over *3300 million cubic meters* of wood (including *1800 million cubic meters* of fuel wood and charcoal), as well as numerous non-wood forest products that play a significant role in the economic life of *100s of millions of people*; contain about *50%* of the world's terrestrial organic carbon stocks, and forest biomass constitutes about *80%* of terrestrial biomass. They contribute over *2/3* of global terrestrial net primary production. Slowing forest loss and restoring forest cover in deforested areas could thus help mitigate climate change. Forests provide more than *75%* of the world's accessible freshwater through forested catchments and prevent or mitigate natural hazards such as floods, landslides, and soil erosion. They play an important role in cultural and spiritual traditions and, in some cases, are integral to the very definition and survival of distinct cultures and peoples. Forests continue to play an important role in providing recreation and spiritual solace in more modernized, secular societies, and are essential for the subsistence and survival of more than *300 million people*, most of them very poor. The *60 million indigenous people* who live in forest areas are especially dependent on forest resources and the health of forest ecosystems.

The dry-land biomes
Dry land ecosystems support tourism through a high species diversity of large mammals, they provide nutrient cycling by processing most arid primary production through a high functional diversity of invertebrate decomposers and they also contribute to rainfall water regulation and soil conservation, and produce a diversity of wild and cultivated plants.

The Mountain landscapes
For many societies, mountains have spiritual significance. Scenic landscapes and clean air make mountains target regions for recreation and tourism. In many mountain areas, tourism is a special form of highland-lowland interaction and forms the backbone of regional as well as national economies. Mountains are particularly important for the provision of clean water, and their ecological integrity is key to the safety of settlements and transport routes. As "water towers," mountains supply water to nearly half the human population, including some regions far from mountains, and mountain agriculture provides subsistence for about half a billion people. Services further include water for hydroelectricity, flood control, mineral resources, timber, and medicinal plants.

5.4.3 Inland waters

The disruption of natural flooding regimes has devastated many riverine habitats and led to decreased sediment transport and a loss of flood buffering and nutrient retention. Flooding can cause severe hardship to humans, with the *1998 floods in China* causing an estimated *$20,000 million* worth of damage, but it is also essential for maintaining sediment-based fertility of floodplains and supporting fish stocks in large rivers. Inland waters have significant aesthetic, artistic, educational, cultural, and spiritual values, and they provide invaluable opportunities for recreation by many communities and, increasingly, for tourism.

Box 5.2: Freshwater habitats and biodiversity

Freshwater ecosystems, including rivers, lakes, swamps and deltas provide numerous benefits to people beyond fresh water. Rice is perhaps the major cultivated wetland plant, providing staple food to around half of the world's population. Moreover freshwater systems yield millions of tons of fish each year. In West Africa, and in parts of East Africa, Asia and the Amazon basin, inland capture fisheries comprise a major dietary input. This is particularly so for land-locked countries, e.g. Zambia (over *50% of animal protein consumed by people*), and Malawi (*75%*). These resources may be critical in times of food stress. Some *20 of the 30 countries* with the highest per capita consumption of inland fish are classified as low income and food deficient (Groombridge & Jenkins, 1998).

Freshwater systems are in decline, in part because they are perceived to be of little value compared with other uses of the land, and because the benefits they do provide are public goods, the use of which is unregulated. Since 1900 over half of wetlands worldwide have disappeared. Freshwater resources in the Mediterranean are under pressure from a growing population of ca *450 million people*, and as one of the principal global tourism destinations. However, many of these services are undervalued, and half of the region's wetlands have been lost. As a result, *56%* of Mediterranean endemic freshwater fish species are threatened (Smith & Darwall, 2006).

Of Kenya's wetlands, between 1970 and 2003, the area of swampland declined by *40%* whilst flow rates in most rivers declined by more than *30%*. Lakes experienced dramatic fluctuations in water levels, with frequent periods of drying out. The reasons for these declines include reduced vegetation cover in catchment basins, invasive species and pollution from surrounding land use intensification (Koyo *et al.*, 2005). For rural people, however, wetlands are critical livelihoods resources. Communities around Yala Swamp in Western Kenya are *100%* dependent upon the wetland for water, whilst *86%* of the population rely on building materials from the area. The costs of wetland degradation on local people is considerable due to the high price of substitute goods – iron roofing sheets cost six times more than papyrus from the swamp, whilst bricks are 14 times the cost of wood and clay (Schuyt, 2005).

5.4.4 Man-made landscapes

Box 5.3: Biodiversity decolonises the country side

The Dutch have a saying that "God created the world, but the Dutch created Holland." About half of the land area in The Netherlands lies below sea level. Much of this land has been reclaimed from the sea. The Dutch built dikes around swampy or flooded land and then pumped the water out, originally with windmills. This resulted in a small scale diversity of rural landscapes based on agriculture, which was traditionally multifunctional, based on labour intensive mixed farming, where animals produced "fertilizer". After World War II, Dutch agriculture changed into a highly specialized intensive farming system, in which the production system is characterized by high inputs of capital and labour. This type of agriculture had a strong negative impact on biodiversity. Further intensification and lower market prices of agricultural products in the last few decades resulted in a large number of farmers seeking diversification of income by applying for as agri-environmental subsidies. Currently one farmer out of seven delivers "agri-environmental services".

Farming for Nature (www.boerenvoornatuur) is an initiative to stimulate diversification in the rural area with the aim to preserve and enhance its natural and cultural values. The rural area can provide many provisioning, regulating, cultural and supporting services such as food for livestock, water, climate, erosion and pest regulation, cultural heritage values, and primary production. The Rural European Platform (www.rurep.org) has similar objectives at the European level. This Platform seeks new ways of financing rural development by cooperation with public and private stakeholders at the local level, as well as CAP payments and other European and/or national funds allocated to rural areas.

5.5 Trends in ecosystem services in marine systems

5.5.1 Provisioning services

Capture fisheries
Fish are consumed in virtually all societies, but the levels of consumption differ markedly. Marine fisheries are a globally important source of food: it is estimated that *1 billion people* worldwide are dependent on fish as their sole or main source of animal protein, while fish provided more than *2.6 billion people* with at least *20 percent of their average per capita animal protein intake* (FAO 2006). Per capita consumption is generally higher in Oceania, Europe, and Asia than in the Americas and Africa. Small island countries have high rates of consumption; land-locked countries often low levels. Reliance on fish is particularly high in some developing countries, accounting for example for up to *70% of animal protein* for China, Thailand and Bangladesh. During the past century, the production and consumption of fish (including crustaceans and molluscs) has changed in important ways. Average per capita consumption has increased steadily: during the last four decades, the *per capita consumption of fish* increased *from 9 to 16 kilograms per year*.

Demand for fish is increasing with population growth, rising wealth and changing food preferences as a result of the marketing of fish in developed countries as part of a healthy diet. Between 1974 and 1999, the number of stocks that had been overexploited had increased steadily and by 1999 stood at 28% of the world's stocks for which information is available. The most recent information suggests that just over half of the wild marine fish stocks for which information is available are moderately to fully exploited, and the remaining quarter is either overexploited or significantly depleted.

Box 5.4: Loss of the North Sea provisioning services

The North Sea is one of the most productive areas in the world with a range of plankton, fish, seabirds and benthic communities and is one of the world's most important fishing grounds. It accounts for some *2.5 million metric tonnes* of fish and shellfish catches annually and a fishing industry with significant jobs including catching, processing, transportation and shipbuilding. Overexploitation of North Sea fisheries is now a major threat to biodiversity and ecosystem health. Most of the stocks of commercial fish species in the North Sea are in seriously endangered condition with *30 to 40% of the biomass* of these species being caught each year. In addition, *70%* of young cod, for example, die before sexual maturity. Furthermore, heavy fishing pressure has resulted in *80%* mortality in young fish. The levels of by-catch of particularly harbour porpoises (ca *7000*), pose a particular risk to overall populations. About *2.5 million* pairs of seabirds breed around the coasts of the North Sea. In 2004, seabirds on the North Sea coast of Britain suffered a large-scale breeding failure. There were strong indications that this breeding failure was linked to a food shortage caused by high levels of fishing for sandeels. The beam trawling in the southern and central North Sea reduces total benthic biomass by *39%* and benthic production by *15%* relative to the un-fished state. It is also estimated that for *1 kilogram* of North Sea sole caught by beam trawl on the seabed, *14 kilograms* of other animals are killed. The spawning stock biomass of Cod had declined from a peak of *250,000 tonnes* in the early 1970s to less than *40,000 tons* in 2001. The biomass of top predators has decreased with *65%* in 50 years. Other services affected by biodiversity loss include marine tourism and recreational services that include bird watching, whale watching and sea angling. The value of the whole production chain from fishing, aquaculture, processing to marketing is estimated to be approximately *0.28%* of the EU gross domestic product. In Europe, the number of fishermen has been declining in recent years, with the loss of *66,000 jobs* in the harvesting sector.

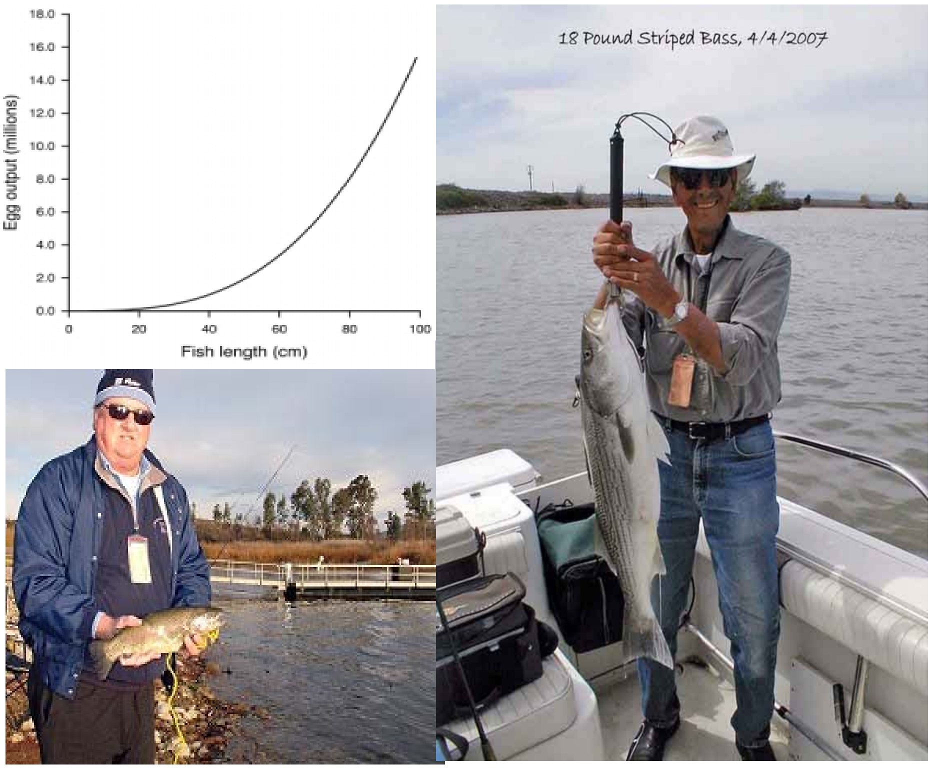
Aquaculture
Although aquaculture is an ancient activity, it is only during the past 50 years that it has become a globally significant source of food. In 2002 it contributed about *27%* of fish harvested and *40% (by weight)* of all fish consumed as food. However, the variety of supply from aquaculture is well below that of capture fisheries: only *5* different Asian carp species account for about *35%* of world aquaculture production, and inland waters currently provide about *60%* of global aquaculture outputs. Farmed species such as salmon and tuna, which use fishmeal, contribute to the problem since much of the fishmeal and oil currently used in the aquaculture industry is derived from wild-caught small pelagic fish. In some countries, such as Chile, small pelagic fish that were once a source of cheap protein for people are now largely diverted for fishmeal.

5.5.2 Cultural services

Recreational fishing
Some species are of considerable *cultural importance* (salmon are an important part of aboriginal culture in the Northeast Pacific, for instance), while others generate substantial income from tourism (especially dive tourism) and recreation. *Recreational fishing* was considered relatively benign until recently, mainly because information about its impact has been limited. Early estimates of global recreational catches were put at only *0.5 million tons*, but recent estimates of over *1 million tons* are probably more accurate. For some inshore fisheries, the catch from the recreational sector can exceed the commercial sector. Recreational fishing is an important economic activity in some countries; in the United States it is worth approximately *$21,000 million a year*; in Canada, *$5,200 million a year* and in Australia, *$1,300 million a year*.

Marine tourism is a growing industry, principally in the marine wildlife tours sector. Similarly, coral reef tourism has increased in visitation levels and value, with a current net present value estimated at *$9,000 million*. The Great Barrier Reef attracts 1.6 million visitors each year and generates over *$1,000 million annually* in direct revenue. Marine fisheries are increasingly valuable for recreation, particularly in developed countries. In the US alone, in 2006 nearly *13 million anglers* made more than *89 million* marine recreational fishing trips on the Atlantic, Gulf and Pacific coasts, capturing almost *476 million fish*, of which *55%* were released alive In the European Union (EU 15), an estimated *8 million recreational sea anglers* spend an estimated *€25,000 million* a year, compared to a *€20,000 million* value for commercial landings in 1998.

Box 5.5: Loss of cultural ecosystem service due to overfishing



Graph: Egg output versus body size in tropical groupers (Serranidae). Large individuals produce more eggs than small ones (after Roberts & Hawkins 2000). Pictures: disappointed and happy recreational fishers.

Overfishing results not only in a decrease of the provisioning services reducing fish catch and in the long run in a collapse of fish stocks, but it changes the demography of fish too with more small individuals, leading to a decline in the cultural service of sports fishing. However, before populations collapse usually individuals start reproducing at a smaller size resulting in smaller fish, and therefore lower reproductive output. Development of fully-protected marine reserves can help to mitigate these loses of ecosystem services (Roberts & Hawkins, 2000). Evidence from the tropics indicates that costs of not setting up marine protected areas are much larger than acting now. In the temperate zone, countries with industrialized fisheries, however, have been slow to implement fully-protected reserves, believing (without evidence) that they will not work as well as in the tropics.

Box 5.6: The benefits of clam fishing practices in lagoon of Venice, Italy

The clam fishing effort in the Lagoon of Venice has strongly increased since 1983, coinciding with the introduction of the Manila clam. It is now responsible for colonising large shallow areas and competing directly in the same ecological niche as the endemic clam species. Furthermore, the relatively high market price of this species, ranging from *€4.06 to 7.15* a kilogram, with a capacity to harvest *150 to 200 kg* of clams per day has contributed to its commercial profitability. Clam fishing activities have changed the morphology and marine life functions of the Lagoon. The consequence has been a reduction of the clam stock, destruction of nursery areas and feeding grounds of many marine species, including commercial fish stocks. Since the adoption of vibrating technologies has brought forward unavoidable negative environmental impacts on the Lagoon they are currently far from being a means for sustainable economical activity. Market data shows a diminishing supply of approximately *40%* in the catch between 2000 and 2001 due to a reduction in clam stocks. Increased

pollution has also contributed to significant environmental damage to the marine ecosystem, including commercial fishes.
The community sees significant benefits in moving to a system of manual technology only, in spite of the loss in present earnings. A move towards full use of vibrating rakes only is one that would yield high economic benefits in the very short term but would then start to make net losses, given damage to the ecosystem service. There are different ways of looking at the '*accepted losses*'. On the one hand the losses can be considered as an estimate of part of the value of the ecosystem and its services (clam provision) in its normal, functional state, while clam fishing still occurs. On the other hand, these values can be seen as relating to stakeholder appreciation of the local economic value of the flow of ecosystem services (clams), where the local authority could see long term economic benefits as larger than those relating to the fisherman and be willing to pay to avoid rapid deterioration of the ecosystem and its services.
The authorities' perspective is represented by a lower discount rate (***3%***) than that of the fishermen (***7%*** private). There are three sets of potential 'benefits' from a move towards more sustainable clam fishing: (1) ensuring a more sustainable income stream for the fisherman; (2) establishing more sustainable economic activity related to clam fishing in the local economic context; and (3) broader ecosystem benefits and services (e.g. other fisheries, amenities, tourism).

5.5.3 Effects of changes in marine biodiversity

The removal or depletion below a certain level of populations of particular species or functional groups has been shown to have dramatic effects on some marine ecosystems and the associated fisheries. Predators in particular ('top-down control') seem to be very influential in shaping and maintaining various habitat states or population levels. In addition, experimental evidence suggests that a loss of species diversity increases vulnerability to the establishment of invasive species.

Marine fisheries are vulnerable to the decline in extent or quality of particular marine habitats that play important roles in the provisioning of key resources (e.g. food, shelter) for targeted species. These include, amongst others: fisheries based directly on coral reefs, seamounts, sea grass meadows and kelp forests. Marine fisheries are also vulnerable to the declines in the extent or quality of coastal habitats, including: mangroves, estuaries and coastal wetlands. Marine fisheries are furthermore affected by changes in inland ecosystems that affect the quality, volume and timing of water inputs as well as erosion regimes.

5.6 Trends in ecosystems services in coastal systems

5.6.1 Introduction

Coastal communities aggregate near the types of coastal systems that provide the most ecosystem services. Within the coastal population, *71%* live within 50 kilometres of estuaries; in tropical regions, settlements are concentrated near mangroves and coral reefs. These habitats provide protein to a large proportion of the human coastal populations in some countries; coastal capture fisheries yields are estimated to be worth a minimum of *$34000 million annually*.

Destruction of coastal wetlands has been implicated in crop failures due to decreased coastal buffering leading to freezing in inland areas. In general, the choice to exploit coastal resources results in a reduction of other services; in some cases, overexploitation leads to loss of most other services. Within the coastal system, choices that result in irreversible changes, such as conversion of coastal habitat for industrial use, urbanization, or other coastal development, often bring short-term economic benefits but exact longer-term costs, as regulating and provisioning services are permanently lost. Choices made outside coastal areas, such as the decision to divert water for agriculture and thus reduce the flow of fresh water to estuaries, are cause for particular concern because virtually none of the benefits accrue to the coastal sector.

5.6.2 Mangroves and coral reefs

The importance of mangroves and coral reefs

The importance and quality of the various goods and services provided by mangroves varies among the various mangrove zones (Ewel et al. 1998). Fringe forests provide protection from typhoons, flooding, and soil erosion; they provide organic matter export, animal habitat and a nursery function. Riverine mangroves also provide protection from flooding and erosion, as well as sediment trapping, a nursery function, animal habitat, and the harvest of plant products (due to highest productivity). Basin forests provide a nutrient sink, improve water quality, and allow the harvest of plant products (due to accessibility).These forests thus buffer land from storms and provide safe havens for humans in the coastal countries in which they occur. Mangroves have a great capacity to absorb and adsorb heavy metals and other toxic substances in effluents. They can also exhibit high species diversity. Those in Southeast Asia, South Asia, and Africa are particularly species-rich, and those in association with coral reefs provide food and temporary living space to a large number of reef species. In some places mangroves provide not only nursery areas for reef organisms but also a necessary nursery ground linking sea grass beds with associated coral reefs . Removal of mangrove can thus interrupt these linkages and cause biodiversity loss and lower productivity in reef and sea grass biomes (MA, 2005b).

Mangroves are highly valued by coastal communities, which use them for shelter, securing food and fuel wood, and even as sites for agricultural production, especially rice production. Due to their function as nurseries for many species, fisheries in waters adjacent to mangroves tend to have high yields; annual net values of $600 per hectare per year for this fishery benefit have been suggested. In addition, an annual net benefit of $15 per hectare was calculated for medicinal plants coming from mangrove forests, and up to $61 per hectare for medicinal values. Similarly large economic benefits are calculated for shoreline stabilization and erosion control functions of mangroves (MA, 2005b).

Reefs provide many of the services that other coastal ecosystems do, as well as additional services: they are a major source of fisheries products for coastal residents, tourists, and export markets; they support high diversity that in turn supports a thriving and valuable dive tourism industry; they contribute to the formation of beaches; they buffer land from waves and storms and prevent beach erosion; they provide pharmaceutical compounds and opportunities for bio-prospecting; they provide curios and ornamentals for the aquarium trade; and they provide coastal communities with materials for construction and so on (MA, 2005b).

Box 5.7: Ecosystem services of Philippine Coral Reefs

Brown-marbled grouper (*Epinepephelus fuscoguttatus*)

In the Philippines, coral reefs are important for fisheries and tourism. Fisheries is a small scale business where *more than 1 million fishers* contribute almost *1 billion US$ annually* to the countries economy. Also tourism has large possibilities for revenues, which can increase up to *US$ 300 000 annually* (estimate based on willingness to pay inventories). Fishing is considered unsustainable (over fishing, destructive fishing methods, sedimentation), and this pressure is expected to increase due to population growth. This pressure is already felt by local fishermen as a reduced catch. White et al. (2000) compared the costs and benefits of not acting versus implantation of marine reserves and showed that the benefits of setting up and maintaining reserves will exceed the costs. Inaction will have dramatic financial effects on both fisheries and tourism.

Quantitative changes in ecosystem services from mangroves and coral reefs

Coral reefs and mangroves are among the world's rarest ecosystems, and both are under serious threat. Some *30%* of reefs are already seriously damaged and *60%* could be lost by 2030 through fishing damage, pollution, disease and coral bleaching, which is becoming more common with climate change. Human activities currently threaten *88%* of reefs in South-east Asia, with *50%* considered to be at high or very high risk. Likewise, and estimated *35%* of mangroves have disappeared in the past two decades, with some countries having lost up to *80%* through conversion for aquaculture, overexploitation and storms. The annual rate of mangrove loss *(2.1%)* is higher than that of tropical rainforest *(0.8%)* (UNEP-WCMC, 2006).

Healthy reefs and mangroves can absorb *70-90%* of the energy in wind-generated waves, thus protecting shorelines from storms and hurricanes. They also support a range of fisheries, and fish nursery habitats and, in the case of reefs, tourism and recreation (valued in some places at up to *\$1 million per* km^2 if the cost of maintaining sandy beaches is considered). Both ecosystems contribute significantly to national economies, particularly those of small island developing states, *90%* of which have reefs and *75%* of which have mangroves. Degradation of mangroves and coral reefs is already causing reduced fish catches and tourism revenues and increased coastal erosion, and may reduce food security and increase malnutrition in coastal communities. Most of the estimated *30 million* small-scale fishers in the developing world are dependent on coral reefs for food and livelihood. For example the productivity of the fisheries sector in Belize, Honduras and Mexico is directly dependent on the health of the adjacent barrier reef. Reef fisheries in the Caribbean generate some *US$310 million a year*, and in South-East Asia *US$2,400 million a year*. Some estimates suggest that reefs contribute up to *25%* of the total fish catch in developing countries, providing food for *1 billion* people (UNEP-WCMC, 2006).

The mean annual economic value of coral reefs and mangroves has been estimated at *US$100,000-600,000 per* km^2 and *$200,000-900,000 per* km^2 respectively. Yet the estimated annual operating costs for marine protected areas are only *US$775 per* km^2, a tiny proportion of the estimated benefits of reefs and mangroves. Currently marine protected areas are dramatically under-represented in the global protected area network, and significant efforts will be required to meet the 2012 CBD target of protecting 10% of total marine area globally (UNEP-WCMC, 2006).

Box 5.8: How to stay dry in the Netherlands: services of dunes and beaches

Dunes, beaches and dikes keep the North Sea from flooding The Netherlands with an almost 300-kilometre-long stretch along the coastline. Most of the area is part of the European network of nature reserves ‘Natura2000’. The nature values of this ecosystem are protected by European law. With *9 million people* living below sea level, coastal defence is a major economic issue in The Netherlands. Climate change, sea level rise, the tsunami in South East Asia in 2004 and the devastating effect of the hurricane Katrina in 2005 in the United States renewed the appraisal of this important ecosystem service of dunes beaches and dikes. In the coming years the Dutch government will invest *742 million euro* to increase the safety of this coastal defence. The dunes have also a long history in the supply of drinking water, e.g. to Amsterdam. Drinking water extraction started in 1853 and since 1957 water from the river Rhine is infiltrated in the dunes for purification and to mitigate desiccation of the dunes. This service has resulted in protection of the dune habitat against urban development. Dune and coastal habitat also have a high recreational value, especially for Germans tourists.

Box 5.9: Loss of ecosystem services in the Pearl River delta region

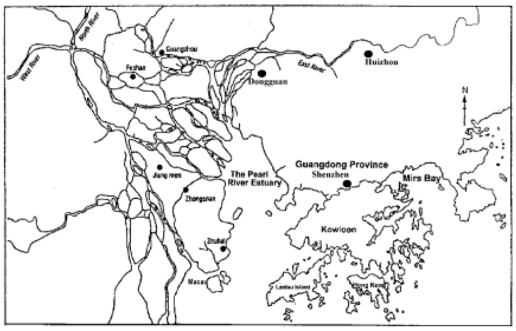


Fig. 1
The Pearl River estuary and eight major cities in the delta region

Industrialization and economic growth in the Pearl River delta region (China) resulted in large environmental degradation of the region. The delta changed in a relative short period from an area with high biodiversity and traditional farming into an industrialized area with low biodiversity. The area had many favourable physical characteristics, such as flat and fertile lands, abundant fresh water and easy access to the sea for agricultural and aquacultural development. Land restructuring resulted in a loss of arable land of over 20% in a single decade. The number of inhabitants increased from *9.6 million* in 1982 to *21.2 million* in 1996. Industrialization and the pressure inflicted by urban development resulted in a strong increase in water pollution; the estimated discharge of industrial effluent equalled *2000 million tons* and that of domestic waste *560 million* tons annually. Most of this discharge is not treated. The high load of effluents polluted the river resulting in frequent algal blooms up into the costal zone and contamination of water resources. Consequently ecosystem services such as provision of clean drinking water, fisheries and disease regulation are greatly reduced. The economic loss due to the environmental degradation was estimated to amount to *US$11,000 million* in the region.

Box 5.10: Loss of ecosystem services due to eutrophication

Many coastal marine ecosystems in the EU are subject to eutrophication caused by increased supply of nutrients of anthropogenic origin. Due to their wide distribution and their role in sustaining important ecological functions of the coastal marine zone, the shallow soft bottom systems are considered the key ecosystem in the Sweden archipelago. Loss of biodiversity has been detected at three different trophic levels. Along most sections of the coast both the upper and the lower depth distributions of sea grass have been reduced, resulting in a narrowing of meadows. In some areas sea grass meadows have disappeared *100%*. The number of species, and the density and biomass of benthic macro fauna is *40-50%* lower under mature algal mats than in normal situation. The number of fish species and the density and biomass of fish has been found to be significantly lower in areas where sea grass is missing. Similarly, *4 x* lower total density and *6 x* lower biomass of gobies has been observed in non-seagrass sites in comparison to seagrass beds.

The production of fish species of commercial and recreational value, will be significantly reduced as the reproduction of these species decreases and they are replaced by non-commercial fish species and crustaceans. In terms of ecosystem services, the loss of benthic fauna diminishes ecosystem's water purification capacity and its ability to manage organic waste. Additionally, decline in benthic fauna further disturbs the nutrient cycling within the system. Social and cultural ecosystem services are affected by algal mats/blooms through reduced aesthetic and recreational attraction.
The overall benefits of improved water quality in the Stockholm archipelago are estimated to be *€6 – €54 million per year*. In the last decade, the total catch in this fishery corresponds to a total gross income to fishermen of about *€19 million per year*. If the *30-40%* reduction in the output of juveniles ultimately results in a corresponding decrease in total catch, total gross income to fishermen would be reduced by *€6 - €8 million per year*. As an estimate of the loss of recreation and tourism services, camping ground owners remove tons of dead red algae every year at *€8119 per km*. These effects of eutrophication are not unique to the Swedish west coast but they are also common in many coastal marine ecosystems in the EU.

5.7 Non-linearity and collapse in ecosystem response to pressures

5.7.1 Introduction

Most ecosystems are robust and can absorb many changes, but they can be pushed to a point beyond which they can no longer withstand external pressures. At this point, any further change in conditions can lead to non-linear change with a critical result – i.e. where there are major implications, often irreversible. This section is an adapted excerpt from P. ten Brink et al. (2008).

5.7.2 Critical thresholds

Thresholds have been discussed since the 'birth' of the sustainable development concept. The Brundtland report[12] mentioned thresholds in the context of sustainable development and survival. This speaks of natural critical thresholds, in other words points beyond which there is a change of state such that some function, service or value is compromised. The 'critical threshold' can be defined as a point between alternate regimes in natural systems. When a threshold in a certain variable in a system is passed, the system shifts in character. These natural 'thresholds' exist and are set by the biological, chemical and other physical laws of the ecosystem.

Examples of natural critical thresholds being exceeded, and their impacts, include:

- Acidification - soils are able to buffer acid deposition through natural release of cat-ions to varying extents depending upon the type of soil. When deposition exceeds this the soils acidify. This threshold concept was termed the 'critical load' and underpinned much of the policy debate on controlling acid emissions[13] – it also underlines that critical thresholds are often locality dependent and there could be different local/regional specifications of critical thresholds.
- Habitat size - below a certain size, areas of habitat (e.g. forest, woodland etc) will not sustain certain species. This relates to food availability, diversity and migration paths. Habitat may become fragmented through the construction of transport corridors.
- Population numbers or density – points exist below which a population will no longer be stable and risk of collapse occurs – e.g. cod spawning stock biomass in the North Sea declined from a peak of 250,000 tonnes in the early 1970s to less than 40,000 tons in 2001[14]. This was linked to over-fishing.

When critical thresholds are crossed, the provision of certain ecosystem services of benefit to society and its economic and social welfare may be lost[15]. Once a critical threshold has been crossed, it may be difficult (or even impossible) and generally

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12 WCED (1987)

13 See Farmer (1997) for a discussion on the buffering capacity of soils, acid deposition and the use of the critical loads concept.

14 See Kettunen and ten Brink (2006)

15 For more see Kettunen and ten Brink (2006) and also ten Brink et al (2002) and also Millennium Ecosystem Assessment (2005)

costly to return the ecosystem to its original state. Note that in some cases crossing the threshold brings about a sudden, large and dramatic change in the eco-system and its functions, whilst in other cases the response is more gradual[16] and in others it is more probabilistic.

Fisheries yields of individual species are well-known to be subject to sudden collapse following overexploitation, often failing to recover to former levels of abundance particularly amongst slow-growing, slow-maturing species. There are many documented examples of recent sudden regime shifts in fresh water and marine systems, with implications for fisheries provisioning. Such shifts seem to be particularly likely in ecosystems that are or have been under intense fishing effort, and which have been simplified by the loss of one or more higher-trophic functional groups. While the collapse of entire fisheries has been observed across relatively large areas, more often the collapse of a particular species or set of species results in a shift in fishing effort towards other species (often further down in the food web) or towards other regions/ecosystems (e.g. towards increasing depths). These shifts mask the underlying sequential collapses from ocean-level or global fisheries statistics. Under current knowledge, it is therefore unlikely that a synchronised global collapse will be observed by 2025, but it is very likely that the slow decline that has been observed since the mid-1980s continues. Climate change and related ocean acidification are the greatest sources of uncertainty in predictions of marine fisheries, potentially responsible for sudden, large-scale, changes in the foreseeable future (MA, 2005b).

5.7.3 Critical trends

Recognition of 'critical trends' that will lead to breach of thresholds is also important. Critical trends are trends that, if not addressed, will lead to a critical threshold being breached. This can be a change in the value of a state variable (e.g. oxygen content in water) which, if continued (i.e. falling oxygen content through pollutant emissions which 'demand' oxygen[17]), would result in the critical threshold of a state being crossed (insufficient oxygen content to support life). The critical trend may refer to a pressure which is changing the state in such a way that it is threatening to cross a critical threshold (such as an increase in vehicle traffic, which in turn affects particulate levels). In many cases, where an actual threshold is not known, identifying a critical trend may serve as a proxy.

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[16] See Walker and Meyers, 2004; Resilience Alliance and Santa Fe Institute 2004

[17] E.g. BOD or COD – biological oxygen demand or chemical oxygen demand. The former can be household sewage whose decomposition takes up oxygen. COD can feature in pollutant emissions from certain industries.

5.7.4 Conclusions

The use of critical thresholds and trends should help make choices and the trade-offs and impacts of these choices explicit. It should help lead to more consistent decision-making. Their use can be instrumental in clarifying the range of winners and losers and hence help clarify responsibilities, ethical questions such as to unfair burdens and needs for compensation, or the need for different decisions. The explicit consideration of critical thresholds should give policy makers the ability better to inform and understand the decisions they are making, and to avoid decisions that lead to unsustainable outcomes. Linking critical thresholds to evaluation tools adds an extra dimension that simplifies the identification of unsustainable options. Through use of critical thresholds, there should be fewer cases of 'unacceptable' trade-offs arising from a lack of awareness and lack of visibility of the costs. In addition, it should be possible to identify more win-win-win (economy-environment-social/human) solutions, thus making a constructive contribution to sustainable development and moving towards an improved culture of sustainable development.

5.8 Invasive Alien Species and ecosystem services

The impacts of invasive alien species (IAS) affect a range of different ecosystem services. While a comprehensive survey has not yet been carried out, *table 5.6* shows examples of IAS impacts across the ecosystem service types, demonstrating that virtually all ecosystem services are affected by IAS.

Table 5.6: Impacts of IAS on Ecosystem Services - Examples

Type of Ecosystem Service Lost	Examples of the service being lost
Provisioning Services	
Food and fibre	• Agricultural losses – e.g. Colorado potato beetle (Finland) • Food: comb-jellyfish reduces anchovy catch (Black Sea) • Forestry losses - black locust (e.g. Cyprus) • Food security: destroy rice field: Golden apple snail (*Pomacea canaliculata*), Rats (*Rattus spp*.); invasive fish (e.g., *Oreochromis niloticus, Cyrpinus carpio*)
Ornamental resources	• *Rhododendron ponticum* displaces other plants in natural areas (e.g. Australia) • The common broom *Cytisus scoparius* has become a pest in production forest and nature reserves, destroying open land-scapes and threatening endangered plant species
Fresh water	• Algae blooms caused by alien phytoplankton such as Chattonella verruculosa and Alexandrium species can be toxic
Other	• Irrigation and drainage: Aquatic weeds (e.g., *Eichhornia crassipes*, S*alvinia molesta*, *Mimosa pigra, Pistia stratiotes.*)
Regulating services	
Climate regulation (eg temperature and precipitation, carbon storage)	• Carbon storage can be reduced by damage / death to trees in forests due to beetles (e.g Spruce bark beetle)
Water regulation (eg flood prevention, timing and magnitude of runoff, aquifer recharge)	• Decrease water levels (e.g. due to Japanese Knotweed or in South African native Fynbos ecosystem) • Hydroelectric: Aquatic weeds (e.g., *Eichhornia crassipes*,

Type of Ecosystem Service Lost	Examples of the service being lost
Provisioning Services	
	S*alvinia molesta*, *Mimosa pigra,Pistia stratiotes.*)
Erosion control	• Erosion of river banks and embankments by invasive weed (eg *Fallopia in* Germany) • The rabbit in Australia, causing soil erosion – impediment of the regeneration of forests and shrubs that prevent soil erosion
Water purification and waste management	• Depletes oxygen (water hyacinth)
Regulation of human diseases	• Invasive can bring in disease (influenza, small pox, dengue fever, malaria, bubonic plague)
Biological control (eg loss of natural predator of pests)	
Pollination	• Competing for pollinators such as bumblebees with the native riverbank species, and so reduces seed set in these other plants (*Impatiens glandulifera*)
Fire resistance (change of vegetation cover leading to increased fire susceptibility)	• Increased fire risk due to drying of land (eg South African fynbos ecosystem) or due to less species diversity and higher ratio of easily flammable trees (eg Portugal due to eucalyptus) • Increase fuel loads, leading to changes in fire regimes *Andropogon gayanus* (Gamba grass) e.g. Australia, Brazil
Other	• Cockroaches (50% exotic) causing asthma
Cultural services	
Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity	• Change in landscape via invasive alien trees can lead to change of sense of place and identity – (e.g. alien trees covering originally treeless highland of Santa Cruz island, Galapagos)
Recreation and ecotourism	• Salmon parasite leads to reduction in value of recreational fishing (eg Norway) • *Chromolaena odorata*, affects the nesting sites of crocodiles (a focus of tourism in South Africa), directly placing these populations at risk • Toxic algae harming tourism (e.g. costs of US $ 75 million/ yr , in USA, incl. health, fishing closure, recreation ; NOAA news)) • Rabbit haemorrhagic disease harming rabbit hunting e.g. Australia
Supporting services	
Nutrient cycling	• When the shrub bush honeysuckle *(Lonicera maackii)* becomes dominant, tree seedlings and herbaceous plants become less abundant (e.g. USA), creating a near monoculture of honeysuckle

Scale of impacts

The impacts of IAS on ecosystems vary significantly depending upon the invading species, the extent of the invasion, and the vulnerability of the ecosystem being invaded. Some impacts are global and of headline importance (see Box 5.8 for some headline cases) whereas some effects take place at national, regional or local level. The latter are also often of fundamental importance to the areas and ecosystems in question, e.g. affecting the flow of ecosystem services to several beneficiaries. Additionally, some species may have invaded only a restricted region, but have a high probability of expanding and causing further great damage (e.g. see *Boiga irregularis*: the brown tree snake). Other species may already be globally widespread and causing cumulative but less visible damage (IUCN, 2005 and see also Van der Weijden et al., 2007).

Box 5.11: Invasive alien species – some major health impacts *(McNeely et al, 2001)*

- An invasive species of rat, carrying a flea, was a vector for the bubonic plague that spread from central Asia through North Africa, Europe and China.
- Smallpox and measles were spread from Europe to the Americas, leading to major illness, mortalities and ultimately the fall of the Aztec and Inca empires.
- Infected cattle introduced into Africa carried the Rinderpest in the 1890s. This spread to domesticated and wild herds of bovids throughout the Savannah regions of Africa. Many cattle populations were decimated and it was estimates that 25% of the cattle-dependent pastoralists may have starved to death in the early 20th century due to this.
- The influenza virus, with its origins in birds, passed on to pigs, and then to humans
- *See Annex III on IAS for more details*

5.9 Economic and social aspects

Marine capture fisheries are an important source of economic benefits, and important for income generation, with an estimated *38 million people* employed directly by fishing, and many more in the processing stages. *90%* of full-time fishers conduct low-intensive fishing (a *few tons per fisher per year*), often in species-rich tropical waters of developing countries. Overfishing affects human well-being through declining food availability in the long term, since fewer fish are available for consumption and the price of fish increases. Due to declines in coastal habitats, fishers are forced to go further offshore and for longer periods of time, resulting in *reduced food security*.

Nearly *40%* of global fish production is traded internationally. Most of this trade flows from the developing world to industrial countries. Many developing countries are thus trading a valuable source of protein for an important source of income from foreign revenue, and fisheries exports are extremely valuable compared with other agricultural commodities. Fish products are heavily traded, and exports from developing countries and the Southern Hemisphere presently offset much of the demand shortfall in European, North American, and Northeast Asian markets. Given the global extent of overfishing, however, it is likely that the global decline in marine fisheries landings, which already affects the poorer consumers in developing countries, will also catch up with consumers in industrial countries.

Many areas where overfishing is a concern are also low-income, food-deficit countries. For example, the exclusive economic zones of Mauritania, Senegal, Gambia, Guinea Bissau, and Sierra Leone in West Africa all accommodate large distant water fleets, which catch significant quantities of fish. Much of it is exported or shipped directly to Europe, while compensation for access is often low compared with the value of the product landed. These countries do not necessarily benefit through increased fish supplies or increased government revenue when foreign distant water fleets access their waters. In some countries, such as Côte d'Ivoire, the landings of distant water fleets can lower the price of fish, which affects local small-scale fishers. Although Ecuador, China, India, Indonesia, and the Philippines, for example, do not provide access to large distant water fleets, these low-income, food-deficit countries are major exporters of high-value fish products such as shrimp and demersal fish. As shown in the West African example, several countries in the region export high-value fish, which should provide a significant national economic gain so that cheaper forms of protein can be imported. In countries such as Ghana, however, the value of exports is often less than the value of imported fish, and the volume of imported fish does not meet the domestic demand for fish.

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6 The Cost of Policy Inaction – in Monetary terms

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Summary

This chapter puts together a) losses in ecosystems and biodiversity, b) what this means for ecosystem services and c) the economic value of the ecosystem services being lost. Doing so produces the estimate that we are currently losing each year land-based ecosystem services worth around €50 billion. This is a welfare loss, not a GDP loss, as a large part of these benefits is currently not included in GDP. These losses continue over time, and are added to by losses in subsequent years of more biodiversity. They could be equivalent in scale to 7% of GDP by 2050. This is a conservative estimate. These costs show that the problem is potentially severe and economically significant, but that we know relatively little both ecologically and economically about the impacts of future biodiversity loss. Further work is needed, which can usefully build on the insights gleaned in this valuation exercise.

6.1 Introduction

The key objective of the COPI project is to illustrate the impact of not meeting the 2010 biodiversity target globally (see Chapter 1). A loss of biodiversity generally leads to a reduction or loss of ecosystem functions that in turn lead to a reduction of ecosystem services that would otherwise benefit society. The exact nature of the relation between biodiversity loss and ecosystem services loss is of course location specific[18], and not always linear, so care is needed both in doing the analysis and in interpreting the results.

As stated in the methodology chapter (Chapter 2), the quantitative modelling part of COPI approach has focused primarily on the analysis of the effects of land-use changes over the period 2000 to 2050 as used in the OECD[19] / GLOBIO[20] work.

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18 The spatial relation of where the services are produced and where the services are used is important. In some cases these are both local (eg provision of wild non market foods), in other cases the local area produced a service that is useful for a wider share of the country (eg water provision), and in other cases global (carbon storage, potentially wood, genetic materials for pharmaceuticals, and less positively, invasive alien species).

19 OECD (2008) OECD Environmental Outlook to 2030.

The land-use changes lead to a change in the biodiversity and change in ecosystem functions (type and level). This will lead to a change in flow of ecosystem services, that will depend on the nature of the change in ecosystem functions, as well as the extent and nature of those who benefit, or no longer benefit, from the service.

The value of the ecosystem service assessed here is an anthropocentric value. Most people would agree that a loss of habitat for a species will be an important issue to bear in mind, even if there are no benefits to society from that species. The authors are aware of this and this should also be borne in mind when considering the results. And, as may be clear from the title of the study, the work focuses on the *cost to society of policy inaction*. To arrive at values, the land use change and associated ecosystem service losses need to be combined with values of the services, which need to be on a per hectare basis as the GLOBIO model uses land-use areas (hectares) (see Chapter 2 and Annex I). The work also builds on the biodiversity quality indictors (here the CBD[21] recognised MSA[22] indicator as it is core of the GLOBIO model). The methodological implication of using a hectare approach and an MSA approach for quality are discussed later in this chapter. *Figure 6.1* shows the overall schematic of the work.

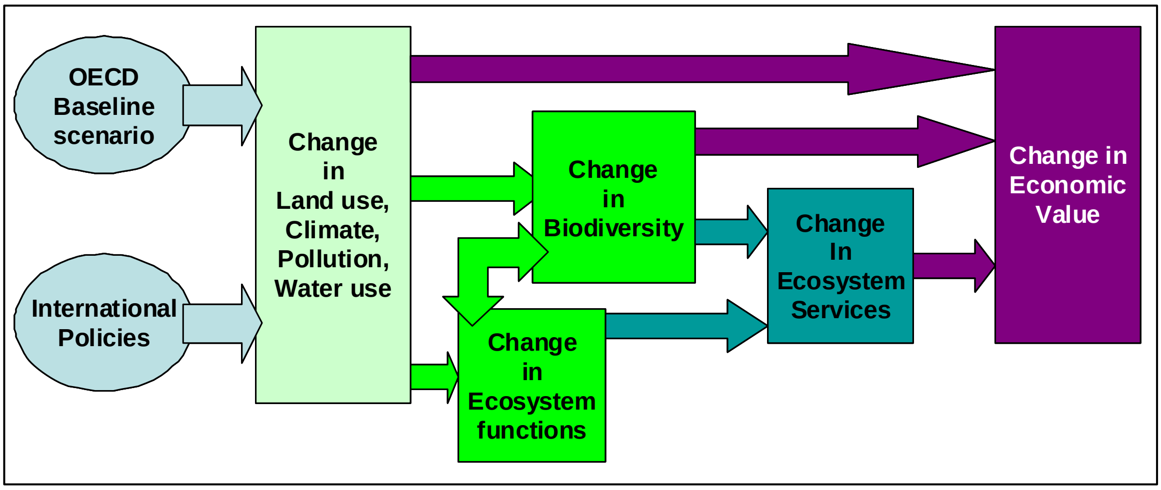

Figure 6.1 Chapter 6 in the conceptual model of the COPI analysis

In addition to the focus on land use changes, the COPI team also reviewed the relevant literature on other key areas of biodiversity loss and ecosystem services losses

- Species - Invasive aliens species (IAS).
- Marine (in particular: ocean fisheries)
- Coastal (coral reefs, mangroves and wetlands[23])

The COPI insights on these issues are also presented here. Except for the marine ecosystem, where results are available of scenario-analyses (see Chapter 4), there is less quantitative analysis. In some cases a “back-of-the-envelope” calculation is

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[20] IMAGE-GLOBIO-model of changes in land use, biodiversity and ecosystem services over the period to 2050

[21] Convention on Biological Diversity. CBD http://www.cbd.int/

[22] Mean Species Abundance, MSA

[23] The further section below also includes inland wetlands

presented to illustrate the importance of issue in monetary terms. The valuation challenge is different for each type of issue.

This chapter presents the monetary assessment and related insights on methodological approaches and recommendations for areas where future work on economics of ecosystems and biodiversity could usefully focus. To facilitate understanding of the numbers, methodological explanations are presented at different stages of this chapter.

What can be said in what terms?

The impact of not meeting the 2010 biodiversity target globally can be presented in a range of forms – in qualitative terms, such as using story lines or simply descriptions of important impacts; in quantitative terms, such as how many people's livelihoods are affected by a loss of fisheries or loss of forest, and in monetary terms, such as what the loss of production of crops to invasive species or what is the value of the carbon stored in biomass (see Chapter 2, *figure 2.4)*. The present chapter focuses on the top part of the pyramid, i.e. the monetary numbers. Note that the monetary numbers range from local specific numbers to high level aggregates, e.g. a total number across ecosystem services, biomes and regions of the world. Both extremes of numbers have their use and importance, as do the range of intermediate numbers. For example the global value of change in carbon storage from forests due to land conversion is an obviously a valuable number to obtain.

Box 6.1: COPI values: Welfare, GDP and interpreting the numbers

It is important for understanding the COPI assessment, to appreciate that the COPI costs are actually a mixture of cost types – some are actual costs, some are income foregone (e.g. lost food production), some are stated welfare costs (e.g. building on willingness to pay (WTP) estimation approaches). Some directly translate into money terms that would filter directly into GDP (gross domestic product); some would have an effect indirectly, and others would not be picked up by GDP statistics (which themselves are only economic statistics and not fully representative of welfare or wellbeing[1]). The combined COPI costs should be seen as welfare costs, and for the sake

Examples of numbers

Global numbers – (note: all $ are US $)[24]

The evaluation challenge is well exemplified by the oft-cited Costanza et al (1997) study. This study focused on providing an estimate for the total economic value of Nature's services. Their result - $ 33 trillion as a value for ecosystem services, as against $ 18 trillion for global GDP - was criticized on the one hand for extrapolating marginal valuations to entire global ecosystems (as economic values estimated for

[24] Note that most of the literature based values are given in US dollars. The COPI analysis has chosen to use EURO values. Note that Euro values, where originally from US$ values or other currencies, were converted from the original current to Euros (or equivalent earlier ECU) in the year that they correspond to and for the COPI numbers homogenised to 2007 money.

small marginal changes are not valid anymore when dealing with big changes)[25], and on the other, for being "a significant under-estimate of infinity" (Toman, 1999; "how can one put a value on the existence of humanity ?"). While the Costanza study's limitation was its focus on the value of the total stock of natural capital, when the question can also be approached, maybe with better understanding among policy makers, from the angle of the value of the loss from the change in stock, it nevertheless played an important role in raising awareness and debate on an issue - biodiversity loss and the value of nature to humanity - that had been generally not been taken into account in decision making before.

The COPI study aims, just like Costanza et al., to highlight the importance of the value of ecosystem services and biodiversity to society and the importance of the loss and urgency of action to halt the loss, but it does so by looking at the marginal losses, and the value of the loss of flow of services. There are, of course, still a wide range of assumptions to arrive at this value. Criticism is welcome, of course, especially if complemented by suggestions for better ways of doing the analysis. The COPI analysis aimed not just at calculating some illustrative numbers, but aimed to create and test a method and develop insights for the methodology to be use in the phase 2 evaluation of the Economics of Ecosystems and Biodiversity (TEEB) work[26].

Another global estimate carried out concerns Invasive Alien Species (IAS). Pimentel et al (2001) developed an order of magnitude estimate to highlight the likely importance of action on IAS – he and his colleagues estimate that IAS represents around $1.4 trillion per year of impacts (equivalent to around 5% of GDP). As with the Costanza number, this is useful to highlight the importance of the issue, but has also come under criticism. Within the COPI study, an update of the costs of IAS has been carried out, building on a literature review, and insights are presented further below (and in Annex III).

Specific values

The value of ecosystem services and biodiversity and their losses varies across locations depending on the (scale and nature of the) provision of services and who benefits from the services, which in turn relates to access to the service. Some examples to highlight the importance of the issues are presented below.

- **Coral reefs*:*** A recent review by the French Government[27] found a wide range of values from different studies for different aspects of the economic value of coral reefs. For example, different studies have estimated the value of coastal protection at $55 to $260,000/ha/yr; biodiversity and existence values at $12 to $46,000/ha/yr; recreation and tourism at $45 to $10,320/ha/yr; fishing at $120 to $360/ha/yr; and total economic value at $1,000 to $893,000/ha/yr. The latter estimate relates to Montego Bay, Jamaica, a popular holiday resort and famous for

[25] As the provision of the ecosystem service can change in a non-linear manner, and the economic values can in principle be extrapolated only if the shape of the demand curve is known

[26] See also Sukhdev et al (2008) The Economics of Ecosystems and Biodiversity. An Interim report.

[27] Ministère de L'Ecologie, du Développement et de L'Aménagement Durables (2008) La préservation des écosystèmes coralliens: aspects scientifiques, institutionnels et socio-économiques version provisoire du 20 mars 2008

its recreational activities, such as diving and sailing. The above-average estimates for certain ecosystem services are due in great part to the high number of users as other sites have equal quality but lesser value in practice. This wide range of values is a particular challenge to benefits valuation, where this seeks to derive a global number. In practice, it is important to identify the cases that are representative, and the cases that are more "exceptions" or "outliers", and calculate a representative range and derive a fair average. For coral reefs, for example, the Montego Bay case is used as a case example, but not integrated in the calculations of ranges or averages to avoid too great an influence on the overall result (see Annex 1 for further discussion).

- **Wetlands:** For Europe, an estimate for the total annual flow of ecosystem services for wetlands (Brander et al, 2007) gave a value of 6 billion (10^9) EUR/year. Averages values per hectare ranged from hundreds of Euros per hectare (in countries with extensive wetlands - Sweden, Finland, Ireland) to several thousands of Euros per hectare (generally the case). These relate to a range of ecosystem services. The Zambezi Basin wetlands provide over *$70 million* in livestock grazing, almost *$80 million* in fish production, and *$50 million* in flood plain agriculture. Carbon sequestration is also a significant value.
- **Watershed protection:** The value of the watershed protection that is provided by intact coastal ecosystems, such as mangroves and other wetlands, has been estimated at $ 845/ha/year in Malaysia and $ 1,022/ha/year in Hawaii, USA[28] .
- For the ecosystem service **water regulation/watershed protection** in the tropical forests in Mount Kenya a value of $273/ha/year was estimated[29], and in Lao PDR, in the Sekong Province of China, a value of €980/ha/yr for the ecosystem service water regulation/flood control was derived[30], reflecting the vulnerability of the region to flooding. In the latter case the values for the costs have been calculated by means of necessary investments in dams to prevent flooding they are seen as very reliable.
- For **recreation and the economic impact of tourist activities**, values can be very large. For example, the economic impact of forest recreation in national forests in the USA, was valued Emerton (1999) [31] at $6.8 billion in 1993 and 139,000 jobs in 1996. The wider contribution to GDP was estimated at $110 billion/year. Total economic value of fishing in national forests: $1.3-2.1 billion in 1996.
- **Pollination:** As regards pollination, Ricketts et al. found the value of bee pollination for coffee production to be worth US$361/ha/year, although the benefits were only felt by producers located within 1km of natural forests (Ricketts, 2004). In **New Zealand**, the varroa mite is a serious pest in honeybee hives and is expected to have an economic cost of US$267-602 million[32]. Importantly beekeepers argue that had border rules been followed or had

[28] Kaiser, B. and Roumasset, J.(2002)

[29] Note that were this value to be transferred to other countries via standard benefit transfer eg adjusting by relative PPP-GDP per capita ratios the total number would be a lot higher, and the value would be well above the average, reflecting the mountainous terrain and risk of flooding.

[30] Rosales et al. (2005)

[31] Moskowitz and Talberth (1998)

[32] Wittenberg et al, (2001)

surveillance detected the mite earlier, the problem could have been avoided entirely. It appears too late to eradicate the mite. This underlines the issue of irreversibility, and also the potential benefits of avoiding the problem rather than dealing with the consequences. The mite is also an invasive alien species (IAS), underlining the importance of suitable control.

- **A further Invasive alien species impact concerns the** zebra mussel - this has led to damage to US and European industrial plants. Cumulative costs for the period 1988-2000 have been estimated at between $750 million to $1 billion[33]
- For the ecosystem service **biochemicals, natural medicines and pharmaceuticals**, found in tropical forests, the values for bioprospecting have been estimated[34] at ranging from $1/ha to $265/ha when employing a random search, including locations with the highest biodiversity. There is a high variation of values within one study. Here, this is once again a good example of the site dependency of values. Even though all tropical forest are rich in biodiversity not each tropical forest is a hot spot region genetic material.
- For **provisioning services**, marine capture fisheries, offer an impressive example. Marine capture fisheries are an important source of economic benefits, with an estimated first-sale[35] value of *$ 84,900 million*, and important for income generation, with an estimated 38 million people employed directly by fishing, and many more in the processing stages. The scale of this (and of course the scale of dependency on fish for protein) underlines the importance of not compromising this fundamental ecosystem service.
- Finally**, carbon storage** – this depends on carbon in the soil, in the trees or grass, the isolation levels and the value depends on these and the price of carbon, which in turn relates to a wide range of factor (political targets, trading mechanisms, supply and cost of measures for CO_2 reductions). The COPI analysis, see further below (and Annex 2), estimated a range of carbon sequestration values for different forestry biomes and different geographic regions demonstrated the scale of the potential losses of carbon storage from land use changes.

Transferring results from one area to another (*benefit transfer*) and "grossing up" to develop regional or global totals present a range of evaluation challenges. Some will reject global numbers on the grounds that they are fraught with too many assumptions to be accurate and hence credible. Others will see them as helpful illustrative numbers to communicate the importance of an issue and source of inspiration for further evaluation to improve the understanding, or source of argument to contribute to policy making to help address biodiversity loss. The COPI approach is to present both the cases and the illustrative global totals and explore what can and cannot be done methodologically and what could usefully be done in follow up research.

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33 National Aquatic Nuisances Species Clearinghouse, 2000 in McNeely et al (2001)

34 Costello & Ward (2006)

35 Value to fishermen, so does not include the value added along the retail chain.

6.2 Approach and coverage

In addition to deriving estimates for values for the cost of inaction, a further important aspect of the COPI work was to explore the methodological possibilities and challenges to creating COPI values, so as to clarify what can be done and what needs to be developed so as to address the wider economics of ecosystems and biodiversity valuation challenge. Hence a summary of the approach, methods and assumptions are noted here, complementing Chapter 2 on methodology, and the supporting annexes. Section 6.2 serves to help readers understand where the results presented in section 6.3 come from.

6.2.1 The COPI analysis – core steps

The core steps of the COPI analysis:
As noted in *Figure 6.1*, changes in land use and pressures on land (pollution, climate et al), lead to changes in biodiversity, changes in ecosystem functions, changes in the supply of ecosystem services which lead to a change in the benefits to society and economy. The changes in benefits that derive from the loss of biodiversity that result from insufficient policy action can usefully be estimated to highlight the scale of the loss – here termed the cost of policy inaction (COPI). To derive the COPI estimate requires availability of data, putting it into a suitable framework (or rather set of linked frameworks), identifying the gaps and applying methodological tools to address the gaps, and then doing the computations and seeing the results in context of the data, the gaps, and methodological assumptions needed to arrive at the COPI figures. Key elements of the COPI analysis are:

Core Step 1: Data for land-use change over the period 2000 to 2050.

The underlying values within the GLOBIO work were used; these combine two elements - change in land-use (*Table 6.1*) and a loss of quality of the land due to climate change, pollution, fragmentation – which is represented by the mean species abundance (MSA) index used in the model (see Chapter 4 and *Table 6.2*). Both elements form a basis for the monetary evaluation (see *Table 6.3* to illustrate the changes for an exemplar biome – boreal forests).

Table 6.1 Total Area by Land-use; Global total aggregated across all biomes

Actual	2000	2050	Difference
Area	Million km^2	million km^2	2000 to 2050
Natural areas	65.5	58.0	-11%
Bare natural	3.3	3.0	-9%
Forest managed	4.2	7.0	70%
Extensive agriculture	5.0	3.0	-39%
Intensive agriculture	11.0	15.8	44%
Woody biofuels	0.1	0.5	626%
Cultivated grazing	19.1	20.8	9%
Artificial surfaces	0.2	0.2	0%
World Total *	108.4	108.4	0%

The main losses come from the loss of natural areas and extensive agriculture. Furthermore, as noted in the scenarios section, the loss of areas is quite conservative. The above rate of loss of natural areas is circa 0.2% per year.

Table 6.2 Loss of quality - due to pollution, fragmentation, infrastructure and climate impacts (Global average all biomes)

Mean species abundance (MSA) change for different land use categories	MSA loss 2000 to 2050
Natural areas	**11%**
Bare natural	**8%**
Forest managed	**20%**
Extensive agriculture	**8%**
Intensive agriculture	**-2%[36]**
Woody biofuels	**0%**
Cultivated grazing	**14%**
World Total	**18%**

In this example, losses occur to natural areas from both a loss of natural area coverage with 76 million hectares converted to other land uses (5% of the natural areas for this biome), and also due to quality losses, with a further 7% loss in quality for the area that remains. See Chapter 3 for more detailed discussion of land use changes and quality changes. *Figure 6.2* presents the composite picture, where land use and quality changes are combined. For each conversion of one land-use to another, there will be a change in biodiversity and in parallel in ecosystem service provision. As shown in Chapter 5, *Figure 5.4*, a habitat in its natural, pre-exploited, preconverted state, has a certain set of services, and when converted, the balance changes – e.g. from natural areas to extensive agriculture, there is an increase in the provision of food, but a decrease in the ecosystem services of climate regulation, soil protection and freshwater.

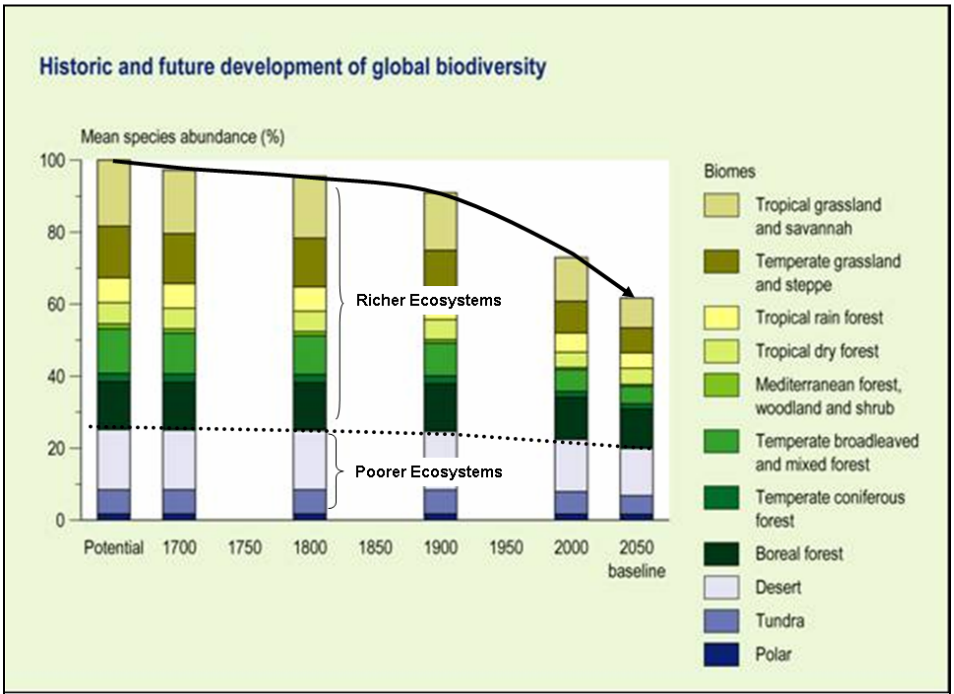
Table 6.3 Example of Changes of land use and biodiversity : Boreal Forest Global coverage

	Land use and land use changes (million hectares and %)				**Ecosystem quality - Mean species abundance**		
	Change 2000 to 2050	**2000**	**2050**	**Change 2000-50**	**2000**	**2050**	**MSA loss**
	%	**(million hectares)**			**(MSA)**		**%**
Boreal forest	0%[37]	1761	1761	0	0.88	0.79	-10%
Natural areas	-5%	1477	1401	-76	0.96	0.89	-7%
Bare natural	-8%	22	20	-2	0.59	0.52	-13%
Forest managed	41%	87	123	36	0.47	0.43	-9%
Extensive agriculture	16%	24	28	4	0.33	0.31	-6%
Intensive agriculture	87%	36	67	31	0.09	0.10	2%[38]
Woody biofuels	84%	0	1	0	0.20	0.20	-0%
Cultivated grazing	5%	114	120	6	0.59	0.53	-10%

[36] Some of the intensive agricultural land has been converted from extensive agriculture or natural areas, and while the conversion leads to biodiversity loss, the new intensive agricultural land can be of higher MSA than the “older” agricultural land, hence the MSA change being positive.

[37] There is no overall change - by definition within the model – in the biome area, only changes in the allocation to different land uses.

[38] Ibid previous footnote



Source: building on *Ben ten Brink (MNP)* presentation at the Workshop: ***The Economics of the Global Loss of Biological Diversity 5-6 March 2008, Brussels, Belgium.***

Figure 6.2 Biodiversity Loss 2000 to 2050 and historic context (MSA hectares)

When the land is further converted or "improved" to intensive agriculture, there can be a further gain in provision of food, and further losses in other services. The exact level of provision depends on local conditions and is dynamic (as some services can be run down if beyond natural capacity – e.g. nutrient mining). There is therefore a trade-off in the conversion with some gains and some losses, not always to the same parties. The provision responds to the existence of biological elements and man-made (fertiliser, machine input etc). The ESS relates to the contribution of the biological elements. It is important to distinguish therefore between the gross output from the land and the net contribution of the ESS. *See Chapters 4 and 5 for details and Balmford et al (2008) for discussions on production functions and balance of natural and man-made inputs.*

Core Step 2: Develop and populate a matrix of ecosystem service (ESS) values across land-uses for each biome (and for each region) – in a form that allows link to the land use data.

This step is described in detail in Chapter 2 and Annex 1. There are several key issues – data coverage, meaning of the data, selection of suitable cases to develop representative pictures of ecosystem service values for land use and biome and populate the ecosystem services matrix. As regards data coverage, there are different levels of information for different regions, different biomes, different ecosystem service types and also for different value types (eg easier to get market based information for use values than non market values on non-use, bequeth value and insurance values – see figure *Figure 6.3*).

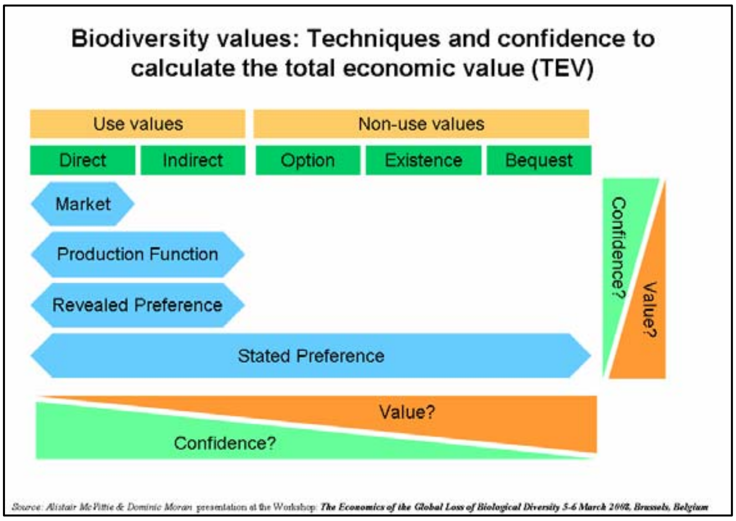


Figure 6.3 –Total Economic value diagram

To populate the matrix entailes four key steps:

- A literature review of ecosystem service values,
- Develop representative values from the data available,
- Original analysis to develop ecosystem service values – carried out for forestry biomes by the COPI Team,
- Gap filling, to address gaps in ecosystem service values by land uses, biomes, geography and into the future.

The first two are core to the developmet of the "valuation database" – see Chapter 2 and Annex I. For the unit values for the foresty biomes, the COPI team calclated unit values for each region (see section 6.3 below and Annex II), and for other areas more extensive use was made of benefit transfer techniques. Together this formed a partly populated ecosystem service-biome-landuse-geographic region matrix/data-base[39]. Elements of gap filling are presented below.

Core Step 3: Gap Filling for ecosystem serviecs values within a biomes – across landuse types:

The data from the literature did not give enough detail on different values for different land used within a given biome and a range of approaches were used by the COPI team to fill these gaps (see *Box 6.1, Filling the Gaps;* other elements are noted in Chapter 2, Chapter 5 and Annex I). Each of the steps has its strengths and weaknesses and the ensuing results should be seen in this context, i.e. as illustrative estimates to highlight the importance of the issue, with the steps forming a basis for further development and fine tuning for the second phase of The Economics of Ecosystems and Biodiversity (TEEB) work.

[39] Note that for operational purposes (needed subsequently for benefit transfer and operational limitations of Excel) in the spreadsheet modelling, a geographic region was generally needed to be taken as a starting point for the database – within COPI this was Europe. See more in benefit transfer discussion.

The first significant gap filling was carried out to develop values for different land use types within a given biome. In general, the evaluation litterature provided a value for ecosystem service for a given landuse type within a biome (usually for natural areas that were being studied). If only these were to be applied, then there would be too many gaps to derive a total value for the change in landuse. To address this evaluation challenge, the COPI team looked at the broad relation beteween ecosystem service provision and landuse types within a biome. *Figure 6.4* is an illustration of these relationships. The relationships between biodiversity and Ecosystem services are presented in *Figures 6.4* and *6.5*. They are working assumptions that have been made to facilitate the analysis.

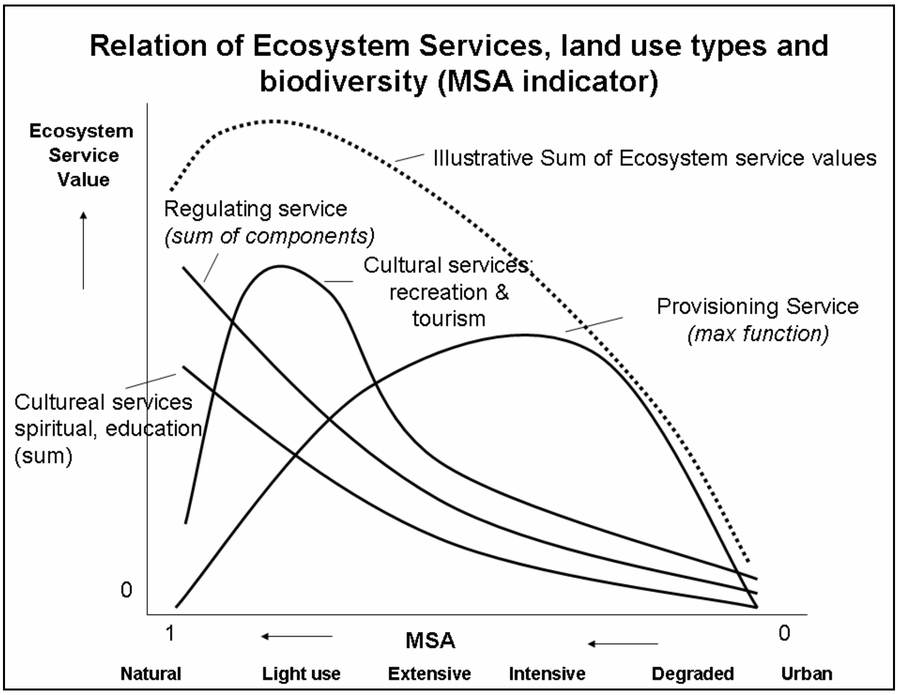


Figure 6.4 Relationship between Ecosystem service provision and land use types

For regulating services (water, air, climate) there is a gradual fall of services as the ecosystem is degraded. For recreation and tourism, generally values require a certain amount of accessibility and infrastructure to have maximum wealth and fall as the quality of the resource falls as a substitute is chosen - hence the values peak early, under *light use*. For other cultural services such as spiritual value or information value it tends to decrease as the ecosystem is degraded. Provisioning services are maximised in converted ecosystems, with the location of the maximum depending on soil quality, market for the goods and also nature[40] and timescale[41] of the analysis. To enable these relationships to help fill gaps, the COPI team estimated a series of relative factors for the ecosystem service (ESS) value across land use types. *Figure 6.5* presents the relative factors for the 4 groups of services. Table A6.2 in the annex of this chapter gives the specific numbers used to fill gaps – with a set of numbers for each specific service. This gap filling approach is a critical component to addressing

[40] Eg if man-made inputs are excluded to derive net ESS value.

[41] Eg if future degradation taken into account.

the evaluation challenge, and it will be an important part of a phase 2 of the Evaluation of Ecosystems and Biodiversity to fine tune these relationships in light of empirical evidence across biomes and regions.

Relation of ESS and MSA
including multipliers for gap-filling in COPI analysis

COPI Category		natural areas			Bare natural	forest managed	Cultivated and managed areas				Artificial surfaces
		Pristine (historic)	Natural	Light forest			grazing area	woody biofuels	Extensive Ag	Intensive Ag	
General*	MSA	1	0.9	0.7	0.9	0.5	0.7	0.5	0.3	0.1	0.05
P*: Provisioning	Importance (gross)	-	*	**	*	***	**	***	****	*****	-
	Index	0	0.2	0.5	0.05	0.7	0.5	0.7	0.8	1	0
R*: Regulating	Importance	*****	*****	****	*	***	****	***	***	*	*
	Index= F*(msa)	1	0.9	0.7	0.05	0.5	0.7	0.5	0.3	0.1	0.05
C1*: Recreation	Importance	-	*****	*****	**	***	****	*	***	*	* (- to ***)
	Index	0	1	1	0.5	0.6	0.8	0.15	0.5	0.1	0.1
C2*: Info (spiritual, education)	Importance	*****	*****	****	*	***	****	**	***	*	*
	Index= F*(msa)	1	0.9	0.7	0.5	0.5	0.7	0.2	0.3	0.1	0.05

* These are broad relationships; for COPI valuation, where data exists that is more precise (eg for carbon storage), this will be used. The numbers here are back-up ratios to help fill gaps

Source: COPI team: Mark van Oorschot (MNP) , P ten Brink (IEEP), Leon Braat (Alterra), Matt Rayment (GHK)

Figure 6.5 Relationship between Ecosystem service provision and land use types - quantification

Core Step 4: Gap Filling for ecosystem services across biomes

The above data gap-filling addresses gaps where there is data on a service within a biome for a given landuse. However, the available data from the literature also leads to some gaps in ESS values for some biomes. In some cases it is clear that there are services (e.g. water purification, carbon storage) and that these are broadly similar between biomes. Where a broad relationship was establishable, the values from one biome were transferred to another. For example there is a value for air quality management for scrubland, and it was thought broadly applicable also to the biomes Mediterranean Scrub and Savannah. Similarly the value of soil quality regulation was thought broadly applicable to other forestry biomes. Some will find the approaches to gap filling necessary and useful, others will feel that certain elements are certain elements are weaker. Hence two evaluation scenarios were used – a partial estimate scenario and a fuller estimate scenario. The partial estimate has fewer gaps filled by transferring values from one biome to another (e.g. forest of one type to another), while the fuller estimate, includes more benefit transfer. Ultimately clarifying the ecosystem service "production function" and how this varies by biome and region will be an important part of future work.

Core Step 5: Applying "Conventional" Benefit transfer

The matrix in Core Step 2, even with the above gap filling does not yet adequately cover the full ranges of regions across the world. A "conventional" benefit transfer approach was therefore applied to address the gaps in ESS coverage for geographic regions (e.g. European values transferred to Australia and New Zealand), and across time (notably 2000 to 2050 for this study).

- For transfering values across regions, GDP (in purchasing price parity (PPP) terms)/capita ratios between countries was used for where the ecosystem service salues were judged to best reflect relative incomes – and where the good was seen as a global good with market prices (eg timber) the common global values were used (ie a transfer ratio of 1). See *Table 6.4* for some example rates and *Table A6.1* in the annex of this chapter.

Table 6.4 Benefit transfer: Across Regions – GDP (PPP) per capita ratios (examples)

Region	North America	Europe	China Region	Eastern Europe & Central Asia	Africa
Model acronym	NAM	EUR	CHN	ECA	AFR
Year 2000	1.47	1.00	0.23	0.17	0.12
Year 2050	1.34	1.00	0.69	0.41	0.15

Core Step 6: Extrapolation "today's" ecosystem service values into the future

Extrapolation into the future from current numbers is an important and necessary step in the analysis and one that is by its nature risky and imprecise. Leaving numbers at today's levels (in real terms) would lead to major weaknesses in the outputs –world population growth, income level growth, change in societal preferences, and increased competitions for limited and declining natural resources will each affect value. Hence assumptions are needed to attempt to take these into account. These are presented in *Box 6.2*.

Box 6.2: Filling the Gaps

For a full analysis, values are needed for each biome, for each land use type, for each ecosystem service and for each year from now until 2050. This is a hard data demand, and so benefit transfer is needed from the cells filled with existing literature to fill some of the gaps, where this can plausibly be done. The approach needed to make use pragmatic choices given time, resources and data availablity.[42]

As noted in Chapter 2 and Annex 1 on the COPI – Valuation Database, and also indicated in the March Experts workshop on the Economics of Biodiversity loss[43], there are many gaps in the literature as regards valuation studies. There is more information on North America and Europe than for many other regions. There is also more information for certain ecosystem services than others – e.g. more information available for provisioning services (i.e. market goods) and for carbon. And there is more information available for certain biomes/landuses than others - e.g. more on forests than on

[42] Within the COPI study we have developed a basis that allows future updates – inclusion of new data and inclusion of new understanding of relationships between the provision of services and land use and provision of services and geographic location.

[43] Workshop on the Economics of Biodiversity Loss, 5-6 March 2008, Brussels

savannahs. At one level this helps to define the research agenda, and also to help see evaluation results in context. However, it also creates a challenge for filling the gaps so as to get numbers that can represent the scale of the importance of this issue.

As regards methods for filling the gaps, the following were used:

a) **Within a given biome and for a given ecosystem service (ESS) –** generally the average across a group of studies[44] allowed a number to be obtained for a given land use within the biome and ESS – though in cases removing extreme cases/outliers where they are not representative of the global issues to avoid unrepresentative averages. The estimated number was taken as the base value and to fill the gaps, the relative expected ESS shares (across landuses for the p rovision of the service in question, within the biome) were applied to the base value to derive values for the ESS for other landuses. *Table A6.1* in the annex of this chapter presents the operational numbers used in the analysis, and *Figures 6.4 and 6.5* present the broad relationships between ESS and landuse and MSA. For gap filling, two options were used (e.g. applied to the provisioning services) - for the fuller evaluation scenario the weightings were freely used, and for the partial estimation scenario a maximum/ceiling value was attributed, reflecting a view that if a change of land use had the potential to yield net private benefits, it would have already taken place. Of course this too is a simplification but the two choices allow for a range to be created. Ultimately, one would wish for numbers of ESS values for a given ESS within a given biome across landuse types to be able to calibrate the different ESS indicators/weights used (*Table A6.2, Figure 6.4 and 6.5*), but little was found in the literature. This could usefully be addressed in the future.

b) **For projecting into the future.** In the COPI work two scenarios were used. As a default, where no data/rationale was available to determine future values, a back-stop assumption was taken that unit values per hectare would grow by population and by wealth (measured by GDP (in PPP) per capita). This makes intuitive sense as a general default, as one could expect many service values to rise with income and with population (e.g. recreation, tourism). Of course, this is a simplification, but given the scale of the challenge and timescale for the work, a necessary one. Where evidence of a different rationale existed – e.g. for provisioning of wood, of carbon prices, and of recreation and other cultural services– these were applied. For example, for carbon storage values, a demand curve into the future was used (here prices grew faster than the combination of population and GDP/capita). – see further below and Annex 2 Different values were allocated across the fuller estimation scenario and partial estimation scenarios – in practice the higher carbon value was added to the fuller estimation and the lower carbon value to the partial estimation. See *Table 6.5* for some examples, and *Table A6.3* for fuller details.

Table 6.5 Benefit transfer: 2000 to 2050 – Multipliers (examples)

	Change 2000 to 2050	
	Partial Estimation scenario	Fuller Estimation scenario
Food, fiber, fuel	1	2.8
Fresh water	2.8	2.8
Air quality maintenance	2.8	2.8
Climate regulation (i.e. carbon storage)	3.59	11.37
Water purification & waste management	2.8	2.8
Cultural diversity, cultural heritage values	2.15	2.8
Recreation and ecotourism	2.06	2.8

c) **For a given ecosystem service – across biomes.** It is clear even where there is an absence of data from the literature, that all forests stock carbon, contribute to water purification, contribute to air quality maintenance etc. There is therefore a choice of leaving blanks for where there is no data, or filling the gaps. Either approach carries some risks and influences on the results and people's interpretation of their meaning. Within the COPI study it was decided – for the high estimation/gap filling scenario – that where there are values for particular ecosystem services for certain forests, that the average could be applied to other forests. Similarly where there are values for grasslands, then the average could also be applied to savannah, scrubland etc. The value of this

[44] In some cases the average or single number from one study – see chapter 2 and Annex 1.

approach is that the gaps do not dominate the results. In the lower estimation scenario, this transfer was not done, and blanks were left. The value of this approach is that it can avoid concern that the transfer is a bit too pragmatic to be justifiable in a rigourous context. As there are competing principles – getting a full picture and having a robust approach – the two appoaches were taken and integrated into the scenarios.

Note, ultimately the areas where gaps existed and techniques needed to fill the gaps are indications of need for further research. As regards priorities, these can be identified by the areas where there are important potential values (e.g. due to major landuse changes) but where little data exists.

Core Step 7: Combine the land use changes with the values for ecosystem services (ESS) under each land use for each region to derive values for the change in ecosystem services.

In the year 2050**,** the land coverage of natural areas and of (natural) forests will have decreased relative to the reference year 2000, as there is conversion to intensive agriculture and to plantations for biofuels. There will therefore be a shift from the ESS from natural areas and forests to ESS from intensive agriculture and plantations, and hence a trade-off between the different provision of services. To arrive at a value for the changes, the loss of area covered by natural areas is multiplied by the range of relevant ESSs for which values are available; the same is then done for forests, and to the post conversion land uses and a picture is developed of losses and gains. This gives the loss in 2050 from what land use there would have been for that year. There will, of course, be gaps, and hence it is important to be clear as to what is not covered and the influence of the gaps. This is done for the both the partial estimation and the fuller estimation scenarios. *Figure 6.6* presents a schematic for the framework.

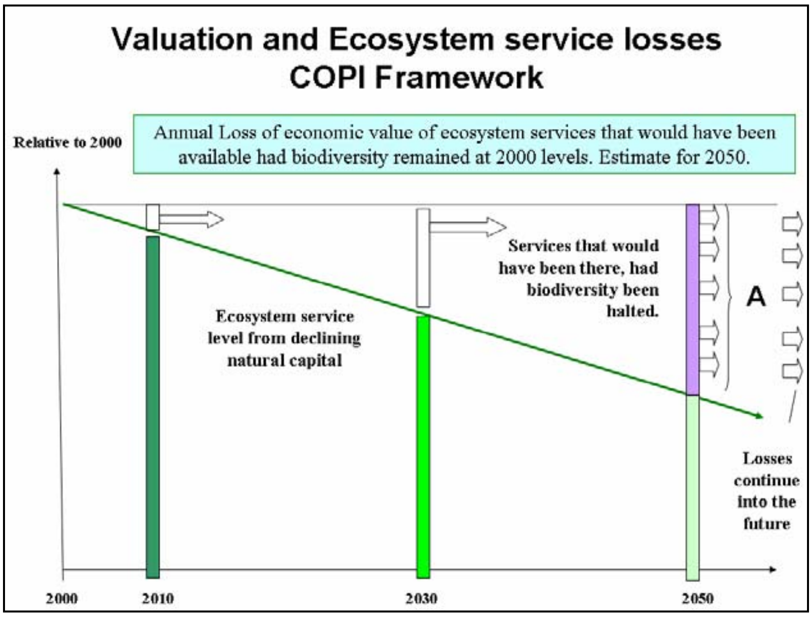


Figure 6.6 COPI framework for presenting economic value of biodiversity loss

Relative to 2000, biodiversity declines to 2050, each year's loss of ecosystem and biodiversity leads to a flow of ecosystem services no longer taking place (and some new ones, depending on the conversion) with the loss felt every year into the future.

Each year's new loss of natural areas (for example), adds to the previous year's loss and cumulative losses add up. By 2050, humanity will benefit less and less from the ecosystem service flows from natural capital stock if biodiversity loss is not halted. The below schematic applies to both land use loss and to quality loss (e.g. a degraded ecosystem generally provides fewer services).

Core Step 8: Ecosystem services (ESS) are also lost where there are reductions in the quality of the land.

As an ecosystem is degraded, this generally leads to a loss of ecosystem services. In the case of agricultural land, this can be addressed by increasing man-made inputs (e.g. fertilisers), but the net contribution of the ecosystem service from the natural component goes down. Grasslands and forests that are fragmented can support fewer species. A degraded ecosystem can regulate water, air and climate less well.

To capture these losses, the land-use and coverage in the final year of the analysis (2050) is taken (million hectares) and multiplied by the value of the services in that year (as per earlier analysis and method steps) and then multiplied by the loss of MSA index between 2000 and 2050 for the land use. The average hectare of grassland would have produced greater services in 2000 than in 2050 where the modelling suggests that pollution, climate change and fragmentation, have led to quality losses. This calculation therefore builds on a broad assumption that the MSA, which is an indicator of species abundance and reflects the health of the ecosystem, in turn broadly reflects the provision of services, at least at an aggregate level. The use of broad relations (generally and specifically for ESS) are obviously important assumptions, and hence the MSA aspect of the evaluation is presented separately from the land-use[45]. Note that the level of individual services does not follow the MSA pattern generally and hence were given different treatment in the gap filling – as noted above and in Chapter 5. As with other assumptions, not treating quality losses would lead to an arguably unacceptable gap in the COPI assessment of what the impact of biodiversity loss is, at the same time including it raises questions as whether the approach is the best one. The COPI team concluded it to be valuable to calculate and present the results, keep them separate for the land use changes based COPI estimate (for results see further below), and raise as an important evaluation challenge for phase 2.

[45] It is useful to also note that the "quality changes" actually reflect slightly more than the effect of climate change (eg some desertification and subsequent loss of land quality and MSA), pollution loading and fragmentation, but also some changes in land-use within the 8 broad land-use categories used (the model has finer detail that is hidden by the aggregation). While the changes are therefore broader than only "quality changes", it will be referred to as such for simplicity.

Analysis of time coverage
The analysis focused on: (a) the changes over the period 2000 to 2050 as the core analysis and also (b) changes over the period 2010 to 2050 and (c) the changes over the period 2000 to 2010. For simplicity the results for 2000 to 2010 are presented as if they are related to the current reality, and the 2000 to 2050 period as this gives the overall picture of the loss. The main results of the analysis are presented in terms of:

- Cost of policy inaction in annual losses in Billion EUR (1000 million, or 10^9 EUR)
  - annual cost in 2050 from not having halted biodiversity loss at 2000 levels.
  - annual cost in 2010 from not having halted biodiversity loss at 2000 levels.
- Cost of policy inaction - value of loss of ecosystem services presented as a percentage share of GDP, for the time periods as above. This includes insights on the costs for different regions of the world losses – note of course that not all the costs of the loss apply to the region itself as, for example, the loss of carbon storage is a global loss.

This is done for as a all land-based biomes together (where there is data – the tundra and wooded tundra could not be addressed, nor could polar and deserts), and separately to allow analysis. The set of forestry biomes is presented together as part of the results as this has received more evaluation attention. Furthermore, details are presented for values for specific services and for geographic regions. Finally, while the COPI numbers have focused on the level of loss of ecosystem services per year in the early period (2000 to 2010) and in 2050, as this allows an intuitive understanding by a wide audience of the likely facts, some results are also presented to look at the capitalisation of 1 year's loss of natural capital (doing a net present value of the stream of lost services into the future), to address other audiences. Details of the later are presented in section 6.3.3.

6.2.2 COPI analysis – complementary areas

The core COPI analysis has focused on changes in land-based biomes and hence covers significantly less than half the globe. For the areas of complementary analysis (coral reefs, invasive aliens etc), the work:

- Built on literature to develop insights on ranges of values for ecosystem services. The values are included in the database (see Chapter 2 and Annex I) or separately (IAS reference included as a separate list);
- Explored the existing literature for potentially applicable future scenarios - e.g. for marine fisheries (see Chapter 4) and to a lesser extent for coral reefs.
- Where there were no future scenarios, pragmatic and conservative views were taken for the likely development of the issue to extrapolate recent trends – e.g. for coastal systems and for invasive alien species.

For details of broad estimates / results and supporting assumptions, see below. Each of these areas of course merits further and more comprehensive attention in the coming years.

6.3 General COPI analysis of land-use change

6.3.1 Main results

Table 6.6 presents the aggregate changes in land-use globally and *Tables 6.7 and 6.*8 the aggregate values for the loss of ecosystem services. Note that both are the aggregate of the wider analysis across geographic regions and across biomes. The land-use changes numbers are repeated here to see the COPI numbers in perspective. To give scale to the various numbers:

- **The loss of natural areas over the period 2000 to 2050 is 7.5 million km^2 - broadly equivalent to the total area of the Australia. When looking at the combined loss of natural and bare natural areas and extensive agriculture the area is equivalent to that of the entire United States of America.**

Table 6.6 Land-use changes

	Land Area	Area loss : Difference		
	2000	2000 to 2010	2010 to 2050	2000 to 2050
Area	million km^2	million km^2	million km^2	million km^2
Natural areas	65.5	-2.7	-4.8	-7.5
Bare natural	3.3	-0.2	-0.1	-0.3
Forest managed	4.2	0.2	2.7	2.9
Extensive agriculture	5.0	-0.4	-1.5	-2.0
Intensive agriculture	11.0	1.9	2.9	4.8
Woody biofuels	0.1	0.0	0.4	0.4
Cultivated grazing	19.1	1.2	0.5	1.7
Artificial surfaces	0.2	0.0	0.0	0.0
World Total	108.4	0.0	0.0	0.0

(Exl Ice / Hot Desert). Note also that by definition there is no change in the overall land available on the planet (we are not assuming any sea level rise) and it is an issue of distribution across land uses. Hence there is not total loss over time.

- **The loss of welfare in 2050 from the cumulative loss of ecosystem services between now and then amounts to $14 trillion (10^12 or million * million) Euros under the fuller estimation scenario – this is equivalent to 7% of projected global GDP for 2050. The loss grows with each year of biodiversity and ecosystem loss.**

In the early years (e.g. period 2000 to 2010) less biodiversity has been lost (than in later years), less land-conversion has taken place, and less damage has occurred due to fragmentation, climate change or pollution. The loss over the period 2000 to 2010 is, however, still substantial.

For the fuller estimate, the welfare losses from the loss of ecosystem services amount to 545 billion EUR in 2010 or just under 1% of world GDP by 2010. This amounts to around 50 billion Euros extra loss per year, every year. In other words the world loses 50 billion EUR from biodiversity losses in the first year, in the second year we lose an additional 50 billion EUR from new ecosystem losses – and also lose again 50 billion from the lost natural capital stock the year before – hence not having halted biodiversity lead to a service loss (opportunity cost) of 100 billion Euros.

Table 6.7 Annual Loss in 2050: The value of ecosystem services that would have benefitted mankind had biodiversity not been lost & remained at 2000 & 2010 levels.

	Value of Ecosystem service losses - Annual Billion (10^9) EUR lost							
	Fuller Estimation		Partial Estimation		Fuller Estimation		Partial Estimation	
	Relative to 2000	Relative to 2010	Relative to 2000	Relative to 2010	Relative to 2000	Relative to 2010	Relative to 2000	Relative to 2010
Area	Billion EUR	Billion EUR	Billion EUR	Billion EUR	% GDP in 2050	% GDP in 2050	% GDP in 2050	% GDP in 2050
Natural areas	-15568	-12703	-2119	-1679	-7.96%	-6.50%	-1.08%	-0.86%
Bare natural	-10	-6	-2	-1	-0.01%	0.00%	0.00%	0.00%
Forest managed	1852	1691	258	213	0.95%	0.87%	0.13%	0.12%
Extensive Agriculture	-1109	-819	-206	-141	-0.57%	-0.42%	-0.11%	-0.08%
Intensive Agriculture	1303	736	307	143	0.67%	0.38%	0.16%	0.09%
Woody biofuels	381	348	55	50	0.19%	0.18%	0.03%	0.03%
Cultivated grazing	-786	-1181	-184	-215	-0.40%	-0.60%	-0.09%	-0.13%
Artificial surfaces	0	0	0	0	0.00%	0.00%	0.00%	0.00%
World Total (Land-based ecosystems*)	-13938	-11933	-1891	-1518	-7.1%	-6.1%	-1.0%	-0.8%

This then increases to 2010 as each year's further loss of the natural capital stock leads to yet further losses in the flow of ecosystem services. By 2010, the loss is "grown to" 545 billion EUR that year, for the land based ecosystems alone. This continues to increase until by 2050, the opportunity cost from not having preserved our natural capital stock, is a loss in the value of flow of services of $14 trillion (thousand billion) a year. The opportunity costs will continue to rise beyond that as long as biodiversity and ecosystem losses are not halted. This then is the cost in the case that the 2010 target is not met. In the first years of the period 2000 to 2050, it is estimated that each year we are losing ecosystem services with a value equivalent to around 50 billion Euros per year from land based ecosystems alone. Losses of our natural capital stock are felt not only in the year of the loss, but continue over time, and are added to by losses in subsequent years of more biodiversity.

Table 6.8 Loss of Value of Flow of Ecosystem Services per year in 2010, for now having halted biodiversity loss at 2000 levels. fuller estimation

World Total and totals for land use types across land based biomes*	Annual loss of Services – value in 2010 Billion (10^9) EUR	Losses as % of GDP
Total	**-545**	**-0.90%**
Natural areas	**-490**	**-0.81%**
Bare natural	**-272**	**-0.45%**
Forest managed	**29**	**0.05%**
Extensive Agriculture	**-51**	**-0.08%**
Intensive Agriculture	**109**	**0.18%**
Woody biofuels	**44**	**0.07%**
Cultivated grazing	**43**	**0.07%**

*** (Exl Ice / Hot Desert)**

The cumulative losses will be equivalent to around 7% of global consumption by 2050. This is a conservative estimate for three main reasons: 1) it is only partial, as not all ecosystem services are valued - significant ecosystem losses from coral reefs, fisheries, wetlands, and invasive aliens are not included 2) the estimates for the rate of land use change and biodiversity loss are fairly conservative[46], with the rate of loss estimated to slow 3) values do not account for non-linearities and threshold effects.

The losses are considerable, both at the global level, and especially for some regions and biomes.

There are important losses that we can expect to occur in the next 50 years, and these relate primarily to the conversion of natural areas and also of extensive agriculture to intensive agriculture, managed forestry, more grazing and also woody biofuels (note that biofuels based on agricultural crops is within the agriculture bands). Overall, the analysis suggests that without halting biodiversity loss, the world in 2050 shall benefit much less from the flow of ecosystem services than in 2000. The loss in the value of the flow of services by 2050 would be equivalent to between

[46] The projection follows from the calculated losses due to a "middle of the road" economic and demographic OECD baseline scenario.

1% to 7.1% of GDP each year were 2000 to be taken as the biodiversity level of reference, and between 0.8% and 6% if 2010 were to be taken as the reference point (which due to continued incurred losses since 2000, of course, has a lower worldwide biodiversity value left than 2000).

The loss in value of ecosystem services in 2010 of not having halted biodiversity loss at 2000 levels is estimated to be equivalent to[47] between just under 1% of GDP. These values related to the losses of services from land based ecosystem services alone, i.e. not taking into account marine fisheries, coastal, wetlands, coral reefs or the impact of invasive alien species (IAS). The total global loss across ecosystem types shall in fact be much greater.

It is useful to also look at the costs across geographic regions, costs for different biomes and costs by ecosystem service type.

6.3.2 Losses across regions

The losses across regions are presented in *table 6.9* in billion Euros per year in 2050 and *in table 6.10* where the welfare losses are presented as a % of GDP to allow comparison. The variation across regions relates to the change in the land-use patterns within each region, quality losses for land in the region, different values for ESS across the regions and, when compared to national GDPs, the variation in national GDPs. The results need suggest that the main regions impacted by biodiversity loss will be – *when seen from a % of GDP basis* (See *Tables 6.9 and 10* Overleaf):

- ANZ - OECD Pacific: Australia & New Zealand
- BRA: Brazil
- OLC: Other Latin America & Caribbean
- RUS: Russia & Caucasus
- AFR: Africa
- and then OAS (Other Asia), then Eastern Europe & Central Asia.

While the welfare losses presented as an average of global GDP is 7%, the welfare losses due to ecosystem and biodiversity losses in the regions range from very small (MEA) to 17% in Africa, 23 to 24% in Brazil, other Latin America & Caribbean and Russia, and highest in Australia/New Zealand. A significant share of the losses is due to loss of the value of carbon storage, and hence a global loss rather than one felt directly by the local populations. Water regulation, air pollution regulation, cultural values and tourism losses, however, do affect national populations. The loss of these services make up more than half of the losses in Australia and New Zealand, but carbon storage losses make up a large share of losses in the other regions (see further below discussion as to which ecosystem services losses have which significance, section 6.4.4).

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[47] The actual numbers are welfare numbers and not all these will translate into actual GDP loss. In other words, actual GDP as measured and reported might not be 1% lower.

When seen from an absolute loss (Billion EURs) point of view, the regions most affected are:

- North America: 3.4 trillion (10^12)EUR loss in 2050 from lost natural areas and overall 2.9 trillion EUR (10^12) loss in the High estimation scenario for 2000 to 2050.
- Africa: 3.15 trillion EUR (10^12)loss in 2050 from lost natural areas, and overall near 2.4 trillion (10^12) loss in the High estimation scenario for 2000 to 2050.
- and then other Latin America & Caribbean, Russia, other Asia, and Europe, and then Brazil and China, where losses are of the order of 1 trillion EUR in each (more in the earlier first countries in the list (e.g. Russia with near 1.5 trillion) and less in the last (China with 0.8 trillion EUR). (*See table 6.9 for details.)*

In other words, most regions of the world face serious losses of ecosystem services from biodiversity loss.

Table 6.9 Losses across geographic areas as in billion EUR per year in 2050 (2050 relative to 2000: Fuller estimation)

	Total	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR
World Total (Land-based ecosystems*)	-13938	-2925	-1116	-226	-713	-929	-1480	-560	-841	-15	-1209	-147	-1398	-2378
Natural areas	-15568	-3416	-1125	-212	-770	-882	-1472	-893	-843	-6	-1201	-150	-1442	-3156
Bare natural	-10	0	0	0	0	0	-1	-5	0	0	0	-1	-1	0
Forest managed	1852	803	176	8	25	-42	-40	228	110	0	107	-1	68	408
Extensive Agriculture	-1109	-64	-24	-4	-3	-68	-65	-173	-3	-2	-305	-32	-118	-248
Intensive Agriculture	1303	110	5	-19	33	31	80	294	61	3	167	22	122	394
Woody biofuels	381	69	32	3	6	125	-10	0	25	0	20	9	64	37
Cultivated grazing	-786	-427	-180	-3	-4	-93	28	-13	-191	-9	2	6	-91	187

* (Exl Ice / Hot Desert)

Table 6.10 Welfare Losses across geographic areas as presented as share of GDP 2050 (2050 relative to 2000: Fuller estimation)

	Total	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR
World Total (Land-based ecosystems*)	-7.1%	-8.2%	-3.9%	-2.8%	-40.4%	-24.0%	-23.3%	-2.1%	-1.9%	-0.2%	-11.3%	-6.6%	-23.2%	-17.0%
Natural areas	-7.96%	-9.6%	-3.9%	-2.6%	-43.6%	-22.8%	-23.2%	-3.4%	-1.9%	-0.1%	-11.3%	-6.7%	-23.9%	-22.6%
Bare natural	-0.01%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%
Forest managed	0.95%	2.3%	0.6%	0.1%	1.4%	-1.1%	-0.6%	0.9%	0.2%	0.0%	1.0%	0.0%	1.1%	2.9%
Extensive Agriculture	-0.57%	-0.2%	-0.1%	-0.1%	-0.2%	-1.7%	-1.0%	-0.7%	0.0%	0.0%	-2.9%	-1.4%	-2.0%	-1.8%
Intensive Agriculture	0.67%	0.3%	0.0%	-0.2%	1.9%	0.8%	1.3%	1.1%	0.1%	0.0%	1.6%	1.0%	2.0%	2.8%
Woody biofuels	0.19%	0.2%	0.1%	0.0%	0.3%	3.2%	-0.2%	0.0%	0.1%	0.0%	0.2%	0.4%	1.1%	0.3%
Cultivated grazing	-0.40%	-1.2%	-0.6%	0.0%	-0.2%	-2.4%	0.4%	0.0%	-0.4%	-0.1%	0.0%	0.3%	-1.5%	1.3%

(Exl Ice / Hot Desert)

6.3.3 Losses across biomes

Table 6.11 presents the losses for the different biomes under the two scenarios for the period 2000 to 2050. The fuller estimation scenario allows more biomes to be included.

Table 6.11 Annual loss in the year 2050 from biodiversity loss, had biodiversity loss not been halted -values across Biomes (with detail for losses from natural areas)

	Annual loss in the year 2050 from biodiversity loss, given that loss had to halted at 2000 levels. Billion (10^9) EUR per year			
	Partial Estimation		Fuller Estimation	
Boreal forest		**-163**		**-1999**
natural areas		-216		-2397
Savanna	**not assessed**	**0**		**-1135**
natural areas	**not assessed**	0		-1183
Grassland and steppe		**-146**		**-582**
natural areas		-123		-501
Tropical forest		**-536**		**-3362**
natural areas		-633		-3863
Tropical woodland	**not assessed**	**0**		**-707**
natural areas	**not assessed**	0		-661
Tundra	**not assessed**	**0**	**not assessed**	**0**
natural areas	**not assessed**	0	**not assessed**	0
Scrubland		**-428**		**-788**
natural areas		-444		-932
Warm mixed forest		**-249**		**-2332**
natural areas		-309		-2774
Temperate mixed forest		**-190**		**-1372**
natural areas		-203		-1457
Cool coniferous forest		**-47**		**-701**
natural areas		-56		-780
Wooded tundra	**not assessed**	**0**	**not assessed**	**0**
natural areas	**not assessed**	0	**not assessed**	0
Temperate deciduous forest		**-133**		**-1025**
natural areas		-135		-1039
Mediterranean shrub	**not assessed**	**0**		**66**
natural areas	**not assessed**	0		18
World Total (Land-based ecosystems*)	*** (Exl Ice/ Hot Desert)**	**-1891**		**-13938**
Natural areas		-2119		-15568
Bare natural		-2		-10
Forest managed		258		1852
Extensive Agriculture		-206		-1109
Intensive Agriculture		307		1303
Woody biofuels		55		381
Cultivated grazing		-184		-786
Artificial surfaces		0		0

The greatest losses are from the tropical forest biomes. The next greatest total losses are from other forest biomes. Total losses from Savanna and Grassland are estimated to be less. Note that the total values reflect the combination of different levels of the value of loss of ecosystem services per hectare (which are also higher for tropical forests than others), and total areas lost/converted. For a range of biomes there have been no estimations – particularly in the partial estimation scenario, though also in the higher estimation scenario. This underlines that the numbers should be seen as underestimates, even the fuller scenario has a range of gaps, both at the biome level, and at which ecosystem services are represented in the calculations (see *section 6.4.4*).

Forestry Biomes

As more information was available on ecosystem service values for the forest biomes and that information was complemented by extensive additional work to develop values for each of the global regions without recourse, as extensively, to benefit transfer techniques, further details are given on the forestry biomes. *Table 6.12a* presents the summary for the forestry biomes for the period to 2050. The losses of services from the change in land use and biodiversity for the 6 forest biomes together are equivalent to 1.3 trillion (10^12) Euro (partial estimation) and 10.8 trillion (10^12) Euro (fuller estimation) loss of value in 2050 from the cumulative loss of biodiversity over the period 2000 to 2050. These numbers have been calculated using values for 8 ecosystem services (see *table 6.13* for services included and not included). When compared to the projected GDP for 2050, these values equate to 0.7% of GDP for the partial estimate, and 5.5% of GDP for the fuller estimate.

Table 6.12a Loss of Ecosystem services for the forest Biome's – value of loss in billion (10^9) EUR in 2050.

Forest biomes	Partial Estimation	Fuller Estimation
Boreal forest	**-163**	**-1999**
natural areas	-216	-2397
Tropical forest	**-536**	**-3362**
natural areas	-633	-3863
Warm mixed forest	**-249**	**-2332**
natural areas	-309	-2774
Temperate mixed forest	**-190**	**-1372**
natural areas	-203	-1457
Cool coniferous forest	**-47**	**-701**
natural areas	-56	-780
Temperate deciduous forest	**-133**	**-1025**
natural areas	-135	-1039
Forest Total	**-1317**	**-10791**
Natural areas	**-1552**	**-12310**
World GDP in 2050 (trillion (10^12) EUR)*	195.5	
Losses of ESS from forests as share of % GDP	-0.7%	-5.5%
Losses of ESS from natural areas in forest biomes as share of % GDP	-0.8%	-6.3%

** from the OECD baseline scenario*

The losses from conversion of natural areas (for the forest biomes this is forest) is around 15% higher than the loss across land uses within the biome. This is due to the gains in ecosystem service flows from the land uses of "Forest managed", "Intensive Agriculture" and "Woody biofuels". Table 6.12b present the summary for forest biomes for the period 2000 to 2010. The average yearly loss of ecosystem services from changes in landuse and biodiversity levels in the forestry biomes comes to around 28 billion EUR per year for each year's loss. In other words, after 10 years worth of loss of natural capital the total loss of services in the year 2010 is 276billion EUR. Similarly, as in the example below, no discounting had been applied, the total loss from 1 year's loss of biodiversity over the 10 year period (as we lose every year following the loss of biodiversity) also amounts to 276 billion EUR – see Box 6.2 for different ways of presenting the costs, and for cost estimates with discounting applied. As with the number presented for the COPI to 2050, the results for 2000 to 2010 also relate to but a subset of ecosystem services.

Table 6.12b Loss of Ecosystem services for the forest Biome's – value of loss in billion (10^9) EUR – over period 2000 to 2010

	Loss of Ecosystem services - 2000 to 2010			**Average loss due to 1 years' Loss of biodiversity**
	Quality	**Quantity**	**Total Loss in 2010**	
World Total (Land-based ecosystems*)	**-130**	**-146**	**-276**	**-28**
Natural areas	-139	-272	-411	-41
Bare natural	0	0	0	0
Forest managed	-17	49	32	3
Extensive Agriculture	-5	-40	-45	-5
Intensive Agriculture	6	85	90	9
Woody biofuels	0	5	5	1
Cultivated grazing	26	27	53	5
Artificial surfaces	0	0	0	0

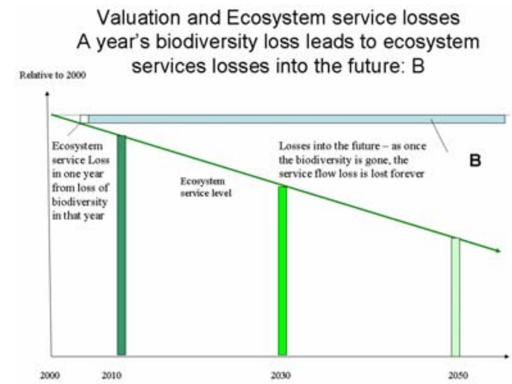
Table 6.13 Ecosystem services covered in the COPI assessment for Forest Biomes

Included (8 services)	*Provisioning services* • Food, fiber, fuel *Regulating services* • Air quality maintenance • Soil quality maintenance • Climate regulation (i.e. carbon storage) • Water regulation (i.e. flood prevention, timing and magnitude of runoff, aquifer recharge etc.) • Water purification and waste management *Cultural services* • Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity, cultural heritage values • Recreation and ecotourism
Not included (10 services)	*Provisioning services* • Biochemicals, natural medicines, pharmaceuticals • Ornamental resources

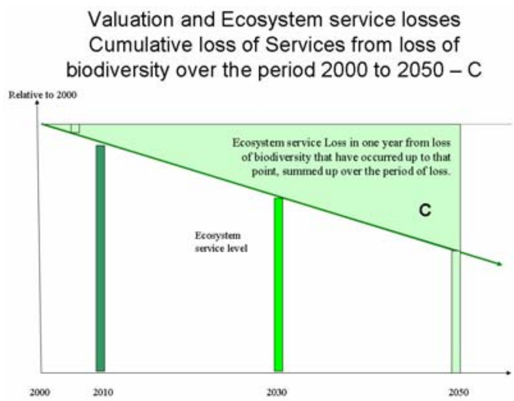
	• Fresh water *Regulating services* • Temperature regulation, precipitation • Erosion control • Technology development from nature (bionica) • Regulation of human diseases • Biological control and pollination • Natural hazards control / mitigation (i.e. storm and avalanche protection, fire resistance etc.) *Cultural services* • Living comfort due to environmental amenities

Box 6.3: Different ways of presenting the scale of the COPI of biodiversity loss – Results for the forestry biomes.

There are several ways of representing the losses for ecosystem services over a time period. This box presents the results for the application of the market capitalisation approach to the loss in value - ie what is the net present value (NPV) of the stream of future loss of services due to loss of ecosystems and biodiversity.
To derive associated NPVs requires the application of a "discount rate". Here two illustrative values are used – a 4% real and a 1% real discount rate. The former is broadly a market discount rate as used in most CBA, and the latter is a social discount rate that tries to integrate ethical issues of future generations.



What is the value over the next 50 years of a year's biodiversity loss today? Total for the forest biomes. Using a 4% real discount rate the net present value of the loss of ecosystem services is around 161 billion (10^9) EUR for the *partial estimate* and 1.35 trillion (10^12) EUR for the *fuller estimate*. With a 1% discount rate the values are significantly higher as the future value is less discounted. The *partial estimate's* NPV is 377 billion EUR and the *fuller estimate* at 3.1 trillion (10^12) EUR.



What is the cumulative value over the next 50 years of biodiversity loss to 2050?
The NPV of the cumulative losses (the "total bill" for the losses) are:

d.r. 4%	Partial estimate	4.1 trillion EUR
	Fuller estimate	33.3 trillion EUR
d.r. 1%	Partial estimate	11.8 trillion EUR
	Fuller estimate	95.1 trillion EUR

These are several messages from this. First whichever way the cost of not halting biodiversity loss is presented, the numbers are compelling and underline the need for urgent action. Secondly, the choice of discount rate plays an important role in the perception of value in the present. Even a relatively "low" (in conventional terms) rate seriously discounts the perception of future value. This raises ethical questions regarding what is an appropriate choice of discount rate for societal evaluations. The COPI study has sought to use the loss in a 2050 to communicate the level and importance of the loss and avoid the discount trap.

6.3.4 Losses and gains per ecosystem service type

Table 6.14 below shows the relative importance of losses (and gains) in ecosystem services and their contribution to the total. Climate regulation, soil quality maintenance and air quality maintenance are the main items, with climate regulation being sensitive to the carbon price assumptions. Food, fiber and fuel are generally positive, with losses stemming from natural areas and extensive agriculture as these are (generally) converted to intensive agriculture. Other ecosystem services are not presented in the table here, either as not significant in the final numbers (eg bio-prospecting), which often reflects the limits of data availability. As noted earlier, these numbers should be seen as working numbers to illustrate the importance of the issue and help clarify where additional research is needed to advance the understanding of the risk of loss of ecosystem services.

Table 6.14 Total Annual loss of value of Service in 2050 (relative to 2000) for different services

2050 relative to 2000: Fuller Estimation	Total	Food, fiber, fuel	Air quality main-tenance	Soil quality main-tenance	Climate regulation (i.e. carbon storage)	Water regulation, & water purification and waste manage-ment	Cultural diversity, identity, heritage & Recreation & ecotourism
World Total (Land-based ecosystems*)	-13938	192	-2019	-1856	-9093	-782	-303
Natural areas	-15568	-383	-2025	-1778	-10274	-748	-291
Bare natural	-10	0	-1	-1	-6	0	-2
Forest managed	1852	184	208	166	1188	70	31
Extensive Agriculture	-1109	-256	-56	-50	-712	-23	-8
Intensive Agriculture	1303	746	38	41	448	21	6
Woody biofuels	381	29	33	30	270	15	2
Cultivated grazing	-786	-128	-217	-264	-6	-116	-41
Artificial surfaces	0	0	0	0	0	0	0

* (Exl Ice / Hot Desert)

6.3.5 The importance of change in quality of the ecosystems and ecosystem services

It is also useful to look at the relative contribution of land-use area change and ecological quality changes to the total monetary losses. *Table 6.15* presents one of the results from the analysis – the high estimation scenario for the 2050 situation vis-à-vis 2000. The economic losses from loss of ecosystem services associated with loss of natural areas are broadly similar for land-use changes and quality changes. However quality losses are generally negative across land-uses[48]. A major difference is that there are positive gains to some land-uses in the land-use change set of numbers.

[48] There is one small exception - of a slight quality rise in intensive agricultural land. This is most probably due to the influence of higher quality (MSA rating) of extensive land that is converted to intensive land and hence entering at a higher average MSA, compensating for other quality losses to the intensive areas.

This is due to the fact that all land-uses, including newly converted from natural land cover, have ecosystem services and it would not be appropriate to completely exclude them. Gains are mainly due to increases in provisioning services (timber and food and (bio)fuels).

Table 6.15 Loss of Ecosystem services – due to land use and quality changes in Billion EUR per year in 2050 relative to 2000

	Land use change	Quality change	Overall
Natural areas	-6734	-8834	-15568
Bare natural	-6	-4	-10
Forest managed	3688	-1836	1852
Extensive agriculture	-996	-113	-1109
Intensive agriculture	1203	100	1303
Woody biofuels	380	0	381
Cultivated grazing	-56	-730	-786
Artificial surfaces	0	0	0
World Total	-2521	-11417	-13938

At a *net level*, the loss for land-use change is smaller than that due to the quality change, given the increases in provision from the forest managed, intensive agriculture, and woody biofuels. Some would argue that the increased benefits from post converted land uses should be ignored in a strict COPI, but we concluded that it is better to present the details to facilitate a more transparent reading of the results. Having the results actually underlines an important point – that of how to treat ecosystem services from post converted land, which in turn relates to an equally important question, that of how to distinguish between the component contributed by biodiversity/ecosystems and which component contributed by man-made inputs (fertiliser, capital goods, labour input). From a conceptual perspective only the biodiversity/ecosystem service component should be attributed and hence where values for provisioning services (e.g. timber, food) exist they should be net of man-made inputs, and also relate to sustainable use (or take a time period sufficiently long such that nutrient mining and other impacts are reflected in the benefits flow changes). In practice, finding material that allows for a clear distinction is difficult (e.g. see Balmford et al, 2002), and it will be the case that certain market value based estimates of the provisioning ecosystem services will need to be interpreted with care.

6.3.6 Key observations as to data inputs, methods, assumptions and interpretation

It is important to underline that the estimates of the COPI for biodiversity loss presented in Section 6.3.1 are "rough" estimates. The results are presented here as the final answer, but rather as intermediate answers to the questions posed, resulting from an approach and set of methods, clarifying areas that are considered important to focus on, and creating a solid basis for future research.

- There is a wide range of gaps in available data. There are more data available for certain regions, biomes and ecosystem services than for others. This therefore creates a cautionary note in too detailed an interpretation of the results – the limitations need to be borne in mind. As regards data availability:
    - For biomes: more data was available for forestry biomes than for others, then scrubland, grassland and steppe. Least good was savannah, Mediterranean scrubland and tundra. This was partly addressed in the "fuller estimation" scenario by benefit transfer from one biome to another for ecosystem services where a relation could be established – though not for tundra as these were left an unfilled gap as difficult to argue for a particular transfer approach.
    - For ecosystem services more data was available on provisioning services of food, fibre and fuel, climate regulation (carbon storage), water purification and regulation. Data for some biomes were available for air pollution regulation and water provision, but less systematically available. Cultural services and tourism was more difficult to get values in per hectare values (reflecting an intrinsic challenge), Several services has little information available – ornamental services, regulation of human diseases, temperature regulation, living comfort and technological development
    - For value types (relating to the total economic value (TEV) classification. More information was available on "direct use value", a bit less for "indirect use value" and less for non-use values (option, existence, bequest).
    - For type of units for values (eg per hectare values or others): a large share of the literature presents values in other units – eg for tourism and recreation and existence values they are often in £, $ or EUR per person. Some are convertible, with care, to values per hectare, others less amenable. While certain values make sense on a per hectare level (eg provisioning of food, fibre, fuel, water provision and purification), values per unit area are less directly representative for tourism.
    - The gaps help clarify an agenda for action for a phase 2 of a wider evaluation of economics of ecosystems and biodiversity.
- Different mechanisms are possible to fill the gaps – each have the strengths and weaknesses. There is a trade-off between local explicit theoretical correctness (which would argue for not filling the gaps as no method to do so is arguably good enough) and the pragmatic need to come to an overall understanding and grasp of the size of the losses in economic terms, and the fact that gaps lead to the final picture being skewed due to what is there and what is not. To address this tension, two scenarios were used. More work is needed in the future on gap filling, benefit transfer and aggregation/scaling up.
- The choice of mechanism to fill the gaps is critical, as inevitably there will be more gaps than literature based data points. For example, the multipliers from 2000 to 2050 are critical, as are multipliers based on expectations of ecosystems services for different land-uses. This area could be improved in the future by an analysis as to what drives the value over time (eg production of the service itself, to use (eg population), to "appreciation" of the use (eg rising by income, affected by scarcity etc).
- Also of great interest is the relationship between ecosystem quality (as measured by the mean species indicator, MSA) within land use types and the levels of

services provided. The analysis above assumes that the two vary proportionately or with a maximum function (see Chapter 5), and this helps to explain a large proportion of the overall COPI estimates. Empirical evidence of the relationships is plentiful, but quantitative causal substantiation is scarce yet.

- Similarly it will be important to do a careful analysis of where relationships between the loss of habitat/landuse area and ecosystem service provision are linear (eg provision of wood) – the core operational assumption within the COPI study - and where they are less sensitive to loss (eg in initial phases of forest loss of a large forest for tourism), where they are very sensitive (eg ecologically poor or fragile areas) and where there are non linearities or critical thresholds (eg level at which species populations cannot be maintained) is important (see Figure 6.7 for simplified schematic). The possibility and limitations of substitution and how this should be integrated into analysis are also important issues to explore further.

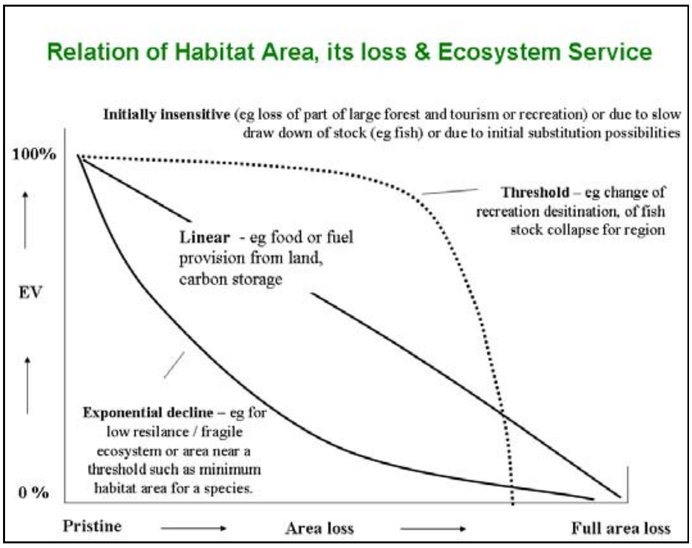


Figure 6.7 Relationship between changes in habitat area and change in ecosystem services

- There is also a range of different ways of arriving at the cost estimate, which can also influence the result. For example in some cases non-market estimates are very low (e.g. for recreation) compared to understanding of the scale of the market. A theoretically correct way may not lead to good answers in all cases unfortunately. It is important to remember that all numbers have their strengths and weaknesses, and it is the overall understanding of the magnitude of the processes that is of particular importance rather than a specific number from a particular case study. Note that part of the complication on the recreation, tourism and indeed other values based on willingness to pay (WTP) approaches (eg existence and bequest values) , is that they are less naturally amenable to translation into "per hectare" values. For a phase 2, it will be useful to clarify which values are most amenable to per hectare treatment, and which less, and how to address the latter issues.
- Some numbers can dominate the results – market values for provisioning services and carbon prices are more readily available than for non market prices. It is important to draw conclusions in light of this.

- Other numbers could potentially dominate the result, but careful treatment can avoid any undue influence – in the case of coral reefs it is clear that there are extremely high per hectare values for one area (where there is not just a quality diving area, but where there is infrastructure and also brand value), but this can hardly be applied to all areas. It is therefore vital to chose the right selection of case values upon which to base the analysis, identifying and stripping out "outliers" (though these are valuable kept for use as case studies) and developing a suitable representative "average" (see Annex 1). The aim has to be to have a representative average that could usefully err (marginally) on the conservative to avoid potential criticism.
- Spatial considerations are important to interpret the results. For example, when looking at losses to a region in billion EUR or in % GDP impacts, it is useful to remember that some of the losses are due to lost carbon storage, and hence a global loss (given climate impact) rather than a local loss, felt locally (e.g. loss of non market forest goods, or water provision or purification).
- The analysis compares the future state with that of a reference point. This is a useful mechanism to arrive at an order of magnitude test-estimate and develop insights on where losses occur and on mechanisms for estimation. A wider scenario based approach could complement the current approach.
- The analysis has been a marginal analysis, and even over the period to 2050, the losses are relatively small in terms of land use changes. Part of this is due to the model used. What is missed by this approach is therefore the potential losses that become more exponential, when critical thresholds are passed. The COPI study has not looked at critical thresholds in the monetary evaluation (some insights presented in the physical impacts chapter 5). It will be valuable to look more at this in the future, and arguably combining with risks assessment could prove one useful way forward.
- Furthermore, the stepwise analysis (scenario drivers-> pressures-changes) does not allow a feedback of the economic impact results back into the OECD economic model, and hence losses to the economy related to ecosystem service losses from biodiversity losses do not link back to the OECD economic projections. Ultimately a feedback mechanism would be required (see figure 6.8). Figure 6.5 shows the different paths of (a) GDP growth and (b) population growth and (c) ecosystems and biodiversity losses (with associated ecosystem service losses) . Clearly as the natural capital is drawn down, and the level of services falls, society and the economy also benefit less. Under current GDP statistics some of the losses will be translated into GDP values directly (eg loss of output of fisheries will be seen, when substitution possibilities run out), other will impacts indirectly (as more expenditure on water purification is needed to compensate for loss of natural purification, taking money away from other foci) and a range will have no GDP impact (eg loss of cultural values, option values, existence or bequest values). A fuller analysis would allow a feedback to take into account changes in inputs to the economy from loss of ecosystem service outputs, and change on manmade inputs to compensate for the loss (Eg growth in water

purification, desalination). This will change the overall numbers, but probably not the high level messages[49].

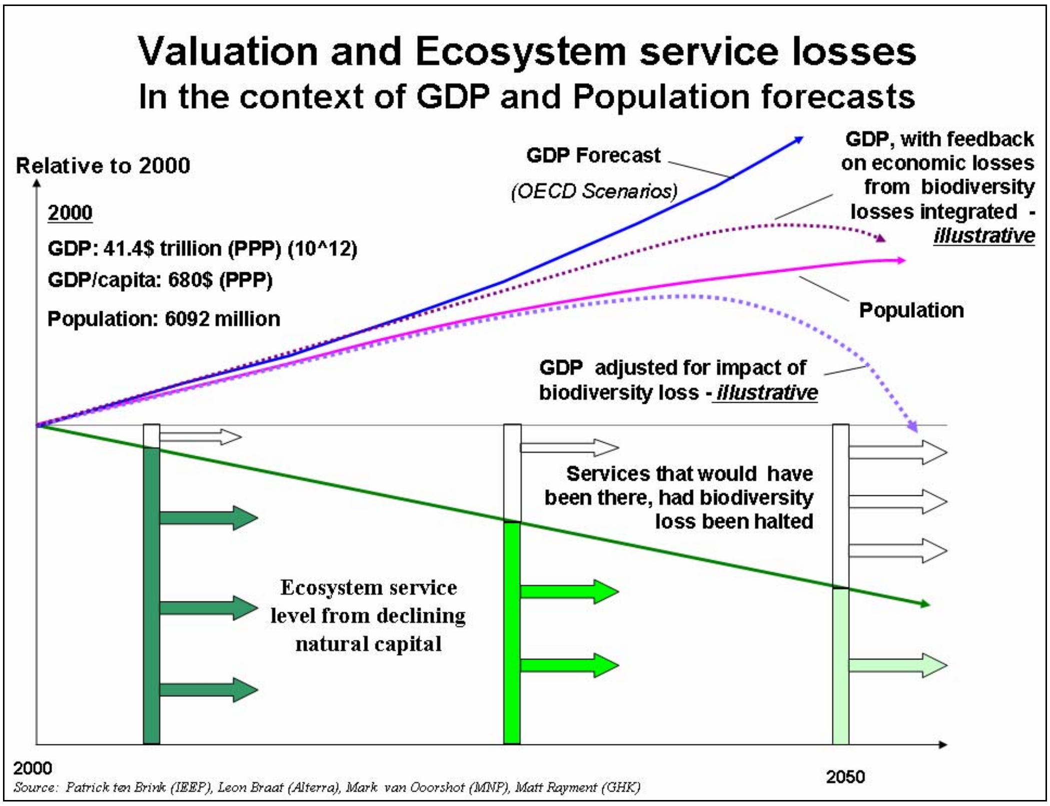


Figure 6.8 Economic projections, ecosystem service losses and economic consequences.

In addition were the carbon prices to be added, then the value of maintaining forests to preserve the carbon store service would likely lead to a different future land use scenario. Hence, if policy makers launch and enforce measures (eg REDDs) then there is potential for a different future.

6.3.7 Insights on potential for the future

- To respond to the fact that the choice of mechanisms to fill the gaps is critical and the fact that gaps will inevitably remain, an important way to build on the current work and strengthen the future developments in this area is to test and calibrate the assumptions. This can be done both using values and projections referenced in the literature, and by using expert panels – eg through a workshop of experts.
- Additional work is need to improve approaches to gap-filling where possible. These are critical links in the work, and a systematic approach at reducing the uncertainties by strengthening data and strengthening gap filling would be valuable.

[49] The loss of services that do not feed into GDP will of course also be important, and can only be picked up with GDP itself were changed or through indicators or accounting systems suitably developed to go beyond GDP.

- Furthermore, further thought on how best to carry out benefit transfer for the different services would be valuable, both geographically and for projecting into the future.
- There are a number of gaps that probably would be able to be filled by circulating the database and associated ecosystem service- biome value matrix. If this could become an open source type collective response, then there is potential for significant improvement. This is a lot of “grey literature” that could be tapped relative quickly with due involvement of the valuation community.
- Future analysis could usefully look at a range of scenarios to compare, under different policy assumptions to help clarify losses, what affects losses and costs. That said, there is still scope for a more detailed COPI analysis as it has the benefit of not being tied to certain policy instruments and hence develop a simple but clear statement of the scale of the problem.
- For a wider assessment it will also be useful to look also at the costs of action. This report highlights the great complexities involved in a COPI assessment. However, the costs of action may be easier to assess, and, if found to be small and manageable, this may reduce the need for a highly detailed COPI assessment.

6.4 The valuation of forest ecosystem services

Within the above COPI evaluation, an important basis were the range of unit values for forestry. Within the COPI study particular effort was focused on deriving new values of ecosystem services on a per hectare basis for the forestry biomes. This adopted a more sophisticated approach than the literature survey and benefit transfer approach used to obtain the unit input numbers for the other areas, and hence noted here to help with transparency and understanding. Key elements are presented below, and a full detailed description is presented in Annex II.

6.4.1 Introduction

This section presents the results of an analysis of a restricted set of forest services identified following the Millennium Ecosystem Assessment (2005) taxonomy: provisioning (wood and non-wood products), regulating (carbon sequestration) and cultural (recreation, passive use or conservation area designation). The first two are summarized here given their particular importance in the COPI evaluation. Annex 3 provides a full report giving methodological insights as well as insights on the cultural ESS too.

Several valuation methods can be applied to estimate the monetary value attached to ecosystem services provided by forest biomes. By using the well-known notion of Total Economic Value (TEV), and depending on the nature of the good being valued, we can identify the best available valuation methodology to be employed for the monetary estimation of each service of concern (see CBD, 2001). A full description and details of the method are presented in Annex II. The Annex also includes all references.

Broadly speaking, both market and non-market valuation techniques have been applied in the literature on which the COPI project relies to draw suitable marginal values for forest services, to be scaled up at the global (OECD regions) level using proper transfer protocols. Given the COPI's global perspective, it is essential to rely on the full body of knowledge already available in the environmental economic literature in order to gather estimates that cover, for each service to be valued, the highest variability in terms of countries (OECD regions) and forest types (COPI biomes).

6.4.2 Provisioning services

Table 6.17 reports the marginal values of provisioning services, estimated by world region and forest biome, adjusted for profits, and converted in €2007. These values can thus be applied to derive total values attributable to forest areas actually designated to production. Differences in marginal values across COPI regions and forest biomes can be interpreted as the result of the effect of the following factors:

- distribution of forest area across COPI regions;
- incidence of forest area designated to production in each COPI regions,
- distribution of forest production sectors across forest biomes and COPI regions.

Table 6.17 Marginal value of provisioning services by COPI region and forest biome, adjusted for profits (2007€/ha/year).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	740	246	770	1,765	-	96	874	1,134	-	1,375	147	619	-	-
Tropical	10	-	2.4	126	368	-	59	17	-	916	-	300	1,886	-
Warm mixed	177	14	51	827	98	0.1	550	469	-	72	-	138	402	-
Temperate mixed	304	99	943	67	-	73	56	55	-	-	159	6	-	-
Cool coniferous	158	107	1,490	-	-	13	372	217	-	-	91	-	-	-
Temperate deciduous	155	142	631	252	-	4.9	231	431	-	1.9	12	1.8	15	-

For projections in 2050, values have been adjusted taking into consideration only purchasing price parity (PPP) adjusted GDP projections in the future (from COPI), and assuming no real prices increase for wood forest products, predicted by some commentators in this literature (e.g. Clark, 2001).

6.4.3 Regulating services: carbon sequestration

Table 6.18 shows the capacity of carbon sequestration by forest biome and COPI world regions. Some of the estimates displayed are taken from original studies which provide carbon capacity by forest type and geographical region (*), while others (**) have been estimated by transferring results from the original studies to similar COPI regions As expected, tropical forest and warm mixed forest are characterized by a higher carbon sequestration capacity .

Table 6.19 and 6.20 show the calculated annual marginal values per hectare by COPI region and forest biome, for 2050, using lower and upper bound scenarios (see Annex II). These estimated marginal values can thus be applied to derive total values attributable to natural and managed forest areas contributing to carbon sequestration.

The lower bound estimates were integrated into the "partial estimation" scenario, and the upper bound values for carbon sequestration were integrated into the "fuller estimation" scenario. The alternative would have been to have had 4 numbers – partial low, partial high, fuller low, fuller high – but it was felt that for this first exercise in phase 1 of the Economics of Ecosystems and Biodiversity that two values are sufficient to get across the key messages and test the approach.

6.5 Other values of ecosystem and biodiversity loss to complement the COPI land based analysis

6.5.1 Invasive alien species[50]

What is known about the economic impacts of IAS – an overview

Alien species can offer increased economic returns (e.g. plantations of fast-growing non-native conifers), satisfy demand for exotic products (e.g. fur trade), feed on and suppress other species (e.g. biological control agents) or simply fulfil a domestic need (e.g. pets and many garden plants) (Hulme, 2007). However, some invasive alien species cause major environmental and economic damage. There is growing evidence of the economic impacts.

Over 120,000 species of plants, animals and microbes have invaded the United States, United Kingdom, Australia, South Africa, India, and Brazil, and many have caused major economic losses in agriculture (Pimentel, *et. al.*, 2001) – see further below for values. Furthermore, a recent European commission supported study shows that 1,347 alien species invading Europe are known to have an economic impact (DAISIE, 2008), and offer valuable cost impact data. A number of studies provide a good overview of the IAS economic costs by classifying the impacts of invasive species into five types. These types related to production, price and market effects, trade, food security and nutrition, and financial costs (e.g. Evans, 2003; Pimentel et. al., 2001; DAISIE, 2008).

[50] This section provides a synthesis of cost issues for IAS, see Annex III for details.

Table 6.18 Capacity of carbon sequestration in the world forests (tC/ha).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	37.37*	37.37*	37.37**	37.37**	-	37.37*	59.4**	25.77*	-	59.4**	37.98*	34**	-	-
Tropical	92**	-	149**	149**	186*	-	225*	96**	-	92*	-	149*	200*	-
Warm mixed	92**	92**	100**	134**	168*	92**	180*	78**	-	78**	-	134*	168**	-
Temperate mixed	51*	59.4*	47.35*	51**	-	37.98*	168**	25.77*	-	0	59.4*	59.4**	-	-
Cool coniferous	37.37**	37.37**	37.37**	-	-	37.37**	59.4**	25.77**	-	0	37.98**	-	-	-
Temperate deciduous	51*	59.4*	47.35*	51**	-	37.98*	168**	25.77*	-	59.4*	59.4*	34.88*	59.4**	-

Note: (*) Directly reported from the original studies by forest type and geographical region. (**) Transferred from the original studies to similar COPI regions.
Source: R.B. Myneni et al. (2001); H.K. Gibbs (2007)

Table 6.19 Marginal value of carbon sequestration by COPI region and forest Biome, projections in 2050 (2050€/ha/year) - Lower bound estimates.

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	864	864	864	864	-	864	1,373	596	-	1,373	878	786	-	-
Tropical	2,126	-	3,443	3,443	4,298	0	5,200	2,219	-	2,126	-	3,443	4,622	-
Warm mixed	2,126	2,126	2,311	3,097	3,882	2,126	4,160	1,803	-	1,803	-	3,097	3,882	-
Temperate mixed	1,179	1,373	1,094	1,179	-	878	3,882	596	-	-	1,373	1,373	-	-
Cool coniferous	864	864	864	-	-	864	1,373	596	-	-	878	-	-	-
Temperate deciduous	1,179	1,373	1,094	1,179	-	878	3,882	596	-	1,373	1,373	806	1,373	-

Table 6.20 Marginal value of carbon sequestration by COPI region and forest Biome, projections in 2050 (2050€/ha/year) - Upper bound estimates.

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	6,712	6,712	6,712	6,712	-	6,712	10,668	4,628	-	10,668	6,821	6,106	-	-
Tropical	16,523	-	26,760	26,760	33,406	0	40,410	17,242	-	16,523	-	26,760	35,920	-
Warm mixed	16,523	16,523	17,960	24,066	30,173	16,523	32,328	14,009	-	14,009	-	24,066	30,173	-
Temperate mixed	9,160	10,668	8,504	9,160	-	6,821	30,173	4,628	-	-	10,668	10,668	-	-
Cool coniferous	6,712	6,712	6,712	-	-	6,712	10,668	4,628	-	-	6,821	-	-	-
Temperate deciduous	9,160	10,668	8,504	9,160	-	6,821	30,173	4,628	-	10,668	10,668	6,264	10,668	-

This evidence is, however, still incomplete. For example, of the estimated 10 million species on earth, only 1.5 million species have been identified and described (Pimentel, *et. al.*, 2001) and far fewer have been the focus of evaluation studies. Furthermore, studies of impacts of IAS have to date, focused more on some countries than others. Most studies appear to focus on America. The review of invasive species impact by Levine *et. al.* (2003) shows that nearly 60% of studies come from America, more than 20% from Oceania and less than 10% studies have been carried out in Europe. Similarly, in a recent review of the impact of invasive alien insects worldwide, only 3 out of the 50 species studied have been considered for Europe (DAISIE, 2008). See Annex III for a box noting the key studies on IAS.

Known examples on the IAS monetary impacts
A wide number of examples of monetary impact across the world exist in the literature, and a summary is presented in Annex III. Some of the cost examples focus on the costs of the impacts – e.g. the damage caused. Others focus on the cost of eradication. A number of others focus on control cost and one costs of prevention. The former two are physical impacts or processes, and the latter two more costs of administrative/control measures. Examples of monetary impacts are presented below.

A key study on the costs of IAS (Pimentel, *et. al.*, 2001), showed that the IAS can lead to very significant impacts on the economy. It has been estimated that invasive species in six nations (USA, UK, Australia, South Africa, India and Brazil) are causing more than US$ 314 billion per year in damages. Most of these monetary costs and estimations refer to management costs, such as eradication, control and monitoring (DAISIE, 2008). Details include:

- For example, in the **United States**, invasive species cause environmental damages and losses adding up to almost $120 billion per year (*ibid.*:16.). Pimentel *et. al.* (2001) report that 88 species of molluscs have been introduced and become established in US aquatic ecosystems. Two of the most serious pests are the zebra mussel (*Dreissena polymorpha*) and the Asian clam (*Corbicula fluminea*). Zebra mussels, for example, colonize docks, locks, ship hulls, water intake pipes, and other mollusks, and cause great damage to power plants and water treatment facilities (e.g. causing US$ 5 billion per year in damages and associated control costs in USA).
- In **the UK** about US$ 3.2 billion in total potential crop production is lost annually because of IA weed infestations (Pimentel, *et. al.*, 2001). Similarly, the crop losses in the UK due to alien arthropods has been estimated to be 2800 million € per year which together with the impact inflicted by pathogens and vertebrates reach a total cost on crops reaching 3800 million € per year (Pimentel *et. al.*, 2001).
- In **New Zealand**, the varroa mite is a series pest in honeybee hives and is expected to have an economic cost of US$267-602 million, and force beekeepers to alter the way that manage their hives. Beekeepers argue that had border rules been followed or had surveillance detected the mite earlier, the problem could have been avoided entirely. It appears too late to eradicate the mite. (Wittenberg et al, 2001, cited in McNeely et al (2001)

Other examples of costs include (see also Annex III):

- The zebra mussel has led to damage to US and European industrial plant. Cumulative costs for the period 1988-2000 have been estimated at between $750 million to $1 billion (National Aquatic Nuisances Species Clearinghouse, 2000 in McNeely et al (2001).
- Rabbits in Australia, have led significant agricultural losses in Australia. An early estimate put this at $373 million/year. Wilson, 1995, cited in White and Newton-Cross, 2000, cited in McNeely et al (2001)
- The introduced comb-jellyfish caused losses to the anchovy fisheries in the Black Sea estimated at $17 million annually (Knowler and Barbier, 2000).
- The introduction of the salmon parasite *Gyrodactylus salaries* to more than 46 rivers and 37 aquaculture facilities in Norway has decreased the density of salmon by 86% in infected rivers. Losses of income and opportunities for recreational fishing due to *Gyrodactylus salaries* have been calculated to about 20 million € (Johnsen, 2006).
- In Germany's inland water systems from erosion of river banks and embankments is estimated at 32 million € per year for *Fallopia japonica* (causes blockages to rivers in autumn when dry stems are carried by the current) species and 12 million € per year for *Heracleum mantegazzianum* (Hogweed related illnesses cost in terms of medical treatment) (SBSTTA 2005). Similarly, the mammal *Ondatra zibethicus* is causing potential impact on aquaculture industry estimated at € 12,4 million/year (€ 4.6 mln/yr for sanitary aspects, € 2.3 million/year for maintenance of waterways, € 1.9 million/year for impacts to hatcheries and fish breeders by damaging ponds and dams). (DAISIE, 2008).

Some numbers are very large and significant at national levels, others are important at local levels, whether for those directly affected by the loss, or those responsible for responding to the loss.

Interpreting and building on the existing information on IAS monetary impacts

As for the more detailed monetary impacts of IAS invasions, the costs of IAS in different studies are often of different nature. Some studies report costs of damages, including costs arising from the preparation of damages, (e.g. insurance losses, restoration or clean-up costs) whereas others document the loss of economic output due to IAS invasion (e.g. lost agricultural and fisheries output, loss of tourism).On the other hand, a number of studies also provide information on the costs of eradication and control, hence can be classified as "costs of action" (See Annex III for details).

Given the partial picture of the overall IAS impacts and the differences in existing cost information it is naturally perilous to try to derive any global estimates for the scale of the IAS impacts. However, it is valuable to try as it can help highlight the importance of the impact in a language that will reach a wider audience. Pimental et al carried out such a calculation (Pimentel, *et. al.*, 2001). He calculated the per capita costs for the losses incurred due to biological invaders in the six nations investigated as being approximately $240 per year. Assuming similar costs worldwide, damage from invasive species would be more than $1.4 trillion per year, representing nearly 5% of the world economy (*op. cit.*). Using the Pimentel et al. information for a basis of a generic transfer of insights from one set of countries to another (e.g. to the developing world) could be broadly considered justified. This has been supported, for example, by McNeely et al (2001) stating that "*There are strong indications that the developing world is experience similar if not proportionally greater, losses"*. McNeely's statement basis itself, for example, on the knowledge that IAS pose a threat to the success of 13 billion dollars investment dedicated to current or planned World Bank funded projects in the developing countries (e.g. due to risks to irrigation, water supply, sanitation and power sectors) and the threat that the white cassava mealy bug and larger grain bored are posing to food security in Africa (Joffe and Cooke, 1998 cited in McNeely et al (2001).

Nevertheless, the existing information provides clear evidence that IAS are an issue across the world and are leading to real costs to national economies. The benefits of addressing the problem are very significant and the next section looks at the costs of action, and how the costs of action relate to the benefits.

Costs of action to prevent, eradicate and control IAS

Different actions have been developed and used world wide against invasive alien species. Local, national and regions suggest that there are different best solutions for different localities and different problems. However, it is generally acknowledged that the costs of later eradication or control (as in some cases only control is possible beyond a certain state of invasion) are much higher than the costs of early eradication (see Annex). It is also the case that often the costs of prevention (action) can be lower than the cost of responding to the problem. These issues are discussed further in the next section on the costs of action.

As noted above, in the UK, crop losses due to alien arthropods has been estimated to be 2800 million € per year which together with the impact inflicted by pathogens and vertebrates reach a total cost on crops reaching 3800 million € per year (Pimentel *et. al.*, 2001). To contrast this - the cost of control most invasive alien plants (e.g. using herbicide) in UK (1983-92) was 344 million/year for 12 species (Williamson, 1998). In the above New Zealand bee example, the costs of a mitigation plan is expected t be $US1.3million in the first phase, compared to expected losses if no action of between US$267-602 million.

In the South African Cape Floral Kingdom, the establishment of invasive tree species has decreased water supplies for nearby communities, increased fire hazards, and threatens native biodiversity justifying government expenditures of US$40 million per year for manual and chemical control (GSC, 2001). These costs of action due to invasive species have become important concerns of many governments future.

The type of the action differs depending upon species and requires different management such as integrated control methods which involve combinations of actions (GISP, 2001). For example, in Germany it has been estimated that the minimum costs to losses in stored grain added to managing three of the most damaging arthropods might be €12 million per year (Reinhardt *et. al.*, 2003). Thus, depending on the invasive alien species, any preventative measures, eradication or management actions should be straightforward to monitor and regulate but, in practice, developing legislation has proved difficult. New invasive alien species continue to occur through contaminant, stowaway, corridor and unaided pathways. Furthermore, the benefits of addressing the IAS can lead to very significant benefit/cost ratios – as the cost of action can be significantly less that the cost of inaction (IAS impacts). Benefit cost rations vary considerably depending on the time of action, the IAS in question, and the nature and locality of the impacts. The Global Strategy Catalogue gives a range of benefit costs of between around 10 to 1 (case of the tree *Melaleuca quinquenervia*), to 20 to 1 (the insect *Ceratitis capitata*, Mediterranean fruit fly), to 30 to 1 (fish sea lamprey, *Petromyzon marinus*), and up to 1659 to 1 for Siberian log impacts (tree, *Larix spp*).

Future trends and development needs

For the future, there are currently no scenarios or models of future likely risks or expected impacts from IAS. It is therefore hazardous to estimate the level of future risks of possible impacts. Nevertheless it is useful to do a very simple back-of-the-envelope calculation to help explore the issue and highlight a potential order of magnitude of the monetary importance of the issue. This is given the box below.

Box 6.3: "Back-of-the-envelope" calculation for future IAS impacts

While there is no certainly as regards likely future IAS, We can, however, expect that the risk of IAS occurrence and IAS impact to depend on the probability of IAS arrival, likelihood of successful invasion, likelihood of impact, and expectations of policy response. From the knowledge of the past (IAS pathways, affected areas and impacts), we know that IAS risk relate grows with increasing volume of trade (and hence shipping, road and aviation transport), the increased movement of people (where for trade, migration or tourism). We can also expect IAS to increase with climate change.

While one could, in principle, look at future scenarios for trade volumes, tourism levels, migration and climate change, and clarify links to IAS risks so as to get a basis for an estimate of future IAS and impacts, this is too difficult to do at present. It would likely require significant new primary research.

At a very pragmatic, and probably very conservative level, one can assume that the risks will grow at least in line with GDP (as we can expect trade to at least grow as fast as GDP; trade has far outstripped GDP growth over the last 100 years) and in line with population (as we can broadly expect international mobility to grow, and also expect that the impacts will affect more people as the population rises). From the OECD/Globio work, we know that from 2000 to 2050, GDP grows from 41.4$trillion (in PPP) in 2000 to 195.5 $trillion (in PPP) in 2050 – a 4.7 fold increase. Furthermore, population is expected to grow from 6.1 billion in 2010 to 9.1 billion by 2050 – a 1.5 fold increase. Combined this represents a 7 fold increase.

While only an order of magnitude estimate, used to highlight the likely importance of action on IAS, if the $1.4 trillion per year current impact (as derived based on Pimentel et al. 2001 above) were to grow in line with GDP and population, it would rise to nearly $9trillion, and in percentage GDP from circa 5% of GDP to circa 7.5% of GDP in 2050.

These numbers are useful as broad illustrations of the potential risk of costs of IAS. In reality, the increased trade, travel and climate change can be expected to lead to a higher risk of impact – in the context of no additional policy action. That said, while this risk and scale of impacts is expecting to increase, so is the realisation of the need for effective policy response. The final impact can be expected to be less as policy responses are implemented. Furthermore, some critics see the Pimental numbers as overstating the risk, and the above 7.5% 2050 GDP figure should be seen with caution.

To conclude, it is critical that information on IAS negative impacts and the benefits of prevention and early action[51] can be expanded. Additionally, methodological tools should be disseminated to provide the basic data and information necessary for informed decision-making on the prevention, eradication and control of invasive species. Furthermore, given the potential scale of the impacts, it would be useful to estimate more closely the risks, costs and benefits of IAS and action to address IAS. The valuation of potential COPI could help inform policy makers and encourage the adoption of suitable prevention, control (eg port authorities, inspectorates) and response/eradication programmes as well as coordination activities across countries.

Based on the analysis of the existing information on IAS monetary costs and with a view to develop more complete regional and global estimates of IAS costs, the following suggestions for analysis for the phase two of The Economics of Ecosystems and Biodiversity have been identified:

- IAS is a global problem, so involving more nations is urgent (e.g. more information in other countries apart from USA, New Zealand, etc.) A good operational data between countries. National, trans-border, regional and international level are required, based on a proactive rather than reactive approach
- Carry out more monetary studies and studies on the relation of economic impacts with environment impacts (normally production impacts/services)
- It will be valuable to find more monetary impact studies for different IASs and different geographic areas affecting different stakeholder groups to underline that the issue affects all.
- Use of tools (eg use of risk assessment) and polices that could help address the problem.

6.5.2 Coral Reefs

Coral Reef Services

Coral reefs provide a variety of valuable ecosystem services. These are summarised by UNEP (2006) and include:

Regulating Services

Protection of beaches and coastlines from storm surges and waves
Reduction of beach erosion
Formation of beaches and islands

Provisioning Services

Subsistence and commercial fisheries
Fish and invertebrates for the ornamental aquarium trade

[51] See annex for more examples across the world

Pharmaceutical products
Building materials
Jewellery and other decoration

Cultural Services
Tourism and recreation
Spiritual and aesthetic appreciation

Supporting Services
Cycling of nutrients
Nursery habitats

Monetary Values

Various attempts have been made to value these services in different parts of the world. Estimated values vary according to the method used and the location, and tend to be highest in areas most important for tourism and recreation and where reefs are appreciated by people with a high willingness to pay for their protection. For example, a study by Cesar (1996) in Indonesia estimated values ranging from $829 per km for reefs in sparsely populated, mostly agricultural areas, to $50,000 per km in areas with high population density and $1million per km in areas important for tourism. Based on a review of available evidence, the UNEP report estimated the overall value of the ecosystem services provided by coral reefs at between US$100,000 and US$600,000 per km^2. The small total area of coral reefs belies their importance in terms of fisheries, other extractive uses, shoreline protection, tourism and recreation. They contribute significantly to national economies, particularly those of small island developing states (SIDS), 90 per cent of which have coral reefs. A recent review by the French Government[52] also found a wide range of values from different studies for different aspects of the economic value of coral reefs. For example, different studies have estimated the value of coastal protection at $55 to $260,000/ha/yr; biodiversity and existence values at $12 to $46,000/ha/yr; recreation and tourism at $45 to $10,320/ha/yr; fishing at $120 to $360/ha/yr; and total economic value at $1,000 to $893,000/ha/yr. The latter estimate relates to Montego Bay, Jamaica, where there are very high recreational and existence values. Overall, the figures suggest that the UNEP estimates are realistic and conservative.

Table 6.21 : Examples of Value of Ecosystem Services from Coral Reefs

Author	Service	$/ha/yr	Location
Costanza (1997)	coastal protection	2,750	World
Cesar (1996)	coastal protection	14,000 (9,000 - 260,000)	Indonesia
White (2000)	coastal protection	77 to 1540	Philippines
Burke (2002)	coastal protection	61	Indonesia
Burke (2002)	coastal protection	55	SE Asia
Burke (2002)	coastal protection	1,100	SE Asia
Cesar (2003)	coastal protection	2,460	Sri Lanka

52 Ministère de L'Ecologie, du Développement et de L'Aménagement Durables (2008) La préservation des écosystèmes coralliens: aspects scientifiques, institutionnels et socio-économiques version provisoire du 20 mars 2008

Author	Service	$/ha/yr	Location
Cesar (2003)	coastal protection	8,360	Sri Lanka
Charles (2005)	coastal protection	1,140	French Polynesia
Spash (1998)	existence value	46,000	Montego Bay, Jamaica
De Groot (2002)	existence value	120	Galapagos
Costanza (1997)	wastewater treatment	58	World
De Groot (2002)	wastewater treatment	58	Galapagos
Costanza (1997)	Biodiversity	12	World
Charles (2005)	Biodiversity	50	French Polynesia
Raboteur & Rhodes (2005)	Biodiversity	75	Guadeloupe
Costanza (1997)	recreation and tourism	3,008	Various
Posner (1981)	recreation and tourism	8,295	St Johns
De Groot (2002)	recreation and tourism	45	Galapagos
Burke (2002)	recreation and tourism	231 - 2,700	SE Asia
Seenprochawong (2003)	recreation and tourism	6,243	Thailand
Chong (2003)	recreation and tourism	1,654	Caribbean
Charles (2005)	recreation and tourism	10,320	French Polynesia
Brander (2006)	recreation and tourism	184	Various
Charles (2005)	research and education	117	French Polynesia
Costanza (1997)	fishing	220	Various
Costanza (1997)	construction materials	27	French Polynesia
De Groot (1992)	Ornaments	0	Galapagos
De Groot (1992)	Crustaceans	1	Galapagos
De Groot (1992)	construction materials	5	Galapagos
Cesar (1996)	fishing	272	Indonesia
Burke (2002)	fishing	239	Indonesia
Burke (2002)	fishing	238	Phillipines
Burke (2002)	fishing	120 to 360	SE Asia
Charles (2005)	Aquaculture	61	French Polynesia
Charles (2005)	fishing	84	French Polynesia
Charles (2005)	genetic resources	240	French Polynesia
Charles (2005)	cultural services	240	French Polynesia
Costanza (1997)	regulating services	2,750	various
Charles (2005)	carbon sequestration	90	French Polynesia
Costanza (1997)	TEV	6,075	various
WRI (1999)	TEV	893,000	Montego Bay, Jamaica
Charles (2005)	TEV	17,100	French Polynesia
Van Beukering (2006)	TEV	8,000	Saipan
UNEP (2006)	TEV	1,000 to 6,000	world

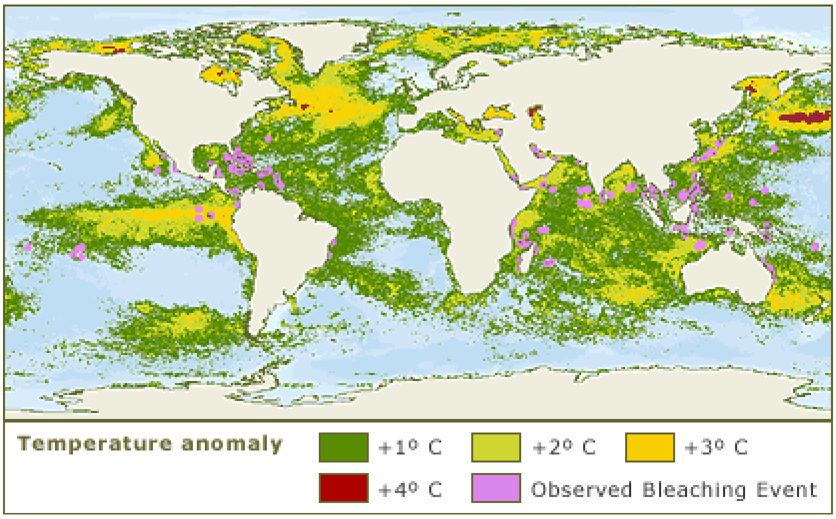
Source: Ministère de L'Ecologie, du Développement et de L'Aménagement Durables (2008) La préservation des écosystèmes coralliens: aspects scientifiques, institutionnels et socio-économiques version provisoire du 20 mars 2008

The figures indicate how difficult it is to generalise about the value of services provided by coral reefs. The value of these services varies widely by location with respect to human population and tourism infrastructure. An illustrative, "back-of-the-envelope calculation" is however presented below, to help highlight the importance of the issue, and the importance of having valuation results on the benefits, potential losses and risks available to help inform policy makers to allow more complete evidence based policy making.

Trends and Future Issues

Coral reefs are scarce globally and under serious threat. Some 30 per cent of reefs are already seriously damaged and 60 per cent could be lost by 2030, according to UNEP. Threats include overfishing, use of destructive fishing methods, coral mining, pollution, sedimentation, anchor damage and tourism, as well as coral bleaching, disease and tropical storms. This combination of impacts is causing a shift, on many reefs, from a coral-dominated ecosystem to one dominated by algae. An example of past bleaching locations is presented in the figure below.

Box 6.4: Coral Bleaching Events and Sea Surface Temperature Anomaly Hot Spots, 1997 – 1998



As noted by the WRI, "Although some records of local coral bleaching date back decades, reports of widespread bleaching have been increasing in recent years. The most recent event was not only widespread, but was also more severe in many areas than earlier events. Actual coral death reached 95 percent in some locations. In a few places massive, centuries-old corals have died; in some other places there has now been at least a partial recovery, with loss of only a few corals". Source: *World Resources Institute* - PAGE, 2000[53]

[53] NOAA-NESDIS (National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service) and UNEP-WCMC (United Nations Environment Program - World Conservation Monitoring Centre). 1999, *Observed Coral Bleaching Events: 1997-1998*. Hendee, J.. 1999, *Coral-list list server coral bleaching archives.*; McClannahan, T.. 0, *CORDIO data set for the Indian Ocean*. Wilkinson, C.. 1998. *Status of the Coral Reefs of the World.*

Box 6.5: Illustrative back-of-the-envelope calculation for the value of coral reefs.

As noted above UNEP (UNEP-WCMC, 2006) estimated the overall value of the ecosystem services provided by coral reefs at between US$100,000 and US$600,000 per km^2 – US$1000 to US$6000EUR/ha (the actual range across sites is naturally much wider).

The global estimate for coral reefs world-wide give the total area as 284 300 sq km, an area just half the size of France[54]. UNEP also notes that 60 per cent could be lost by 2030, which is equivalent to 170,580km^2. Combining this with the above range would give a range of the losses of between $17 billion and $102 billion per year of lost services. These values would of course be serious underestimates as the unit value could be expected to rise as the loss increases, and the unit value could also be expected to rise over the period to 2030 as incomes and populations grow. GDP is expected to double over the period 2010 to 2030, and if unit values rise at the same rate, the above losses would be $35 billion to $200 billion of lost services, and this still does not include any increase in the unit value due to scarcity. The figures should therefore be treated as simple back-of-the-envelope calculations for illustrative purposes, to help underline the importance of understanding the value of this part of the natural capital. It is important to complement these global numbers with a local/national perspective. Coral reefs, contribute significantly to national economies, particularly those of small island developing states (SIDS), 90 per cent of which have coral reefs. For many small island states, were the coral reefs to be lost, the major source or welfare and wellbeing could be lost. This is beyond numbers for the islands concerned.

As coral reefs become scarcer, their monetary value will increase as long as people are interested to visit and are be prepared to pay increasing sums to enjoy the services that they provide. As the quality of the reefs decreases, the numbers of people interested may decrease as well, with consequences in terms of economic revenues to be obtained from their presence.
Securing the services provided by coral reefs requires investment in their protection and management, but evidence suggests that management costs are a small fraction of the ecosystem services provided. Based on an estimated cost of US$775 per km^2 for maintaining marine protected areas, UNEP (2006) estimates that management costs could be as little as 0.2% of the value of the ecosystem protected.

6.5.3 Marine and coastal systems (based on MA, 2005b)

Provisioning services

Marine capture fisheries are an important source of economic benefits, with an estimated first-sale value of *US $ 84,900 million*, and important for income generation, with an estimated 38 million people employed directly by fishing, and many more in the processing stages. 90% of full-time fishers conduct low-intensive fishing (a few tons per fisher per year), often in species-rich tropical waters of developing countries. Their counterparts in industrial countries generally produce several times that quantity of fishing output annually, but they are much fewer, probably numbering about *1 million* in all, and their numbers are declining. In industrial countries, fishing is seen as a relatively dangerous and uncomfortable way to earn an income, so as a result fishers from economies in transition or from developing countries are replacing local fishers in these nations.

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54 Spalding MD, Ravilious C, Green EP (2001) *World Atlas of Coral Reefs*. University of California Press, Berkeley, USA. See http://coral.unep.ch/atlaspr.htm

Overfishing affects human well-being through declining food availability in the long term, since fewer fish are available for consumption and the price of fish increases. Due to declines in coastal habitats, fishers are forced to go further offshore and for longer periods of time, resulting in reduced food security. In Canada, the collapse of the cod fishery resulted in severe unemployment, compounded by restrictions on subsistence fishing. Fisheries and fish products provide direct employment to nearly *27 million people*. Globally, the bulk of people employed in fisheries are poor, and many are without alternative sources of work and sustenance. In addition, fish and fishing are enormously important to the cultural life of many coastal communities, and often define the "quality of life" of people with a cultural tradition of harvesting the sea.

Cultural services: recreation and tourism
Recreational fishing was considered relatively benign until recently, mainly because information about its impact has been limited. Early estimates of global recreational catches were put at only 0.5 million tons), but recent estimates of over 1 million tons are probably more accurate. For some inshore fisheries, the catch from the recreational sector can exceed the commercial sector. Recreational fishing is an important economic activity in some countries; in the United States it is worth approximately $21000 million a year; in Canada, $5200 million a year and in Australia, $1300 million a year.

Marine and coastal tourism is a growing industry, principally in the marine wildlife tours sector. Similarly, coral reef tourism has increased in visitation levels and value, with a current net present value estimated at $9000 million. The Great Barrier Reef attracts 1.6 million visitors each year and generates over $1000 million annually in direct revenue. Marine fisheries are increasingly valuable for recreation, particularly in developed countries. In the US alone, in 2006 nearly 13 million anglers made more than 89 million marine recreational fishing trips on the Atlantic, Gulf and Pacific coasts, capturing almost 476 million fish, of which 55% were released alive In the European Union (EU 15), an estimated 8 million recreational sea anglers spend an estimated €25000 million a year, compared to a €20000 million value for commercial landings in 1998. Coastal communities aggregate near the types of coastal systems that provide the most ecosystem services. Within the coastal population, 71% live within 50 kilometres of estuaries; in tropical regions, settlements are concentrated near mangroves and coral reefs. These habitats provide protein to a large proportion of the human coastal populations in some countries; coastal capture fisheries yields are estimated to be worth a minimum of $34000 million annually.

Trade and economic and social consequences
Nearly 40% of global fish production is traded internationally. Most of this trade flows from the developing world to industrial countries. Many developing countries are thus trading a valuable source of protein for an important source of income from foreign revenue, and fisheries exports are extremely valuable compared with other agricultural commodities. Fish products are heavily traded, and exports from developing countries and the Southern Hemisphere presently offset much of the demand shortfall in European, North American, and Northeast Asian markets.

Given the global extent of overfishing, however, it is likely that the global decline in marine fisheries landings, which already affects the poorer consumers in developing countries, will also catch up with consumers in industrial countries.

Box 6.6: Monetary values in marine and coastal systems

The estimates of monetary value of the various marine ecosystem services range from:

- Capture fisheries alone worth approximately $81000 million in 2000(FAO 2002);
- Aquaculture worth $57000 million in 2000 (FAO 2002);
- Marine tourism, much of it in the coast, $161000 million in 1995;
- Recreational fishing is an important economic activity in some countries; in the United States it is worth approximately $21000 million a year; in Canada, $5200 million a year and in Australia, $1300 million a year.
- Similarly, coral reef tourism has increased in visitation levels and value, with a current net present value estimated at $9000 million. The Great Barrier Reef attracts 1.6 million visitors each year and generates over $1000 million annually in direct revenue.

*To compare: o*ffshore gas and oil was worth, $132000 million in 1995; and trade and shipping,$155000 million in 1995 (McGinn 1999).

Many areas where overfishing is a concern are also low-income, food-deficit countries. For example, the exclusive economic zones of Mauritania, Senegal, Gambia, Guinea Bissau, and Sierra Leone in West Africa all accommodate large distant water fleets, which catch significant quantities of fish. Much of it is exported or shipped directly to Europe, while compensation for access is often low compared with the value of the product landed. These countries do not necessarily benefit through increased fish supplies or increased government revenue when foreign distant water fleets access their waters. In some countries, such as Cote d'Ivoire, the landings of distant water fleets can lower the price of fish, which affects local small-scale fishers. Although Ecuador, China, India, Indonesia, and the Philippines, for example, do not provide access to large distant water fleets, these low-income, food-deficit countries are major exporters of high-value fish products such as shrimp and demersal fish. As shown in the West African example, several countries in the region export high-value fish, which should provide a significant national economic gain so that cheaper forms of protein can be imported. In countries such as Ghana, however, the value of exports is often less than the value of imported fish, and the volume of imported fish does not meet the domestic demand for fish.

6.5.4 Freshwater habitats and wetlands

Wetlands (both sweet and salt water wetlands) and inland waters were not subject to specific focus in the analysis, however, it is useful to present some indicator figures to underline their importance. As noted in Chapter 5, freshwater ecosystems, including rivers, lakes, swamps and deltas provide numerous benefits to people beyond fresh water. Yet, freshwater systems are in decline, in part because they are perceived to be of little value compared with other uses of the land, and because the benefits they do provide are public goods, the use of which is unregulated. Since 1900 over half of wetlands worldwide have disappeared. When looking at the value per hectare of wetlands, a different picture as regards their value develops. *Table 6.22* below presents ranges of estimates for the value of wetlands in Europe.

Table. 6.22 Number of wetland sites, wetland area, mean value per hectare per year, and value per year by country (Europe)

Country	Number of wetlands	Wetland area (ha)	Mean value per ha per year(€)	Wetland value per year (€)
Austria	211	31,748	5,052	73,963,391
Belgium	92	10,480	9,627	60,732,148
Bulgaria	81	11,584	3,110	25,036,877
Croatia	140	18,761	4,628	47,475,181
Cyprus	3	1,956	4,724	7,595,396
Czech Rep	105	8,987	4,435	29,141,830
Denmark	729	164,961	3,896	263,838,528
Estonia	1,146	197,786	837	84,206,563
Finland	14,140	1,971,961	224	235,125,655
France	1,419	358,163	5,693	864,049,557
Germany	1,391	418,945	4,353	618,570,668
Greece	302	64,766	3,992	144,611,864
Hungary	1,090	96,500	3,309	212,146,699
Ireland	2,173	1,210,044	676	244,892,005
Italy	344	68,891	9,125	325,640,760
Latvia	883	156,580	764	60,461,032
Lithuania	563	57,548	1,543	54,035,601
Malta	1	25	76,933	1,923,323
Netherlands	273	269,753	7,871	427,448,549
Poland	913	110,386	4,032	256,990,351
Portugal	162	28,293	7,686	131,077,826
Romania	1,532	384,611	2,615	350,190,915
Slovakia	74	4,293	5,792	21,719,982
Slovenia	13	3,249	7,340	12,093,048
Spain	392	112,684	6,647	318,159,071
Sweden	20,242	2,729,131	263	359,995,507
United Kingdom	2,119	753,691	2,480	876,741,398
Total	**50,533**	**9,245,777**	**1,193**	**6,107,863,724**

Source: Brander et al (2007)

The total value for Europe is estimated at 6 billion (10^9) EUR/year, based on averages values ranging from hundreds of EURs per hectare (in countries with extensive wetlands (Sweden, Finland, Ireland) to thousands of Euros per hectare (generally the case).

Africa

Estimates of the economic value of wetlands across Africa reveal considerable benefits from a range of different systems:

- The Nakivubu urban wetland in Uganda provides up to *US$1.3 million* in water treatment and purification benefits annually to *100,000 local residents and nearby Kampala.*
- The Hadejia-Nguru wetlands, a floodplain in Northeast Nigeria provides *US$11 million* in agricultural activities, *$3.5 million* in fishing and *$1.6 million* in fuel wood, annually. The economic value of the intact wetland is estimated to be much

greater than the value of planned upstream irrigation and water development projects.
- Lake Chilwa, Malawi's first Ramsar site, produces over *20%* of the national fish catch. Its fisheries are valued at *US$18 million* per annum, alongside agriculture and other provisioning services.
- The Zambezi Basin wetlands provide over *US$70 million* in livestock grazing, almost *US$80 million* in fish production, and *US$50 million* in flood plain agriculture. Carbon sequestration is also a significant value.

Examples in other regions
The disruption of natural flooding regimes has devastated many riverine habitats and led to decreased sediment transport and a loss of flood buffering and nutrient retention. Flooding can cause severe hardship to humans, with the ***1998 floods in China*** causing an estimated ***$20,000 million*** worth of damage, but it is also essential for maintaining sediment-based fertility of floodplains and supporting fish stocks in large rivers. Of course, it is difficult to allocate exactly how much of the total damage could have been avoided has there been lesser ecosystem and biodiversity loss, but clearly the scale of the damage is sufficient to argue for a close look at the potential value of natura capital in natural hazards management.

6.6 Synthesis across values

The COPI landcover based analysis derives a broad set of estimates, with losses of ESS from biodiversity and ecosystem loss represented at between 1 and 7.5% of global GDP loss every year by 2050. This is a conservative estimate for three main reasons:
1) it is only partial, as not all ecosystem services are valued - significant ecosystem losses from coral reefs, fisheries, wetlands, and invasive aliens are not included
2) the estimates for the rate of land use change and biodiversity loss are fairly conservative in the OECD/Globio model, with the rate of loss estimated to slow
3) values do not account for non-linearities and threshold effects .

As regards the partial coverage, the range of values for other areas have demonstrated that that values for fisheries, coastal areas, coral reefs and wetlands/inland waters and invasive alien species are all significant.

The exact monetary scale is not known and arguably not knowable. The best that can be achieved are orders of magnitude estimates that help clarify and communicate the urgency of action to avoid the problems. One should also be careful about % of GDP estimates, as ultimately there is significantly more to livelihood and wellbeing than GDP, and also average figures hide important detail. A % GDP loss figure, needs to be seen in the context of the level of impacts on the individual, of population groups etc. In some cases the destruction of a local forest will hardly show up in % GDP terms, but it will be clearly felt by local communities depending on the provisioning and other services from that forest.

The scale of the ecosystem service losses underlines the important of improving understand of the losses better and seeing where this information can put halting biodiversity further up the agenda, and also where the valuation information can be integrated into tools and decision making to improve the evidence base of decisions making and hence improve our governance of natural capital, our natural heritage, and help ensure that ecosystem and biodiversity loss is halted. See chapter 7 for specific conclusions and recommendations.

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Annexes to Chapter 6

Table A 6.1 Benefit transfer – GDP (PPP) per capita ratios

Ratio of GDP per capita related to EUR, (with GDP in purchasing price parity (PPP) terms)													
	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR
Year 2000	1.47	1.00	1.09	1.22	0.39	0.35	0.12	0.23	0.34	0.19	0.17	0.35	0.12
Year 2050	1.34	1.00	0.98	1.11	0.34	1.06	0.24	0.69	0.37	0.30	0.41	0.33	0.15

Source: from GLOBIO / OECD model

Table A6.2 Multipliers for Gap filling (the General MSA is presented as a comparator – the values used to fill the gaps are those for the individual services).

		Provisioning services					Regulating services											Cultural services				
Description area 2000	**General MSA**	**Provisioning services**	Food, fiber, fuel	Biochemicals, natural medicines, pharmaceuticals	Ornamental resources	Fresh water	**Regulating services**	Air quality maintenance	Soil quality maintenance	Climate regulation (i.e. carbon storage)	Temperature regulation, precipitation	Water regulation (i.e. flood prevention, timing and magnitude of runoff, aquifer recharge etc.)	Erosion control	Water purification and waste management	Regulation of human diseases	Biological control and Biological control and pollination	Natural hazards control / mitigation (i.e. storm and avalanche protection, fire resistance etc.)	**Cultural services**	Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity, cultural heritage values	Living comfort due to environmental amenities	Recreation and ecotourism	Technology development from nature (bionica)
Natural areas	0.9	0.2	0.2	0.9	0.2	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0	0.9	1.0	1.0	1.0
Bare natural	0.9	0.0	0.0	0.1	0.0	0.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	0.5
Forest managed	0.5	0.7	0.7	0.5	0.7	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.6
Extensive Agriculture	0.3	0.8	0.8	0.3	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.4	0.5	0.4
Intensive Agriculture	0.1	1.0	1.0	0.1	1.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Woody biofuels	0.5	0.7	0.7	0.1	0.7	0.5	0.5	0.5	0.5	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.3	0.2	0.2	0.2
Cultivated grazing	0.7	0.5	0.5	0.2	0.5	0.7	0.7	0.7	0.7	0.1	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.8	0.8	0.8
Artificial surfaces	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table A6..3 Time inflators for 2000 to 2050

	Food, fiber, fuel	Biochemicals, natural medicines, pharmaceuticals	Ornamental resources	Fresh water	Air quality maintenance	Soil quality maintenance	Climate regulation (i.e. carbon storage)	Temperature regulation, precipitation	Water regulation (i.e. flood prevention, timing and magnitude of runoff, aquifer recharge etc.)	Erosion control	Water purification and waste management	Regulation of human diseases	Biological control and pollination	Natural hazards control / mitigation (i.e. storm and avalanche protection, fire resistance etc.)	Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity, cultural heritage values	Living comfort due to environmental amenities	Recreation and ecotourism	Technology development from nature (bionica)
Partial estimation scenario	1	2.8	2.8	2.8	2.8	2.8	3.59	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.15	2.8	2.06	2.8
Fuller Estimation scenario	2.8	2.8	2.8	2.8	2.8	2.8	11.37	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8

Note: 2.8 = Average EU rate for GDP per capita and by population for period

Separate transfer values are used to transfer to other regions across the world (addressing different GDP/capita and population rates)

Source of variants from 2.8: FEEM

Table A6.4 Base Assumptions for the regions – population, GDP and GDP per capita (in PPP)

			Population			Gross Domestic Product (GDP) in purchasing price parity (PPP)			GDP/capita		
OECD Region	**Description**	**Group**	**2000**	**2010**	**2050**	**2000**	**2010**	**2050**	**2000**	**2010**	**2050**
			millions	**millions**	**millions**	**$trillion in PPP**	**$trillion in PPP**	**$trillion in PPP**	**$ (PPP) / capita**	**$ (PPP) / capita**	**$ (PPP) / capita**
NAM	North America	OECD	410.1	450.0	565.3	10.5	14.1	35.7	25651	31315	63128
EUR	OECD Europe	OECD	589.6	606.7	607.5	10.3	12.9	28.5	17427	21316	46963
JPK	OECD Asia (Japan & Korea)	OECD	194.4	199.4	177.4	3.7	4.4	8.2	19036	22140	46221
ANZ	OECD Pacific (Australia & New Zealand)	OECD	24.5	26.2	33.8	0.5	0.7	1.8	21317	26636	52292
BRA	Brazil	BRIC	168.1	190.5	242.9	1.1	1.5	3.9	6771	7949	15962
RUS	Russia & Caucasus	BRIC	164.8	160.1	127.7	1.0	1.7	6.4	6173	10925	49756
SOA	South Asia (India+)	BRIC	1367.2	1603.1	2321.1	2.8	5.1	26.6	2057	3192	11452
CHN	China Region	BRIC	1275.4	1364.9	1404.0	5.1	10.0	45.2	3992	7343	32174
MEA	Middle East	OTHER	173.8	216.2	370.1	1.0	1.6	6.4	6005	7519	17392
OAS	Other Asia	OTHER	531.5	597.7	755.2	1.7	2.8	10.7	3274	4709	14106
ECA	Eastern Europe & Central Asia	OTHER	122.1	124.9	118.0	0.4	0.7	2.2	2973	5639	19030
OLC	Other Latin America & Caribbean	OTHER	244.6	283.0	385.3	1.5	2.0	6.0	6028	7137	15648
AFR	Africa	OTHER	826.5	1050.9	2014.1	1.7	2.8	14.0	2074	2638	6932
World	**World**	**World**	**6092.7**	**6873.5**	**9122.3**	**41.4**	**60.5**	**195.5**	**6797**	**8798**	**21430**

7 Conclusions and recommendations

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Building on the work of the COPI team:

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7.1 Introduction

> *"It seems appropriate to assign the term 'Anthropocene' to the present, in many ways human-dominated, geological epoch."*
>
> **Paul J. Crutzen,** Nobel Prize–winning chemist [55]

Our society's activities are changing life on earth and the functioning of ecosystems, from the local to the global level. The scale of the changes and risks are such that without significant action our epoch risks being the sixth[56] in the line of major global species extinctions[57]. But it is more than geological names and headline statements of dramatic risks, it is about the viability of ecosystems and the services they offer, it is about impacts on the welfare and wellbeing of the current and future populations and societies and about wider ethical questions of our role in the stewardship of the planet's natural resources .

It is therefore important to understand the facts of past losses and to understand the risks of potential future losses and what the scale and implications of these losses are. The growing recognition of the urgency has led to the call for the study on The Economics of Ecosystems and Biodiversity (originally named the Review of the Economics of Biodiversity Loss, see the Preface to this report), and the specific call for the "Cost of Policy Inaction; the case of not meeting the 2010 target" study. This chapter presents the conclusions of the COPI analysis (see Box 7.1 for a summary of the COPI ambitions), and key insights and recommendations.

[55] NATURE|VOL 415 | 3 JANUARY 2002 |www.nature.com

[56] The last and most famous of the five mass extinction occurred at the end of the Cretaceous period (65 million years), this was the KT event, where 70% of life became extinct, including the dinosaurs. Source: Ricard V Solé and Mark Newman (2002)

[57] http://www.newscientist.com/channel/life/dinosaurs/mg16422167.700

Box 7.1: COPI Ambitions and approach

The COPI study started with several ambitions. A major aim was to arrive at an overall illustrative value for the cost of policy inaction - more specifically, the cost of not halting biodiversity loss – to clarify and communicate the importance of looking more closely at the cost of ecosystem and biodiversity loss. A second major aim was to scope out what is possible methodologically and help gain insights for the wider valuation challenge on the economics of ecosystems and biodiversity. For the former, the COPI team chose to focus in-depth on one area – that of changes in landuse and biodiversity in land based biomes and associated ecosystem service losses. The availability of the global biodiversity (GLOBIO) model and OECD scenarios (see chapters 1 to 3) allowed these changes to be explored in a comprehensive manner and over a useful time period 2000 to 2050 – when combined with valuation input data in a suitable format. This allowed for a major step forward in evaluating ecosystem and biodiversity loss.

Clearly this is only part of the picture, as there are also ecosystem and biodiversity losses in wetlands, coastal areas, marine ecosystems which were outside the scope of the GLOBIO model. Hence the core land cover based focus was complemented by a wider literature review of values in these other areas.

The COPI study therefore has two tiers – depth through the model-based analysis, and breadth through the wider literature review and some broader calculations. The latter is useful to help put the core COPI analysis into context as well as exploring a basis for a wider evaluation (e.g. using a series of models and scenarios to help develop a comprehensive global picture).

In addition, through the assessment, methods and assumptions could be tested so as to learn lessons on valuation of ecosystems and biodiversity that could feed into the wider Economics of Ecosystems and Biodiversity (TEEB) work. Furthermore, a basis of information was created – notably the valuation database – that could prove a useful resource for work by others in the area.

Part of the COPI work was also to see the underlying GLOBIO model and OECD scenarios in context so as to help interpret the results and assess whether they are conservative or not. Hence the work included a look at historical developments in ecosystems and biodiversity – to see if the projected losses in the future fit with our understanding of the reality of the past decades. Some insights of past changes are noted below as they help communicate the urgency of action and underline the need for COPI and wider TEEB work.

7.2 Changes in Biodiversity

The past losses of biodiversity confirm that there is an urgency for action.

- In the last 300 years, global forest area has shrunk by approximately 40%. Forests have completely disappeared in 25 countries, and another 29 countries have lost more than 90% of their forest cover. The decline continues[58].
- Since 1900, the world has lost about 50% of its wetlands. While much of this occurred in countries in the temperate zone during the first 50 years of the last century, there has been increasing pressure since the 1950s for conversion of tropical and sub-tropical wetlands to be converted to alternative land uses[59].

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[58] United Nations Forest and Agriculture Organisation, 2001.*Global Forest Resources Assessment 2000* United Nations Forest and Agriculture Organisation, 2006 *Global Forest Resources Assessment 2005.*

[59] http://www.ramsar.org/about/about_wetland_loss.htm

- Some 20% of the world's coral reefs – which generally have a high biodiversity matching tropical forests - have been effectively destroyed by fishing, pollution, disease and coral bleaching and approximately 24% of the remaining reefs in the world are under imminent risk of collapse through human pressures.[60]
- In the past two decades, 35% of mangroves have disappeared. Some countries have lost up to 80% through conversion for aquaculture, overexploitation and storms.[61]
- The human-caused (anthropogenic) rate of species extinction is estimated to be 1,000 times more rapid than the "natural" extinction rate typical of the Earth's long-term history.[62]
- The great apes are our closest living relatives yet are among the most endangered species on the planet. All populations of all remaining species are endangered or critically endangered, and all are in decline. Orangutans in Borneo and Sumatra have declined by *75%* and *93%*, respectively, since 1900. More than *70%* of African great ape habitat has already been affected by development[63].
- Fishing pressure has been such in the past century that the biomass of larger high-value fish and those caught incidentally has been *reduced to 10% or less of the level* that existed before industrial fishing started. The losses of biomass and fragmented habitats have led to local extinctions.

These global averages, dramatic as they are, hide even more dramatic changes. Locally and regionally the levels in many places are much higher, with much greater impact on the livelihoods of societies The effect of trends such as these is that approximately 60% of the earth's ecosystem services that have been examined have been degraded in the last 50 years, with human impacts the root cause[64].

Further declines in global biodiversity as well as local extinctions of species are expected in the next few decades because of continuing population growth, economic expansion, conversion of natural ecosystems to human environments and global climate change.

- Further loss of biodiversity on land is projected to be about 11% worldwide between 2000 and 2050. In some biomes and some regions, projected losses are about 20%. Natural areas will continue to be converted to agricultural land, will be affected by the expansion of infrastructure and by climate change.
- Land currently under extensive (low-biodiversity impact) forms of agriculture will be increasingly converted to intensive agricultural use, with further biodiversity losses and with structural damage to the environment. Almost 40% of land

[60] Wilkinson C., 2004: *Status of Coral Reefs of the World: 2004 report*

[61] Millennium Ecosystem Assessment, 2005: *Global Assessment Report 1: Current State & Trends Assessment*. Island Press, Washington DC. Detail: Chapter 19 Coastal Systems. Coordinating lead authors: Tundi Agardy and Jacqueline Alder. Original reference: 35%: Valiela et al. 2001; 80% reference: Spalding et al. 1997

[62] Millennium Ecosystem Assessment, 2005 *Living Beyond Our Means: Natural Assets and Human Well-being*. Island Press, Washington DC. Page 15

[63] Caldecott, J & Miles L (eds) 2005 World atlas of great apes and their conservation UNEP-WCMC, U of C , Berkeley Press, Berkeley CA, USA

[64] Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington DC.

currently under extensive agriculture is expected to be converted to more intensive use by 2050.

- In addition to the projected change of land-based biodiversity losses, there are other equally large and in some cases larger expected losses in marine and coastal biomes.
- The studies of Alder et al. (2007) with the global fisheries model indicate that current trends or increased effort, whether for commercial or recreational fisheries, will lead to further collapses in stocks and ecosystems; the scenarios differ only in their rates of decline. The consequences of this process are not reflected in policy response yet as suggested by the reality of the slow implementation of protective measures in marine systems and the continuation of subsidy policies.
- The expected losses of coastal ecosystems is dramatic in itself, with habitat and species populations disappearing forever locally and some globally. It is also dramatic in light of the risk of an eventual total marine ecosystem collapse, as coastal systems are the remaining potential for future restoration. The conversion to food production sites (e.g. shrimp or fish farms) is, ironically, counterproductive.
- By 2030, less than *10%* of African great ape habitat will be free of disturbance. Chimpanzees are more numerous and more adaptable than Gorillas, but overall trends are negative; Bonobos (known to some as pygmy chimpanzees), our closest relative, are likely to disappear completely as they are hunted for food in many areas particularly in times of conflict and food shortage.
- On a more positive note, the number and extent of protected areas have been increasing rapidly worldwide in recent decades; they now cover almost 12% of global land area. However, the biomes are unevenly represented in that coverage. Marine areas are under-represented in all categories of protected areas. Realisation of actual protection is at risk with the increasing pressure on land and resources due to the increasing human populations.
- A focus on protected areas only is not enough as some 20% of threatened species occur outside protected areas and some protected areas are "paper parks" and are not managed and protected sufficiently well to guarantee that biodiversity be maintained. The GBO2 (Global Biodiversity Outlook 2)[65] analyses in 2006 already showed that full implementation of the protected areas targets will only decrease the biodiversity losses on land by 2-3%-points (compared to projected losses of 8-11% points). Whilst degradation is usually less within protected areas than in surrounding unprotected zones and many of the world's flagship protected areas are threatened by external pressures and lack of adequate protection.

[65] http://www.cbd.int/gbo2/

Changes in ecosystem services

With conversions of natural ecosystems to other forms of land use, such as cropland, pasture land or urban land, or by unsustainable fishing of the oceans, or converting coastal mangrove to shrimp farms, the total flow of services from ecosystems to humans in a region is altered.
While ecosystem conversion often generates substantial economic benefits and improvements in human well-being, it also deteriorates the capacity of ecosystems to provide other services, in particular regulating services, and supporting services that are essential for other groups of people or for society at large. The changes often bring short-term private economic benefits for a few people but long-term social costs for many.

- The publication of the Millennium Ecosystem Assessment has been instrumental in emphasising the concept of ecosystem services in all levels of environmental and nature policy. It is not yet common knowledge, though, to what extent human welfare is dependent on the availability and quality of ecosystem services. Ecosystem services form the conceptual bridge between loss of biodiversity and loss of welfare and well being.
- The climate debate has cleared the way for raising the awareness of the general public as well as of economic policy makers, that relentless conversion of natural ecosystems into economic production units, creates backlashes which are already turning out to be economically significant. The COPI study offers additional facts on the meaning of ecosystem service losses to human well being to help address the awareness gap.
- Maximisation of provisioning services such as food, fish and timber has reduced the area with intact ecosystems and biodiversity and thus with the capability to provide regulating services such as climate and flood control, and air and water purification.
- Losses of ecosystem services have social and economic consequences. It is estimated that 1 billion people worldwide are dependent on fish as their sole or main source of animal protein, while fish provided more than 2.6 billion people with at least 20 percent of their average per capita animal protein intake. The expected decline of ocean fisheries will therefore have severe social consequences. Similarly, water scarcity is a globally significant and accelerating condition for 1–2 billion people worldwide, leading to problems with food production, human health, and economic development. The impacts of invasive alien species are global and affecting the flow of ecosystem services to many.
- With the loss of biodiversity at gene, species and system levels of 30 - 50% in the last few centuries, much potentially relevant information for future human welfare has already been lost. The most important source of technological innovations helping to improve living conditions and well being of humanity is arguably nature, and this is being eroded.

It is essential for achieving sustainable use of natural resources to understand the different relations between ecosystem services and biodiversity, and the trade-offs involved in a conversion from one type of land use to another as this leads to a different portfolio of services.

- The relations between losses of services and biodiversity differ across services. The assumption has been made in this study that they tend to be proportionate to biodiversity loss for regulating services (eg if we lose 10% of biodiversity, we lose 10% of the ecosystem service and 10% of the value). In other cases there can be an increase in productivity as biodiversity drops, at least in the short term – for example where there is a choice to focus on a particular service such as the provision of food.

It is also essential to take account of the *net change* in services, as some benefits may increase while others get lost in the conversion. Increasing one particular local service with private benefits generally leads to losses of regional or global services with public benefits. For a full and relevant assessment, it is also quite important to address the *net benefits of changes*, taking account of the energy cost of human interventions in exploiting ecosystem services.

- Knowledge of the relationships between the levels and quality of ecosystem services on the one hand and biodiversity and other indicators of ecosystem functioning is progressing although many gaps remain. The fields of agricultural science, forest ecology, fisheries biology and economics, and outdoor recreation management all have extensive knowledge of necessary conditions, possible risks and optimal use strategies. What is less known is the specific relationship between a desired level of service and the minimum required biodiversity, or the sensitivities to change in biodiversity under the various local conditions. Also still largely unknown are the complex relationships involved in multiple use of ecosystems, at various spatial scales at the same time.

Economic value

The study has shown that the problem of the economic and social consequences of biodiversity loss is potentially severe and economically significant, but also that significant gaps remain in our knowledge, both of the ecology and of the economics of the impacts of future biodiversity loss. Further work is needed, which can usefully build on the insights gleaned in this valuation exercise.

On the evaluation challenge: from Costanza to COPI

The evaluation challenge is well exemplified by the oft-cited Costanza et al. (1997) study. This study focused on providing an estimate for the total economic value of Nature's services. Their result - $ 33 trillion as a value for ecosystem services, as against $ 18 trillion for global GDP - was criticized on the one hand for extrapolating marginal valuations to entire global ecosystems (as economic values estimated for small marginal changes are not valid anymore when dealing with big changes[66], and on the other, for being "a significant under-estimate of infinity" (Toman, 1999) (as how can one put a value on the existence of humanity). While the study's limitation was its focus on the value of the total stock of natural capital, when the question can also be approached, maybe with better understanding among policy makers, from the

[66] As the provision of the ecosystem service can change in a non-linear manner, and the economic values can in principle be extrapolated only if the shape of the demand curve is known

angle of value of the loss from the change in stock, it nevertheless played an important role in raising awareness and debate on an issue - biodiversity loss and the value of nature to humanity - that had been generally not been taken into account in decision making before.

The COPI study aims, just like Costanza et al., to assess the importance of the value of ecosystem services and biodiversity to society and the importance of the loss and urgency of action to halt the loss, but it does so by looking at the losses from changes in the stocks of natural capital, and the change in value of the loss of flow of services that ensue.

There are, of course, a wide range of assumptions needed to arrive at this value– and there is a specific COPI challenge in the route taken. This includes the choice of model and its choice of parameters (growth rates for GDP, population, links to landuse, aggregation issues), the selection of a "land use changes" approach which requires per hectare values to allow computation, the use of assumptions on how changes in biome quality affect ecosystem service provision, the use of benefit transfer and future value change assumptions (see Chapter 2, Chapters 5 and 6 and the Annexes for a presentation of the range of data inputs, steps and assumptions).

The COPI analysis is aimed not just at calculating some illustrative numbers, but also at creating and testing a method and developing insights for the methodology to be used in future evaluations. The numbers here should therefore be seen as indicative and the insights from the COPI evaluation challenge should be seen as one useful input to the wider evaluation challenge of The Economics of Ecosystems and Biodiversity (TEEB) being launched at COP9. Shortcomings in the COPI approach, and there will inevitably be some, could therefore be seen as challenges to be solved within the wider TEEB.

On ranges of value estimates

The COPI study has focused primarily on developing COPI values for changes in land-based ecosystem over the period 2000 to 2050 by detailed modelling, and complemented this focus with a literature review and some broad-brush estimation for other areas. For practical computational purposes, most (but not all) of these have been on *single specific values,* though seen in the context of ranges, underlining that the value of ecosystem services and biodiversity and their losses varies across locations depending on the (scale and nature of the) provision of services and who benefits from the services, which in turn relates to access to the service. A few observations:

- A recent review by the French Government[67] found a wide range of values from different studies for different aspects of the economic value of coral reefs. The high estimates for ecosystem services in some places are in great part due to the high number of users as other sites have equal ecological quality but less economic users in practice.

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[67] Ministère de L'Ecologie, du Développement et de L'Aménagement Durables (2008) La préservation des écosystèmes coralliens: aspects scientifiques, institutionnels et socio-économiques version provisoire du 20 mars 2008

- For the ecosystem service "water regulation / watershed protection" in the tropical forests in Mount Kenya a value of $273/ha/year was estimated[68], and in Lao PDR, in the Sekong Province of China, a value of € 980/ha/yr for the ecosystem service "water regulation /flood control was derived, reflecting the vulnerability of the region to flooding. This again is an example of ranges of values as they occur in the literature.
- For recreation and the economic impact of tourist activities, especially in developed, rich countries or accessible to people from rich economies, values can be very large. They often reflect the willingness to pay for scarce services.
- Pollination: Ricketts et al. (2004) found the value of bee pollination for coffee production to be worth US$ 361/ha/year, although the benefits were only felt by producers located within 1 km of natural forests. In New Zealand, the varroa mite *(Varroa destructor[69])* is a serious pest in honeybee hives and is expected to have an economic cost of US$267-602 million[70]. A further invasive alien species impact concerns the zebra mussel (*Dreissena polymorpha*) - this has led to damage to US and European industrial plant (they colonise water intake pipes, severely restricting the water flow to power plant or other municipal or private facilities that rely on fresh water[71]). Cumulative costs for the period 1988-2000 have been estimated at between $750 million to $1 billion[72]. Both examples indicate the size of the economic value and differences in estimation when ecosystem services affect key industries.
- For the ecosystem service "biochemicals, natural medicines and pharmaceuticals", found in tropical forests, the values for bioprospecting have been estimated[73] at ranging from $1/ha to $265/ha when employing a random search, including locations with the highest biodiversity. There is a high variation of values within one study. This is once again a good example of the site dependency of values. Even though all tropical forests are rich in biodiversity not each tropical forest is (already) a recognised hot spot region for genetic material.
- Marine capture fisheries are an important source world wide of economic benefits, with an estimated first-sale[74] value of *$ 84,900 million*, and important for income generation, with an estimated 38 million people employed directly by fishing, and many more in the processing stages. The scale of this and of course the scale of dependency on fish for protein underlines the social importance of not compromising this fundamental ecosystem service.
- Finally, carbon storage – this depends on carbon in the soil, in the trees or grass; the isolation levels and the value depends on these and the price of carbon. The

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68 Emerton (1999). Note that were this value to be transferred to other countries via standard benefit transfer eg adjusting by relative PPP-GDP per capita ratios the total number would be a lot higher, and the value would be well above the average, reflecting the mountainous terrain and risk of flooding.

69 http://en.wikipedia.org/wiki/Varroa_destructor

70 Wittenberg et al, 2001

71 http://nationalatlas.gov/articles/biology/a_zm.html

72 National Aquatic Nuisances Species Clearinghouse, 2000 in McNeely et al (2001)

73 Costello & Ward (2006)

74 Value to fishermen, so does not include the value added along the retail chain.

COPI analysis demonstrated the ranges of the potential losses of carbon storage from land use changes.

On benefit transfer

Transferring results from one area to another (benefit transfer) and / or "grossing up" to develop regional or global totals, presents a range of valuation challenges. Some will reject global numbers on the grounds that they are fraught with too many assumptions to be accurate and hence credible. Others will see them as helpful illustrative numbers to communicate the importance of an issue and source of inspiration for further evaluation to improve the understanding, or source of argument to contribute to policy making to help address biodiversity loss. The COPI team approach has been to present both the cases and the illustrative global totals and explore what can and cannot be defended methodologically and what could usefully be done in follow up research.

On the value of loss of ecosystem services from land based biomes

It has to be noted that the monetary losses are current and future welfare losses, not a loss of GDP, as a large part of the benefits from ecosystem services is currently not included in GDP, and GDP includes monetary estimates of human activity of which the welfare contribution is at least dubious. Losses of our natural capital stock are felt not only in the year of the loss, but continue over time, and are added to by losses in subsequent years of more biodiversity. These cumulative welfare losses of land based ecosystem services could be equivalent in scale to 7% of (projected) GDP by 2050.

Methodological Observations:

The 7% figure should be seen as a conservative estimate, as:

- it is partial, excluding numerous known loss categories, e.g. all marine biodiversity, deserts, the Arctic and Antarctic; some ecosystem services are excluded as well (disease regulation, pollination, ornamental services, etc), while others are barely represented (e.g. erosion control), or underrepresented (e.g. tourism); losses from invasive alien species are also excluded;
- estimates for the rate of land use change and biodiversity loss are globally quite conservative;
- the negative feedback effects of biodiversity and ecosystems loss on the development of GDP are not accounted for in the model;
- values do not account for non-linearities and threshold effects in ecosystem functioning.

Losses across regions

The losses across regions vary significantly, relating to the change in the land-use patterns within each region, quality losses for land in the region, different values for ecosystem services across the regions and the variation in national and regional GDP. The results suggest that the main regions impacted by biodiversity loss will be – *when seen from a % of GDP basis*- Australia & New Zealand, then Brazil, then "Other Latin America & Caribbean", Russia & Caucasus, Africa and then "Other Asia", then Eastern Europe & Central Asia. While the welfare losses presented as an average of global GDP is equivalent to 7%, the welfare losses due to ecosystem and biodiversity losses in the regions range from very small in the Middle East to 17% in Africa, 23 to

24% in Brazil, "Other Latin America & Caribbean" and Russia, and around 40% in Australia/New Zealand.

Methodological Observations:
A significant share of the losses is due to loss of the value of carbon storage, and hence a global loss rather than one felt directly by the local populations. Water regulation, air pollution regulation, cultural values and tourism losses, however, do affect national populations directly. The loss of these services makes up more than half of the losses in Australia & New Zealand, but carbon storage losses make up a large share of losses in the other regions.

Losses across biomes
The greatest losses are from the tropical forest biomes. The next greatest total losses are from other forest biomes. Total losses from Savanna and Grassland are estimated to be less. Note that the total values reflect the combination of different levels of the value of loss of ecosystem services per hectare (which are also higher for tropical forests than others), and total areas lost/converted. As more information was available on ecosystem service values for the forest biomes and that information was complemented by extensive additional work to develop values for each of the global regions without recourse, as extensively, to benefit transfer techniques, further details were given on the forestry biomes.

Methodological Observations:
For a range of biomes there have been no estimations – particularly in the *partial estimation* scenario, where there was no use of benefit transfer for values of particular ecosystem services from one biome to another, though also in the *fuller estimation* scenario (e.g. tundra and wooded tundra), where some benefits transfer from biome to biome was carried out (e.g. one forest biome to another). This underlines that the numbers should be seen as underestimates, even the fuller scenario has a range of gaps, both at the biome level, and at which ecosystem services are represented in the calculations.

Losses and gains per ecosystem service type
Climate regulation, soil quality maintenance and air quality maintenance are the main areas where there are ecosystem service losses, with climate regulation being sensitive to the carbon price assumptions. Food, fiber and fuel are generally positive (gains seen here), with losses stemming from natural areas and extensive agriculture as these are (generally) converted to intensive agriculture.

Methodological Observations:
Some other ecosystem services do not come up as significant in the final answer (e.g. bio-prospecting), which often reflects the limits of data availability. As noted earlier, these numbers should be seen as working numbers to illustrate the importance of the issue and help clarify where additional research is needed to advance the understanding of the risk of loss of ecosystem services.

Importance of change in quality of the ecosystems and ecosystem services
The economic losses from loss of ecosystem services associated with loss of natural areas are found to be broadly similar for land-use changes and quality changes. However quality losses are generally negative across all land-use types as a loss of quality (e.g. due to pollution or climate change's effect on soil) affects them all[75]. For land-use changes, there are, however, some positive gains to some land-uses in the land-use change set of numbers. This is due to the fact that all land-uses, including conversions of natural land cover, have ecosystem services and it would not be appropriate to completely exclude them. Gains are mainly due to increases in provisioning services (timber and food and (bio) fuels).

Methodological Observations:
The assessment of the impacts of changes in ecosystem quality on the amount of services provided ultimately relies to a large extent on the scientific evidence collected and the assumptions made in the valuation case studies used in the matrix. Creative solutions, based on elaborating assumptions on the shape of the relationships between biodiversity and the various types of services, have been developed to extrapolate and fill data gaps.

7.2 Notes on the methodologies

To derive a global COPI estimate a range of assumptions are needed to build on the loss of biodiversity from the GLOBIO/OECD work (which itself contains a range of assumptions), translate this into the loss of ecosystem services, derive marginal values of the loss of services for the range of land uses, biomes, geographic regions, project into the future to 2050, and aggregate. Each step requires some assumptions, as is generally the case for global assessments.

Some assumptions are particularly critical – e.g. the assumption that there is a linear relation between biodiversity loss and ecosystem service losses (passing a critical threshold would underline that this assumption can lead to a high level of underestimation), which links to the broad issue as to whether marginal values calculated today would still apply in the future, even if duly adjusted for population levels (where value linked to number of people benefiting) or adjusted to income (where linked to ability to pay).

On the GLOBIO model and OECD baseline scenario
The combination of the OECD baseline scenario with the GLOBIO land use-biodiversity model has provided a valuable tool to create a quantitative image of the future for land use changes, which in turn enabled the COPI analysis to be carried out. As noted earlier, there are several limitations to this model and its use and the results need to be seen in this context:

[75] There is one small exception - of a slight quality rise in intensive agricultural land. This is most probably due to the influence of higher quality (MSA rating) of extensive land that is converted to intensive land and hence entering at a higher average MSA, compensating for other quality losses to the intensive areas.

- The focus of the model is land based ecosystems and does not deal with wetlands, coastal and marine issues, nor with invasive alien species. Complementary data and models are needed to be able to capture the important developments in the other biomes.
- The OECD baseline scenario is demographically and economically quite conservative, with land conversion being slower than historic levels.
- No allowance has been made for a feedback loop –the loss of ecosystems and biodiversity lead in turn to a loss of ecosystem services that should feed back into the economic parts of the model. In the analysis presented, GDP grows independently of the natural capital loss, which is a clear limitation. As GDP estimates includes a number of economic activities which have no direct link to the ecosystem services, the loss of GDP due to such feedback is not expected to be proportional, but regionally it will be substantial (see Chapter 6).

On the valuation database

The COPI database, structured along ecosystem services and biomes, generates numbers that feed into the COPI assessment in a transparent and structured way. The selection criteria reduced the number of usable economic evaluation studies dramatically. Numbers in other units are still valuable as cross checks to the numbers selected as appropriate for the COPI analysis, and as results in their own right. The reason for the limited utility of the data has its roots in the fact that most economic valuation studies have been conducted to evaluate specific conservation programs or specific locations rather than to generate mean values per biome suitable for an up-scaling. For this purpose, most studies generate figures more correlated to the project or habitat (e.g. aggregated value of the willingness to pay (WTP) per visit, or WTP for the protection of a specific area) than on a per-hectare basis.

The majority of the available studies corresponds to specific entities like specific forests or lakes and are therefore difficult to transfer or interpret in a more general context – benefit transfer is possible, though needs to be done with due attention to the particularities of the local study and assessment as to whether local conditions can be related to conditions elsewhere. In some cases this is not that controversial (e.g. carbon storage in forests), and in other cases more so (e.g. recreational values). In addition, studies tend to focus on rather attractive or ecologically valuable habitats like wetlands, coral reefs etc, leaving a paucity of evidence for habitats with a lower profile – e.g. scrublands, grasslands and tundra.

There is also more information on certain ecosystem services than others in the valuation literature. There tends to be more information available on climate regulation service (on carbon storage elements), and on provisioning services for market goods (e.g. forest products), and less information available on regulatory services such as air pollution control, water provision and regulation, soil formation. On recreation values, there is a wide range of information available, but less on a per hectare basis.

We must therefore acknowledge that the scale of this part of the valuation challenge – of finding values for ecosystem services on a per hectare basis so as to be able to link to changes in land area – is large, and significant work is needed to find the right data, understand and interpret it, and transform, in an acceptable manner, the numbers into useable per hectare values. The insights on data availability and how they can and cannot be used are also valuable for wider valuation of ecosystem and biodiversity work and help provide a realistic picture of what can be done with what tools. Note that complementary approaches to a per hectare basis approach would be valuable. This would allow the problem to be analysed on a different basis, adding the possibility of greater clarity, understanding and testing for robustness.

On filling the gaps

A range of methods were applied to fill the gaps so that a global picture of the value of biodiversity loss could be developed and illustrative values estimated. The success of these methods is manifest in the fact that it was possible to arrive at indicative numbers that are meaningful and useful. A benefit of the approach has been to be transparent as regards assumptions and open about the development needs to allow the development of a robust value of ecosystems and biodiversity for the wider Economics of Ecosystems and Biodiversity review.

On estimating the value of COPI

A detailed spreadsheet model was created that allowed the OECD/GLOBIO outputs to be linked to the COPI valuation database and create values for changes in land use and quality for the period 2000 to 2050, for the different land uses, biomes, regions and ecosystem services. This model, while complex, can easily be updated and its workings are transparent. It should therefore provide a useful basis for upgrade as better data is available on the ecosystem services and better gap filling methods are created to address gaps that will inevitably remain.

The overall approach of seeking COPI values in each of the qualitative, quantitative and monetary levels has proved valuable. Furthermore, the valuation challenge will remain non-trivial, whatever the level of resources directed at the question, and there will remain a need for pragmatism and assumptions and transparency. All numbers need to be seen in context and especially global aggregates or global estimates created by extrapolation or grossing up. There should be no illusion about the possibilities for the level of accuracy of final numbers – there will be a potential for a fair level of accuracy for local valuations, but for global values the totals will always remain illustrative and order-of-magnitude estimates. This is fine, as they will be fit for purpose to clarify the level of urgency of action globally, and be more operational locally.

On data

It is important to underline that the estimates of the monetary COPI for biodiversity loss presented in Chapter 6 are "rough" estimates, but nevertheless based on considerable experience of monetary valuation. A range of 50% either side of the reported values would be the likely range of uncertainty for the estimates provided. The results are presented here not as the final answer, but rather as intermediate answers to the questions posed, resulting from an approach and set of methods, clarifying areas that are considered important to focus on, and creating a solid basis for future research.

- There is a wide range of gaps in available data. There are more data available for certain regions, biomes and ecosystem services than for others. This therefore creates a cautionary note with regard the interpretation of the results – the limitations need to be borne in mind.
- Different mechanisms are possible to fill the gaps – each has strengths and weaknesses. There is a trade-off between local explicit theoretical correctness, which would argue for not filling the gaps as no method to do so is arguably good enough, and the pragmatic need to come to an overall understanding and grasp of the size of the losses in economic terms, and the fact that gaps lead to the final picture being skewed due to what is there and what is not. To address this tension, two "gap-filling scenarios" were used. As stated above, the partial estimation scenario was more cautious and had fewer gaps filled, and the fuller estimation scenario adopted wider gap filling to help present a more complete picture, though where there was too little data (eg for tundra and wooded tundra, and for a series of ecosystem services) no gap filling was carried out.
- The choice of mechanism to fill the gaps is critical, as inevitably there will be more gaps than literature based data points. For example, the multipliers from 2000 to 2050 are critical, as are multipliers based on expectations of ecosystems services for different land-use.
- Also of great interest is the relationship between ecosystem quality (as measured by MSA) within land use types and the levels of services provided. The analysis assumes that the two vary proportionately or with a maximum function[76] (see Chapter 5), and this helps to explain a large proportion of the overall COPI estimates. Empirical evidence of the relationships is plentiful, but quantitative causal substantiation is as yet scarce. A more detailed investigation of the effects of changes in land use and ecosystem quality on the provision of different services within biomes should be a priority for future research, as this determines the estimated value of changes in net service provision.
- There is also a range of different ways of arriving at the cost estimate, which can also influence the result. For example in some cases non-market estimates are very low (e.g. for recreation) compared to understanding of the scale of the market. It is important to remember that all numbers have their strengths and weaknesses, and it is the overall understanding of the magnitude of the processes that is of particular importance rather than a specific number from a particular case study. Some numbers can dominate the results – market values for provisioning services and carbon prices are more readily available than for non market prices.
- The analysis compares the future state with that of a reference point. This is a useful mechanism to arrive at an order of magnitude test-estimate and develop insights on where losses occur and on mechanisms for estimation.
- The evaluation made in COPI has been based on a marginal analysis, assessing the impacts of changes in biodiversity and ecosystem services and not their overall value. However, over the period to 2050, some of the expected losses are

[76] For provisioning services, notably for food, the landuse is managed in a way that seeks to maximise one service, and that can take place with lower biodiversity levels.

relatively large, in particular at the regional level.. The elaboration of detailed assumptions on the functional form of the relationship between changes in biodiversity and changes in ecosystem services, and on the evolution of economic values over time, has helped to deal with the difficulties of assessing relatively large changes. However, what remains missed by this approach is the assessment of the potential losses that become more exponential, when critical thresholds are passed.

7.3 Recommendations: Policy

The COPI results follow from a no-new-policy scenario. They underline that such a scenario would lead to substantial losses of services due to the deterioration of our natural capital, and that there is thus a high level of urgency for action to help address these losses. This would inevitably require attention at many administrative levels in parallel. As noted in Chapter 3, there are policies that directly focus on ecosystems and biodiversity, such as the Habitats and Birds directives in the EU. There are also policies that focus on broader environmental issues but have the potential also to be used to support conservation and sustainable use of ecosystems and biodiversity, such as the EU EIA and SEA Directives. On the other hand, there are a number of policies that continue to have direct or indirect negative effects on ecosystems and biodiversity, e.g. aspects of the EU common fisheries and agricultural policies. Additionally, there are several regions on the globe where policies on conservation and sustainable use of biodiversity are still lacking, thus even the potential to address unsustainable use of natural resources is still rather limited.

The economic consequences of the loss of biodiversity and ecosystem services, as assessed in the COPI study, will need to be compared to the consequences of actions to conserve them and use them sustainably, based on appropriate scenarios, in order to develop full policy recommendations. Presently, due to methodological difficulties and patchy data on ecosystem services, most policy decisions with impacts on biodiversity conservation are not based on a full assessment of costs and benefits.

The existence, use and improvement of valuation information can be valuable for policy making and policy tools in a number of areas. Valuation can help in a range of fields:

- In providing information on the benefits of ecosystems and biodiversity, valuation can help encourage the use of associated policy instruments, such as payments for environmental services (PES) and benefit sharing.
- In providing information on the costs of losses of ecosystems and biodiversity, valuation can help develop instruments that make people that benefit from the services pay for the associated costs. Information can help, for example, strengthen liability rules, elaborate compensation requirements and looking again at which subsidies are needed and which are harmful and no longer fit-for-purpose. There is also potential in areas which at first sight might not be obvious candidates for attention – for example, in the EU at the Eurovignette directive,

which currently does not permit pricing for environmental externalities, but arguably should.

- Furthermore, information on the contributions of ecosystems systems to societal welfare and economic activity, valuation can help with decision making - for example at the local level the information can help with planning (e.g. for permit applications). At the regional level benefits and costs can help with regional development plans and associated strategic analysis and help with investment allocations and prioritisation. At the national level, greater information on the interrelationships between ecosystems and the economy and society can help improve national accounts and national policies that reflect a fuller understanding of how natural capital benefits the country.

In summary, there is an urgent need to look at the range of biodiversity relevant policies, including related policy- and decision making processes and evaluation tools, to see where perverse incentives exist to damage ecosystem and biodiversity and where valuation information can be used to create more environmentally sustainable policies.

7.4 Recommendations: research

In the course of the study, it became clear that the COPI work should contribute to The Economics of Ecosystems and Biodiversity (TEEB) interim report; it also creates insights for work on the value of ecosystems and biodiversity for Phase II of TEEB and beyond.

As regards methodological developments areas for further study are:

- It is important to widen the range of models used and of scenarios developed so as to assess the value of ecosystems and biodiversity across all the main biomes and services. The models and scenarios used should also appropriately address the impact of the main pressures and underlying drivers of biodiversity decline and the loss of ecosystem services, and of actions to reduce these pressures, at the relevant geographical scales. It is therefore important to invest in a range of scenarios and models across biomes and across ecosystem services to have more sophisticated modelling approach. This can build *inter alia* on insights from the "Scoping the Science" project.
- There is a need to fill some information gaps on ecosystem service values – notably for regulatory functions, and other areas where values are non-market. In particular, it would be useful to look at:
    - water provision and water regulation
    - soil formation and quality.
    - natural hazards control – e.g. to address flooding, mud and rock slides, storms, fire and drought, sea surges and tsunamis.
    - bioprospecting
    - food provision – to help clarify the importance of genetic diversity for long term resilience eg of agricultural ecosystems.

- Information is needed on the values of different land use types within different biomes. The COPI work builds more on values for natural areas, and for certain land uses (e.g. managed forests), and has less information available on the regulating services provided by most human-modified ecosystems, for example, depending on agricultural practice (extensive and intensive). Concentrated research in this field would help to inform an assessment of the net impact of changes in biodiversity on service delivery within biomes by allowing meaningful comparisons between alternative uses of ecosystems under appropriate scenarios.
- Benefit transfer can address some of the gaps in knowledge, but has limitations, given that many benefits are location-specific and that the spatial dimension may be complex (e.g. the relationship between service provision and service use). Benefit transfer needs to take into account these issues – both as limitations (where one should one do benefit transfer) and as possibilities for more sophisticated or more appropriate transfer approaches (where to apply GDP (PPP) per capita weightings, where to use a two-step process with meta-analysis, where to apply production functions to avoid direct transfer).
- In some cases, the services are global and there are global prices (e.g. carbon and bio-prospecting), which arguably need different treatment from local services of local benefits (e.g. local water purification or natural hazards management). In other cases values have a local or regional scale and reflect willingness to pay and hence income levels (here traditional benefit transfer can be applied). In other areas, production values and hence ecosystem services differ due to geographic context rather than to economic context – e.g. climatic conditions (sun, rain) and soil quality are critical determinants of provisioning services (food, wood and fibre). Here production function-based approaches are more appropriate. In view of all these observations a case can be made for at least some primary studies to fill crucial gaps in the valuation databases.
- There is a need to understand better the production functions of the different services and clarify which elements are due to the contribution of natural ecosystems rather than "man-made" inputs such as fertiliser, pesticides, machinery and labour. This will be critical if one is to understand the contribution of nature and hence what should be valued. At a practical level it is also critical to be able to move from gross values for provisioning services such as food and fibre outputs, to net values.
- There is a need to understand better the relationship between area loss and changes in ecosystem service provision. It will be valuable to clarify where the relationships between area loss and ecosystem service loss are linear(eg wood provision), where they are exponential(sensitive ecosystems with low resilience), where substitution possibilities mean that economic impacts appear to be smaller than they are in the longer term (forest loss and cultural values or tourism), and where there are critical thresholds(species minimum area requirements). This is important for understanding the provisioning functions and for integration of the knowledge into policy making.
- Associated issues that need further understanding include that of ecosystem resilience (not just of how resilience is affected by reduction in ecosystem area, but also by other pressures such as air pollution, water stress, temperature change, physical damage, etc.) and critical thresholds. The Millenium Ecosystem

Assessment has stressed that ongoing pressures on biodiversity and ecosystems generate increasing risks of non linear, potentially abrupt changes in their services, with significant consequences for human well-being. How to address these risks would deserve further elaboration both for the ecological part of the evaluation and for the economic tools, and ultimately for policy making.

- The issue of substitutability and its limits and ethical issues need further attention. Where there is a possibility to substitute for the loss of ecosystem services (e.g. tourism destinations change from one damaged coral reef to another that is not yet damaged), the total value of a particular service (in this example tourism) may not change, but the changes can be vitally important for the local economy, and other losses (other services) should also not be overlooked, as can easily be the case when obtaining impressive numbers of tourism values can be easier than obtaining numbers for other ecosystem services from the coral reefs (e.g. bio-prospecting potential, breeding ground values etc). Even in the case of nearly perfect substitutability – there is still a loss or degradation of an ecosystem and its service, and there is an ethical case of not ignoring the loss. The same argument applies to fisheries, simply substituting one stock with another and obtaining similar revenue, if looked at simply from the revenue stream, misses this aspect of the loss. This therefore argues for a more sophisticated approach to looking at the lifetime costs and revenues and also developing the ethical arguments.
- In the context of the last two points, it is important to do further work on clarifying how other tools, such as risk assessment, can complement the valuation tool.

Finally, pragmatism will remain important even if the various recommendations are all heeded – there will always remain limitations as to what valuation can do, and what is theoretically "pure". In some cases practical assumptions are needed to develop the "big picture". For the wider objectives of looking at what incentives and policy tools can help address the ecosystem and biodiversity loss challenge and how to get political support to develop and apply these, there is a need to see what level of accuracy is actually needed for the job at hand – in practice there will be a need for a mix of small local numbers that are accurate, and bigger numbers to raise the profile, that need to be robust and transparent, but where an order of magnitude answer is "fit-for-purpose" for communicating the importance of the issues and raising the political profile and urgency for action.

Annex I The Valuation Database

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I.1 Introduction

The database is not just a compilation of studies dealing with the issue of economic evaluation, as are current databases like EVRI and others, but rather a focused database looking at and categorising ecosystem services values that can be used to arrive at COPI values when linked to a land-use change type model – hence seeking ESS per hectare values.[77] Furthermore, the work has a role as a scoping exercise in order to get a better picture on the overall data availability and to provide a framework for the general data processing for future work on The Economics of Ecosystems and Biodiversity (TEEB) work. The database also provides the basis for the first indicative assessment of the costs of policy inaction as given in chapter 6.

The inventory of economic valuation studies is a core foundation for the project. Its roles can be summarised as follows:

- **structuring the data** -- it provides the data in a structured form, from which the integrated COPI assessments at various levels can be developed;
- **characterising the data** -- it documents the nature of the valuations and the range or forms they can take;
- **identifying gaps and opportunities** -- to develop suggestions for new and additional policies and priorities needed in response to insights on ecosystem services (ESS) across relevant geographical and sectoral examples.

To fulfil these objectives, a database has been developed that meets these key criteria.

- **Contains up-scalable data** -- the main precondition for the data recorded in this database is that the numbers can be used for an upscaling exercise on a global level. In addition, it is essential that the values be suitable for benefit transfer given the fact that there is a very uneven distribution of available information across ESS, biomes and geographical regions. To fulfil these requirements, the database presents data in economic values that are comparable and explicit in respect to the evaluated environmental good to avoid double counting.
- **Identifies data coverage and gaps** -- the database is structured in a way that it clearly indicates which data is available and where a data gaps to give advice for the phase II.
- **Accommodates future needs** -- the database is flexible in a way that new data can easily be added.

[77] Note that other values were collected and collated to allow complementary analysis – eg of coral reefs, wetlands, and invasive alien species though these were not integrated into the structured database.

To ensure that the above-mentioned criteria are met, the database contains only studies for which data can be presented on a €/ha basis and which can also be attached to a specific biome, ecosystem function and region. The use of these stringent criteria results in significant narrowing of the number of suitable case studies. This is necessary to ensure a sound and robust COPI assessment as it must be guaranteed that the underlying data is representative and not prone to double counting.

I.2 Methodology

Data gathering

As the aim of the project is to provide a scoping exercise on what a worldwide COPI assessment could look like in phase II, the literature search tried to use existing databases, such as the Environmental Valuation Reference Inventory (EVRI) to the maximum extent possible. Even though a considerable number of studies have been identified that provide economic values for specific ecosystem services, only a small proportion of these studies provided information detailed enough to be incorporated in the Valuation Reference Database. Hence, in addition, a literature search of scientific databases (Web of Science, Agricola) for peer-reviewed publications was conducted, as well as an internet search for grey literature.

Mean values for ecosystem function

Taking into account that 19 different ecosystem services (ESS) in combination with 13 different biomes and 14 geographic regions would result in 27,664 necessary values to feed into the COPI assessment, there is an urgent need to reduce complexity and fill in gaps. As a first step to reduce the complexity, mean values for different EES-biome combinations across regions were calculated using PPP-adjusted GDP values in Euro for the year 2007. These mean values serve as a good starting point for the up-scaling procedure presented in chapter 6.

The economic values derived from the original study were converted to Euros by taking the average annual exchange rate of the reference year into account. Where the average annual exchange rate was not available, the official exchange rate of 31 December of the reference year was used. In the next step, these economic values were adjusted to 2007 Euro values. In this respect, the historical consumer price index of the euro-zone was applied. Most valuation studies provided explicit information on reference year of the economic value. However, in cases where the reference year of the estimate was not explicitly stated (as it was the case in some meta studies), the year of publication of the study has been taken as a reference year. Furthermore, all values were then standardized according to 2007 Euros using the Purchase Power Parity/GDP index from the Globio model. Annex II "the forest study" presents a statistical way to do this assessment if sufficient information is available to undertake a benefit transfer based on transfer functions. In addition for each ESS it has to be checked whether the underlying studies evaluate competing or non-competing uses. In the first case, mean values can be used, but in the latter case the non-competing values must be added together to find the overall value for the respective ESS.

Min-max procedure
To assess the suitability of using the calculated mean values, minimum and maximum values were identified for each ESS-biome combination and compared with the mean. This allowed the team to assess their representativeness and hence transferability for each ESS-biome combination. The results of this comparison are presented in the table of results (see table 3). Where the ranges were found to be appropriate, mean values were fed into the COPI assessment. Where value ranges were found to be unsuitably high, they have been taken into account in the COPI assessment by stating minimum and maximum values to be used for the different scenario calculations.

Cross-check of single values
Available estimates were used when they were regarded as representative and methodologically sound. For some ESS-biome combinations data availability is limited to individual studies. To ensure that these are suitable for the up-scaling procedure, they must be verified.[78] Given the scope of this study, this assessment could not take the form of a statistical procedure, so consisted instead of a basic plausibility check. The underlying rationale here is that economic evaluation studies and their results may not be representative for a specific biome. This is due to the fact that these studies are frequently undertaken to highlight the importance of a specific ecosystem service in the case-study area and to raise awareness in the decision-making process. To avoid this, the results of the studies have to be critically assessed by comparing them with related studies using expert judgement. For an example of what such an assessment might look like, see Box I.1 (calculation procedure). This assessment eliminated certain economic values from the database, because they represented people's willingness to pay for a certain ecosystem service at very prominent places, i.e. where the reported value quite likely much higher than the assumed global average value.

Fixed data processing procedures
The database contains several summary tables containing information on (i) the overall count of studies for specific ESS-biome combinations, (ii) the mean value, (iii) maximum and (iv) minimum values as well as (v) sums for selected ESS where the underlying values represent sub-functions of a given ESS that must be summed up to represent the overall value of the function.

Filling the gaps
This is detailed in chapter 5 and 6 as chapter 5 discussed the relation between ESS and Landuse type (and hence a basis for transferring values between Landuse types within the same biome) and in chapter 6, which presents the evaluation results, and it is useful to transparently show the results in the context of the scaling up and gap

[78] Please note that all studies have to pass a quality check in order to be incorporated into the database, so if sufficient studies are available for the calculation of the mean, no double-checking is necessary.

filling approaches so that the numbers can be seen in perspective. Note that two scenarios were created – a partial analysis scenario, where there was a lesser level of gap filling/estimation, and a fuller analysis scenario, where more (but not all) of the gaps were filled. The choice of two scenarios reflected the opposing principles – one of theoretical purity (ie only use numbers from original data and selective gap filling where fair rationales exist) and one of the ambition of having a representative number (without the gaps filled, the final answers would arguably not be very representative of reality). Details are given in Chapter 6.

I.3 The COPI Valuation Database - structure and available data

The Value Reference Database contains the figures to be used for the completion of the monetary biome-land cover sheet in the COPI spreadsheet. It provides the monetary values needed for the eventual COPI assessment and thus represents the core of the COPI spreadsheet. By linking an estimate for a specific ecosystem service to a biome, a land use type and a geographic region, we can assess the overall loss of ecosystem services over the period 2000 to 2050.

The data in the database are displayed in two parts:

Part 1 is the core of the database. Estimates have been summarised in a seven-column table, from which the values will feed into the monetary biome-landcover sheet. Table I.2 represents the synthesis of the Valuation Reference Database.

Part 2 contains all relevant information that characterises each value/the respective study in detail, e.g. the actual location of the case study.

The overview table helps to navigate easier within the database.

Table I.1: Core of the Valuation Database

Used in COPI assessment	Useable value	PPP-adjusted usable values	ESS reference	Biome	Landuse type	Geographic region
1 = yes *0 = no*	*EUR/ha in the year 2007*	*EUR/ha adjusted by PPP to feed into matrix*	*# from ESS table to allow sorting (1-19)*	*# ref to allow sorting (1-13)*	*# ref to allow sorting (1-8)*	*# region from Globio (1-14)*

To use the values in the database for an up-scaling exercise the values of each study has to be defined in an explicit manger. Hence for each study the following criteria were recorded if possible (see Table I.2).

Table I.2: Structure of the Valuation Database

Column heading	Content
COPI Database reference number	#
Author/reference	*Name (year)*
Services covered	*Description - note if single service or aggregate*
Used in COPI assessment	*Indication whether the figures have finally been used for the assessment*
Unit - physical basis/unit	*e.g. kgN/ha*
Value per unit	*e.g. EUR/kgN*
Economic Value	*e.g. EUR/ha*
Time coverage	*annual or NPV*
Annualisation factor	*where relevant (eg NPV result given)*
Year of value	*e.g. 1999*
Inflator to 2007	
Type of value	*market price or WTP or etc*
ESS reference	*# from ESS table to allow sorting*
Location	*description et country*
Location: geographic region	*# region from Globio*
Biome	*# biome*
Comments	*comments on transferability etc.*

Next to the biome and the service covered information regarding the geographical region was recorded to indicate (i) for with region the service was recorded which gives information about the completeness of the database and for which regions the value can be applied as well as (ii) if the value has to be adjusted to European circumstances (see below). The nomenclature of the ecosystem services followed the *Millennium Ecosystem Assessment* (MA 2005). The column time coverage has been introduced to ensure that all values are on an annual basis. Often enough values are recorded on a net present value basis. These were than annualised.

The economic values derived from the original study were converted to Euros by taking the average annual exchange rate of the reference year into account. Where the average annual exchange rate was not available, the official exchange rate of 31 December of the reference year was used. In the next step, these economic values were adjusted to 2007 Euro values. In this respect, the historical consumer price index of the euro-zone was applied. Most valuation studies provided explicit information on reference year of the economic value. However, in cases where the reference year of the estimate was not explicitly stated (as it was the case in some meta studies), the year of publication of the study has been taken as a reference year.

Furthermore, to take into account the different meaning of one Euro in different regions of the world, all values were then standardized using the Purchase Power Parity/GDP index from the GLOBIO model.

I.4 Results – values for Ecosystem Services across biomes

So far, the database contains a total of 186 monetary values, split over several biomes, land-cover types and geographic regions. Nevertheless, the literature search for the database revealed a very unequal distribution of the available evidence for the different biomes and ecosystem services. Out of the total dataset, only around 30 values cover scrublands and grasslands, and 20 values cover temperate and tropical forests. The majority of values cover wetlands, swamps and floodplains (27), mangroves (15) and marine ecosystems such as coral reefs (19). Even though these values cannot be attached to one of the biomes from the GLOBIO model, they have been recorded, because they are valuable information that can be used in a more descriptive way (see also Annex III on invasive alien species).

Regarding the regional distribution it becomes apparent that there is a higher number of values available for Europe and America (North and South) than for Africa or Asia. This is not surprising. A look at the regional distribution of the entries in the EVRI database confirms this. An additional literature review has been undertaken to even out this imbalance.

The second main issue is that there is considerably variation between the values within one EES-Biome category. Hence decisions have to be made how calculate the mean and if all available values will be considered.

Table I.3 Available data for the different biome/ecosystem service combinations.

		PPP-adjusted values (EUR/ha) / [number of usable values] / range			
		Biome category			
ESS ref	**ESS name**	**Grassland**	**Scrubland**	**Tropical Forest**	**Temp. Forest**
1	Food, fiber, fuel	106 [3] (28 – 243)	779 [2] (515 – 1044)		246/14/99/10 7142**
2	Biochemicals, natural medicines, pharmaceuticals	0 [1]		514 [5] (12 – 2394)	3 [2] 2,2-3,6
4	Fresh water			9,6 [1]	
5	Air quality maintenance		793 [2]*		
6	Soil quality maintenance			1176[79] [1]	
7	Climate regulation	36 [3] (0 – 102)	347 [1]		240/ 542/382/240/ 382**
9	Water regulation	2,4 [1]		503/1356[3] 80-3062	344 [3] 0,2-980
10	Erosion control	23 [3] (1 – 44)	44 [1]		
11	Water purification and waste management	240 [3]*	838 [4]*	104,16 [1]	104 [1]
13	Biological control and pollination	57 [2]*			5 [1]
14	Natural hazards control / mitigation			6 [1]	

[79] Adjustment of the mean. See Box 1 "Assessment procedure".

		PPP-adjusted values (EUR/ha) / [number of usable values] / range			
		Biome category			
ESS ref	**ESS name**	**Grassland**	**Scrubland**	**Tropical Forest**	**Temp. Forest**
15	Cultural diversity and values		112,4 [1][80]	8 [2] (2 – 173[81])	99/25,4/11,9/ 9,9/11,9**
16	Living comfort due to environmental amenities				
17	Recreation and ecotourism			91 [1]	1,3/1,3/1,3/1, 3/1,3**
19	Primary production, nutrient cycling, soil formation			1116 [2]*	12 [1]
SUM	**Individual values extracted from reference database**	**18**	**11**	**15**	**14**
SUM	**Values used in COPI assessment**	**7**	**6**	**9**	**7**

* Value is the sum of the different underlying studies as these studies have evaluated different sub-functions of the respective ecosystem function. In these cases, a calculation of a mean would not be appropriate, hence no ranges are presented.

** Values derived from the extra study on forests (see Annex). The different values are referring to the following forest biomes: boreal forests, warm mixed forests, temperate mixed forest, cool coniferous forests, and temperate deciduous forests.

In the table above, the majority of values are mean values. Nevertheless, there is always a cross-checking necessary to ensure that the subsumed values are exclusive or non-exclusive uses. There are cases where an aggregate has been used for the COPI assessment. Here, different sub-functions of the same ecosystem service have been summed up to come to an aggregate value. For instance, food production and the supply of raw materials are two sub-functions under ecosystem service 1 (food, fiber, fuel). These functions can be summed up, because they are distinct and non-exclusive. In cases of identical functions, or when functions exclude each other, mean values have been calculated and were used in the further COPI assessment.

As can be seen from table I.3, some values are better documented, while others are less well documented. In the following, we provide additional information on the mean values to be used in the COPI assessment and explain in detail how the individual mean values have been developed to ensure transparency of the process:

80 Adjustment of the mean. See Box 1 "Assessment procedure".

81 Adjustment of the mean. See Box 1 "Assessment procedure".

Box I.1: Assessment procedure for the final values used in the COPI assessment

Grassland / food, fiber, fuel [15/1] The mean value was derived from three individual studies. Fleischer and Sternberg (2006) estimate the value of herbaceous biomass for meet production at EUR 243/ha; Costanza et al. (1997)[82] estimate the value of food production at EUR 46/ha (net rent), and Ruijgrok et al. (2006) estimate the value of food, fibre and fuel production at EUR 28/ha (WTP). The estimates stem from Israel, the US, and the Netherlands, respectively. The mean value was calculated without any adjustments.

Grassland / climate regulation [15/7] The mean value was derived from two individual studies. Costanza et al. (1997) estimate the value of climate regulation between EUR 0/ha and EUR 6/ha (opportunity cost), depending on the specific site. Ruijgrok et al. (2006) estimate the value of carbon storage at EUR 102/ha (WTP). The estimates stem from North America and Europe, respectively.

Grassland / erosion control [15/10] The mean value was derived from two individual studies. Costanza et al. (1997) estimate the value of soil formation at EUR 0.81/ha (opportunity cost) and the value of erosion control at EUR 24/ha (net rent). Ruijgrok et al. (2006) estimate the value of erosion control at EUR 44/ha (avoided cost method). The estimates stem from North America and Europe, respectively.

Scrubland / food, fiber, fuel [17/1] The mean value was derived from two individual studies. Rodriguez et al. (2006) estimate the value of food, fiber and fuel provision at 1044 EUR/ha (cultural domain analysis). Ruijgrok et al. (2006) value the same service at EUR 515/ha (WTP). The estimates stem from Europe and Latin America, respectively.

Scrubland / cultural diversity [17/15] Here only one value is available. As WTP studies on this issue generally evaluate specific sites of a broader interest, the value can not be used directly. For a simple and pragmatic benefit transfer it was assumed that only up to 10% of all scrublands a specific cultural value can be attached – otherwise they would not be special. (Please note, if more data becomes available the adjustment procedure as presented for the forest values should be used.

Tropical forest / biochemicals, natural medicines, pharmaceuticals [20/2] The mean value was derived from four individual studies. Simpson et al. (1996) estimate the values of pharmaceuticals at EUR 13/ha on a global scale (modelling market price), while Costello and Ward (2006) value the same service at EUR 109/ha on a global scale (modelling market price). Costanza et al. (1997) estimate genetic resources at EUR 33/ha (market value). Eade and Moran (1996) estimate genetic material at EUR 24/ha and medicine at EUR 2394/ha. The regional values stem from studies from North and Latin America.

Tropical forest / soil quality maintenance [20/6] Here just one value has been available provided by Eade and Moran 1996, in a case study for the Rio Bravo. As the normed value of the original study (EUR 5880 /ha) seemed to be very high in comparison to the figures available on the value of nutrient cycling (ESS 19) it was assumed that this value is very case-study specific and was hence adjusted. To ensure a conservative calculation only 20% of the original value entered into the final COPI calculation.

Tropical forest / water regulation [20/9] For this EES, three individual studies were available that differ significantly. Kaiser and Roumasset (2002) estimate watershed protection at EUR 926/ha for North America, while Emerton (1999) estimates the value of watershed protection Mount Kenya at EUR 3061/ha. Eade and Moran (1996) estimate the value of flood control in Latin America at EUR 80/ha. As the benefits of flood control highly depend on site-specific conditions such as precipitation

[82] Costanza et al. (1997) values were included in the database analysis, because they are often enough valuable reference points. In addition, they were compiled by highly recommended researchers in the field of ecosystem service valuation and are often based on meta-analyses.

but also vulnerable infrastructure, an adjustment of the mean value was undertaken to ensure conservative calculations. In this case, two means where calculated, the one considering all three values will only be used in the higher scenario, while for the lower scenario the mean of the lower two values will be used.

Tropical forest / cultural diversity and values [20/15] Here two values of different natures were available. Costanza et al. (1997) estimate the cultural value at EUR 2/ha on a global scale (CVM). Eade and Moran (1996) estimate the existence value at EUR 173/ha. The latter study stems from Latin America.

Temperate forest / biochemicals, natural medicines, pharmaceuticals [1212/2] The mean value was derived from two individual studies. Rosales et al. (2005) estimate the value of pharmaceuticals at EUR 3.55/ha, while Howard (1995) estimates the same service at EUR 2.24/ha. The studies stem from South-East Asia and Africa, respectively.

Temperate forest / water regulation [1212/9] The mean value was derived from three individual studies. Rosales et al. (2005) estimate the value of flood control at EUR 980/ha (varied methods). Howard (1995) estimates the value of watershed protection at EUR 51/ha. Costanza et al. (1997) estimate the value of water regulation at EUR 0.17/ha (damage costs). The studies stem form South-East Asia and Latin America, respectively.

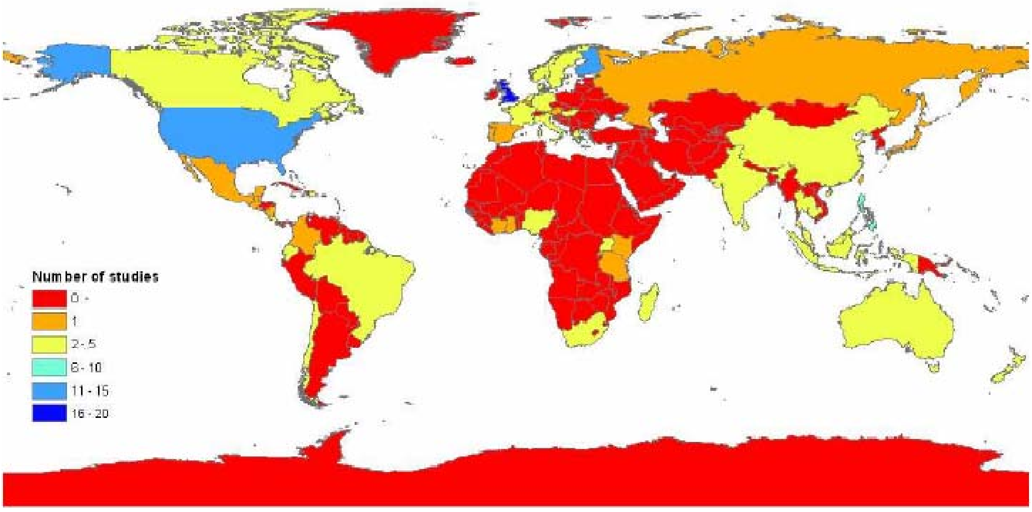
I.5 Documentation of the data gathering

As mentioned above the number of suitable economic assessments to be used in the COPI assessment is rather limited. Hence it is of importance to demonstrate how the literature search has been conduced to draw conclusions and recommendations out of these exercise for the phase II of COPI. The original idea has been to use existing databases as main source of input for the COPI-database to the highest extent possible to ensure a cost-effective use of existing knowledge. Nevertheless, this has been proven to be not possible. Hence an extensive literature search has been conducted as well.[83] Finally a list of used studies will be presented.

Use of existing databases

As mentioned above, the primary aim has been to use available databases to the extent possible. There are a number of databases, which contain valuation studies that could potentially be of interest for the COPI assessment (see Box I.2). Since EVRI is by far the most developed database we focus on the description of results of the query of this specific database. In order to qualify for further processing in the COPI database, the valuation studies had to fulfil certain criteria. Firstly, monetary or quantitative values were required on a hectare and annual basis. Secondly, the values needed to be assignable to a certain biome and geographic region and, if possible, to a land cover.

83 Please note that the literature search did not include forest biomes to the same extent as the other biomes as this search was mainly covered by the separate exercise on forests by FEEM described in the Annex II.



Source: McVittie & Moran, 2008.

Figure I.1: EVRI database – "Biodiversity"

The number of studies available in the EVRI database seems comparatively high, which gives reason to believe that the COPI database can be easily filled with estimates from EVRI. However, since the complex nature of the COPI methodology requires us to be highly selective with regard to available estimates, the outcome of an extensive search within the database was rather limited. For 23 selected ecosystem services, the EVRI search function retrieved a total of 185 studies. For most enquiries, it turned out that a lot of the retrieved studies did not cover the designated ecosystem service in an appropriate way (often the service was only mentioned or described in qualitative terms). For the rest, a study was considered potentially suitable for the COPI assessment if the estimate's underlying area (preferably in hectares) and an associated time period (preferably per annum) was provided. Taking into account the above criteria, only nine of the 185 initially retrieved studies provided values, which could potentially be incorporated into the COPI database. The next hurdle is the proper allocation of the estimates to specific biomes and geographic regions. This only allowed for three of these nine studies to be further processed within the overall COPI assessment. However, since each of these studies covered several ecosystem services, the search ultimately generated a total of **17 individual estimates**, which have been incorporated into the COPI database (see table 6.4).

Table I.4 results from the EVRI enquiry

Ecosystem service (search string)	Total hits	Potentially suitable
Provisioning		
Food	24	3
Fibre	1	-
Fuel	20	1
Biochemicals	-	-
[Natural] Medicine	2	-
Pharmaceuticals	-	-
Ornamental [resources]	-	-
Fresh water	9	1
Regulating		
Air quality [maintenance]	59	-
Soil quality [maintenance]	3	-
Climate regulation	-	-
Carbon storage	5	3
Temperature regulation	-	-
Precipitation	4	-
Water regulation	2	-
Flood prevention	1	-
Erosion control	9	-
Water purification	2	-
Waste management	-	-
[Regulation of human] Diseases	12	-
Biological control	3	-
Pollination	2	-
[Natural] Hazard [control]	24	1
Total	**185**	**9**

Main reason for this low degree of suitability of the evaluated studies is the different nature and purpose most economic studies are designed for. This is especially true for studies using stated preference methods e.g. Contingent Valuation Method (CVM). These values are rarely estimated on a per hectare dimension and it is very difficult to convert them. The argument here is that people do not value ecosystem services on a per hectare or per kilogram basis. Rather, they value 'the environment as a whole' when performing recreational activities. Examples are the WTP to visit a forest or recreational fishing. The first may bear little relation to the size of the forest, since other attributes are more important, while the second is more likely to depend on the amount of fish caught. Furthermore, cultural services are often highly site specific and the value for one site may tell us little about that of another. Transfers and aggregation exercises using values on a per hectare basis will therefore be biased (Navrud, 2008). As the EVRI database is very much focused on Europe and North America (see Figure I.1) a traditional literature review was conduced as well (see next chapter).

Box I.2: Description of potential data bases:

- The *Environmental Valuation Reference Inventory (EVRI)* has been developed by Environment Canada and provides more than 1250 studies, which mainly cover North America, but to some extent also Europe, Asia and South America. EVRI is the most developed database, both with respect to the number of studies and the level of detail provided, as well as the practical handling of the search function.
- *Valuebase* has been developed by the Swedish Beijer Institute. It contains more than 170 valuation studies from Sweden. A drawback with this database is the absence of area specifications (e.g. hectare) related to the economic estimates.
- *EnValue* has been developed by the New South Wales Environment Protection Agency. The focus of the approximately 400 studies is on Australia. The database does not provide any details, such as monetary estimates, but basically lists all existing valuation studies.
- The *RED (Review of Externality Data)* database has been developed with funding of the European Commission. Its focus is on power generation, transport and waste. RED only contains a limited number of studies, and few details related to the economic estimates are provided.
- The *New Zealand non-market valuation database* contains approximately 100 valuation studies from New Zealand. The drawback with this database is that most of the studies do not provide estimates on a per hectare basis.

General Literature Review

The general literature review was conducted using the Web of Science citation database. This multidisciplinary database incorporates both the Science Citation Index Expanded (1975 – present) and Social Sciences Citation Index (1975 – present). This database provides access to approximately 8,700 research journals worldwide. Various combinations of key words were used in the search, proceeding from the general to the more specific. The terms 'services, valuation, value' were first combined with terms 'ecological, environmental, ecosystem' and then with specific ecosystem types or geographical names, including:

- tundra
- (Mediterranean) shrubland
- grassland / woodland
- steppe
- savannah
- prairie
- rangeland
- pastureland
- Serengetti
- Pampas
- grazing land

The most general searches produced the most citations. For example, 'ecological + services' yielded 151 results, of which six results also included a reference to the key word 'economic' but none included actual financial values. The more specific searches yielded few citations. For example:

- valuation + shrubland : two references with financial information
- service + shrubland : six references, none with financial information
- value of ecosystem services: two of 23 references included financial information
- value + woodland: seven references, none with financial information
- value + steppe: two references and no financial information

I.6 Insights – strengths, gaps, methods for using values, and needs

The proposed database, structured along ecosystem services and biomes, offers the possibility to generate numbers to feed into the COPI assessment in a transparent and structured way. Nevertheless, in order to qualify for further processing in the COPI database, the valuation studies had to fulfil certain criteria. Firstly, monetary or quantitative values were required on a per hectare and annual basis. Secondly, the values needed to be attributable to a certain biome, landcover type and geographic region. These essential selection criteria reduce the number of usable economic evaluation studies dramatically.

This has been foreseen to some extent, since it is clear that most economic valuation studies have been conducted to evaluate specific conservation programs or specific locations rather than to generate mean values per biome. For this purpose, most studies generate figures more correlated to a project or specific habitat (e.g. aggregated value of the WTP per visit, or WTP for the protection of a specific area) than on a per-hectare basis. The majority of the available studies corresponds to specific entities like specific forests, lakes or landscape elements and are therefore difficult to transfer or interpret in a more general context. In addition, studies tend to focus on rather attractive or ecologically valuable habitats like wetlands, coral reefs etc., leaving a paucity of evidence for habitats with a lower profile. We must acknowledge that the dimensions of this problem are surprisingly large.

In respect to the aims of the database, it can be concluded that it has been useful to:

- define representative samples of case studies per biome/ecosystem service unit
- analyse relevant samples and insert them in a spatially explicit framework
- ensure the possibility of a benefit transfer
- provide information about knowledge gaps

It seems that a considerable part of the data needed is not or not easily available in the public literature. Currently, for some ecosystem services there are only few corresponding values in the Value Reference Database, e.g. with regard to water supply as a provisioning service. In this respect, the figures that will be retrieved from the final COPI assessment can only be interpreted as a lower-bound estimate. During the second phase of the review, the existing gaps will have to be filled in order to come to more representative figures. To sum up: though there are information gaps in the current database, a first approach has been developed that is suitable to further elaboration in a second phase when more resources and time are available.

I.8 Recommendations for Phase II of the review

The literature review under this scoping exercise showed clearly that there are substantial gaps in the data availability for a range of biomes, ecosystem services as well as regions. A completion of the database is the prerequisite for the final COPI assessment. The reasons for the data gaps differ. For example, variations in the representation of different geographic regions and biomes may have their causes in the research interest or location of the research institute, as well as the kind of publications. Differences in the coverage of ESS have their roots in the different level of complexity of the ESS. The more complex an ESS, the fewer scientific data available, as the measurement of quantitative effects becomes more challenging. In addition, if data should be available, the subsequent economic assessment will be even more difficult.

For phase II, four main requests can be formulated to make sure that more values will be available to feed into the COPI assessment:

- **New studies** -- New ESS valuation studies are needed in areas (ESS, regions, biomes) where there are severe knowledge gaps. It should be stressed that future research should not focus on well-known aspects, such as timber or CO_2 sequestration (although there is certainly also potential for improvement), but rather on the existing gaps.
  - To ensure that the newly commissioned evaluation studies are usable for the next COPI assessment and for any other up-scaling and benefit transfer exercises, it must be assured that these studies have a clear quantity structure in respect to the evaluated ecosystem service. Often enough studies try to assess the TEV and become more or less a black box regarding the exactly evaluated service.
  - In addition the majority of studies are based on Contingent Valuation Methods. It would be advisable to have more specific ecosystem service evaluations based on replacement cost or production function approaches.
- **Improved benefit transfer approaches** -- New practicable approaches for benefit transfer must be developed. So far, there is just the possibility to do this for selected, well documented cases as forest or wetlands (see Annex II)
- **Further literature review** -- In phase II, more resources should be dedicated to the literature review. Especially for some geographical regions like Africa or Asia it can be assumed that there is grey literature hidden that cannot easily be discovered by means of scientific search engines. This literature search has to go beyond a simple scanning of the literature. It is necessary to make more use of grey literature and local knowledge. In this respect expert workshops focusing on specific ecosystem services may be advisable to generate new knowledge.
- **Verification of study results**: As the unit values derived form the literature review have major impact on the overall results more quality checking is necessary. There is a need for a framework to assess the suitability of studies and their results. A prominent example is the assessment of biomedical resources. Here studies rely on very severe assumptions.
- **Use of non-economic studies** -- Existing natural scientific knowledge has to be made usable for economic assessments. This would mean that methods have to be developed to use existing non-economic studies and their results to derive economic values. This would require an interdisciplinary research task, but should be feasible within the next two years. With this framework it would be possible to enlarge the data basis significantly.

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Annex to COPI Annex I Studies used for the calculations in the COPI assessment

COPI DB ref-no	Author/reference	ESS name	Biome categ.	Geographic region	Economic Value	Unit
1	Ruijgrok et al. 2006	Food, fiber, fuel	Scrubland	EUR	500	EUR/ha/y
2	Ruijgrok et al. 2006	Climate regulation	Scrubland	EUR	337	EUR/ha/y
3	Ruijgrok et al. 2006	Erosion control	Scrubland	EUR	43	EUR/ha/y
4	Ruijgrok et al. 2006	Water purification and waste management	Scrubland	EUR	609	EUR/ha/y
5	Ruijgrok et al. 2006	Water purification and waste management	Scrubland	EUR	170	EUR/ha/y
6	Ruijgrok et al. 2006	Water purification and waste management	Scrubland	EUR	34	EUR/ha/y
7	Ruijgrok et al. 2006	Water purification and waste management	Scrubland	EUR	0	EUR/ha/y
8	Ruijgrok et al. 2006	Air quality maintenance	Scrubland	EUR	700	EUR/ha/y
9	Ruijgrok et al. 2006	Air quality maintenance	Scrubland	EUR	70	EUR/ha/y
10	Rodriguez et al. 2006	Food, fiber, fuel	Scrubland	OLC	1477	EUR/ha/y
11	Rodriguez et al. 2006	Cultural diversity and values	Scrubland	OLC	1590	Nuevos Soles/ha
12	Ruijgrok et al. 2006	Food, fiber, fuel	Grassland	EUR	27	EUR/ha/y
13	Ruijgrok et al. 2006	Climate regulation	Grassland	global	99	EUR/ha/y
14	Ruijgrok et al. 2006	Erosion control	Grassland	EUR	43	EUR/ha/y

COPI DB ref-no	Author/reference	ESS name	Biome categ.	Geographic region	Economic Value	Unit
15	Ruijgrok et al. 2006	Water purification and waste management	Grassland	EUR	121	EUR/ha/y
16	Ruijgrok et al. 2006	Water purification and waste management	Grassland	EUR	11	EUR/ha/y
20	Costanza et al. 1997	Climate regulation	Grassland	NAM	7	$/ha/yr
21	Costanza et al. 1997	Climate regulation	Grassland	NAM	0	$/ha/yr
22	Costanza et al. 1997	Water regulation	Grassland	NAM	3	$/ha/yr
23	Costanza et al. 1997	Erosion control	Grassland	NAM	29	$/ha/yr
24	Costanza et al. 1997	Erosion control	Grassland	NAM	1	$/ha/yr
25	Costanza et al. 1997	Water purification and waste management	Grassland	global	87	$/ha/yr
26	Costanza et al. 1997	Biological control and pollination	Grassland	global	25	$/ha/yr
27	Costanza et al. 1997	Biological control and pollination	Grassland	global	23	$/ha/yr
28	Costanza et al. 1997	Food, fiber, fuel	Grassland	NAM	57	$/ha/yr
29	Costanza et al. 1997	Biochemicals, natural medicines, pharmaceuticals	Grassland	global	0	$/ha/yr

COPI DB ref-no	Author/reference	ESS name	Biome categ.	Geographic region	Economic Value	Unit
32	Fleischer et al. 2006	Food, fiber, fuel	Grassland	MEA	98	$/ha
82	Eade, Jeremy D.O., and Dor	Food, fiber, fuel	Tropical forest	OLC		$/yr
83	Eade, Jeremy D.O., and Dor	Food, fiber, fuel	Tropical forest	OLC		$/yr
84	Eade, Jeremy D.O., and Dor	Biochemicals, natural medicines, pharmaceuticals	Tropical forest	OLC	2000	$/yr
85	Eade, Jeremy D.O., and Dor	Biochemicals, natural medicines, pharmaceuticals	Tropical forest	OLC	7	$/ha/yr
86	Eade, Jeremy D.O., and Dor	Climate regulation	Tropical forest	OLC	n.a.	13$/ton/yr
87	Eade, Jeremy D.O., and Dor	Soil quality maintenance	Tropical forest	OLC	1699	$/ha/yr
88	Eade, Jeremy D.O., and Dor	Water regulation	Tropical forest	OLC	23	$/ha/yr
89	Eade, Jeremy D.O., and Dor	Cultural diversity and values	Tropical forest	OLC	50	$/ha/yr
90	Costanza et al. 1997	Natural hazards control / mitigation	Tropical forest	AFR	5	$/ha/yr
91	Costanza et al. 1997	Fresh water	Tropical forest	SOA	8	$/ha/yr

COPI DB ref-no	Author/reference	ESS name	Biome categ.	Geographic region	Economic Value	Unit
92	Costanza et al. 1997	Primary production, nutrient cycling, soil formation	Tropical forest	global	10	$/ha/yr
93	Costanza et al. 1997	Primary production, nutrient cycling, soil formation	Tropical forest	SOA	922	$/ha/yr
94	Costanza et al. 1997	Water purification and waste management	Tropical forest	global	87	$/ha/yr
95	Costanza et al. 1997	Biochemicals, natural medicines, pharmaceuticals	Tropical forest	NAM	41	$/ha/yr
96	Costanza et al. 1997	Recreation and ecotourism	Tropical forest	NAM	112	$/ha/yr
97	Costanza et al. 1997	Cultural diversity and values	Tropical forest	global	2	$/ha/yr
98	Costanza et al. 1997	Climate regulation	Temperate forest	NAM	88	$/ha/yr
99	Costanza et al. 1997	Water regulation	Temperate forest	OLC	0	$/ha/yr
100	Costanza et al. 1997	Primary production, nutrient cycling, soil formation	Temperate forest	global	10	$/ha/yr

COPI DB ref-no	Author/reference	ESS name	Biome categ.	Geographic region	Economic Value	Unit
101	Costanza et al. 1997	Water purification and waste management	Temperate forest	global	87	$/ha/yr
102	Costanza et al. 1997	Biological control and pollination	Temperate forest	global	4	$/ha/yr
103	Costanza et al. 1997	Food, fiber, fuel	Temperate forest	global	50	$/ha/yr
104	Costanza et al. 1997	Food, fiber, fuel	Temperate forest	global	25	$/ha/yr
105	Costanza et al. 1997	Cultural diversity and values	Temperate forest	NAM	2	$/ha/yr
182	Costello and Ward, 2006	Biochemicals, natural medicines, pharmaceuticals	Tropical forest	global	133	$/ha/yr
183	Simpson et al., 1996	Biochemicals, natural medicines, pharmaceuticals	Tropical forest	global	11	$/ha/yr
184	Howard, 1995	Biochemicals, natural medicines, pharmaceuticals	Temperate forest	AFR	0	$/ha/yr
185	Rosales et al., 2005	Biochemicals, natural medicines, pharmaceuticals	Temperate forest	SOA	0	$/ha/yr
186	Emerton, 1999	Water regulation	Tropical forest	AFR	273	$/ha/yr
187	Howard, 1999	Water regulation	Temperate forest	AFR	5	$/ha/yr
188	Kaiser and Roumasset, 2002	Water regulation	Tropical forest	NAM	1022	$/ha/yr
190	Rosales et al., 2005	Water regulation	Temperate forest	SOA	87	$/ha/yr

Annex II Economic Valuation of Forest Ecosystem Services: Methodology and Monetary Estimates

Anil Markandya, Aline Chiabai, Helen Ding, Paolo Nunes and Chiara Travisi

II.1 Introduction

Forest services

This section provides an explanation of the general approach applied for the monetary assessment of the services provided by forest biomes. The analysis is focused on a restricted and selected set of relevant forest services (see Table AII 0) identified following the Millennium Ecosystem Assessment (2005) taxonomy. Two factors are considered for their selection: a) relevance to decision-making; and b) availability of data.

The estimation of such services, although not covering the full range of forest instrumental values, will allow the quantification of those values which are expected to be relevant to context where it is necessary to make decisions and trade one value against the other. Finally, non-anthropocentric values, such as moral and spiritual values, which should be taken into account in decision-making, do not lend themselves to quantification.

Table II.0 List of forest Ecosystem Services addressed for the monetary estimation.

MEA category	Ecosystem Services
Provisioning	Food, fiber, fuel
Regulating	Climate regulation (i.e. carbon storage)
Cultural	Recreation and ecotourism Passive use

Source: modified from MEA (2005)

Valuing forest services

<u>The nature of forest values</u>

Several valuation methods can be applied to estimate the monetary value attached to ESSs provided by forest biomes. By using the well-known notion of Total Economic Value (TEV), and depending on the nature of the good being valued, we can identify the best available valuation methodology to be employed for the monetary estimation of each ESS of concern (see CBD, 2001).

Broadly speaking, both market and non-market valuation techniques have been applied in the literature on which the COPI project relies to draw suitable marginal values for forest services, to be scaled up at the global (OECD regions) level using proper transfer protocols.

Application of transfer protocols

Given the COPI's global perspective, it is essential to rely on the full body of knowledge already available in the environmental economic literature in order to gather estimates that cover, for each service to be valued, the highest variability in terms of countries (OECD regions) and forest types (COPI biomes). In this regard , a crucial role is played by the use of research synthesis techniques, such as meta-analysis and value transfer. We will firstly perform simple meta-analyses and, secondly, apply value transfer techniques to adjust values already estimated for a given study area to new, unexplored, contexts.

Meta-analysis

The meta-analysis that will be applied here focuses on explaining differences in WTP estimates for recreation and passive use by means of a multivariate meta-regression whose dependent variable is a standardized WTP measure, and whose explanatory variables are related to theoretically expected differences, methodological issues, and differences in the study setting. In particular, we will look at the effect of the following explanatory factors on the magnitude of WTPs for forest recreation and passive use:

- size of the recreational forest site or, for passive use, the forest area designated to conservation of biodiversity;
- income level in the study area.

Value transfer

Value or benefit transfer is a technique in which results of studies performed earlier are applied to obtain values in a new policy context (Brouwer, 2000).

Three main types of value transfer can be distinguished:

- simple transfer of a mean(or median) WTP estimate (namely the *effect size*);
- transfer of a demand or bid function (i.e. benefit function transfer); and
- transfer of an estimate based on meta-analysis (Florax et al., 2002).

For recreational values we apply value transfer based on a straightforward meta-analysis. In doing this, we focus on one single exemplar country that provide a representative picture of forest recreation. For this purpose the UK appears to be the most suitable country as many studies on the value of recreation for different forest types are already available in the economic literature. The values obtained for UK are then transferred to all other COPI regions. The value transfer is therefore based on a two-step approach: (i) estimation of marginal value for UK, and (2) value-transfer from UK to each COPI region.

For passive use values we will also apply value transfer based on a meta-analysis. The value transfer methodology is based on a two-step approach: (i) estimation of marginal values by forest biome in a number of COPI regions, and (2) transfer to the remaining COPI regions. In the reminder of this section, for each service to be valued, we discuss: data availability, methodologies applied, results about marginal values and how these values should be used.

II.2 Provisioning services

Data availability

The economic value of the provisioning services is estimated as marginal value per hectare per year. In order to compute this estimate we employ data on export values, export quantities and total domestic production from the FAO database (FAOSTAT[84]), and from those obtain estimates of net income. Final computations to estimate marginal values have been made using only the hectares actually designated to production, also available from FAO/FRA2005 (2006). All the estimates are computed in $ 2005 (as available from FAO), and then converted into €2007.

Methodology

The market-based methodological framework is presented in Figure 1. Marginal values for forest provisioning services vary according to the following factors:

- product category (wood forest products WFPs and non wood forest products NWFPs),
- country,
- forest biome, and
- size of the forest designated to production.

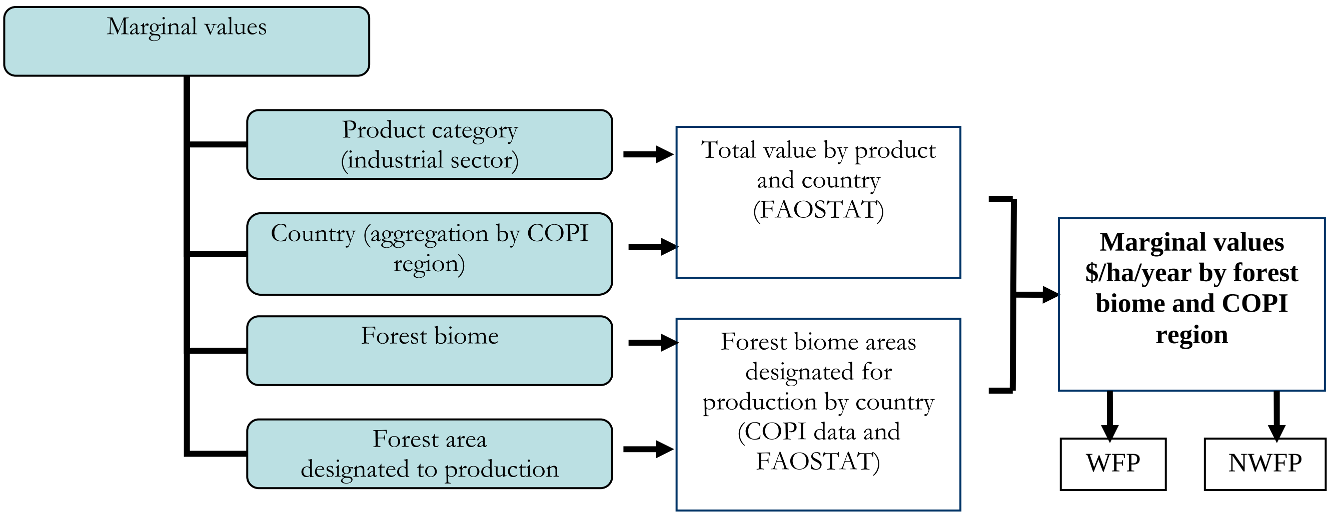

Figure I.1. Methodological valuation framework for forest provisioning services.

The valuation framework consists of two phases.

a) Calculation of total annual values: the FAO export values at country level by different product categories (which are associated to different industrial sectors) are adjusted for domestic production quantity and converted into estimates of net income, in order to estimate total provisioning values for each COPI region.
b) Calculation of marginal values: total values are combined with information about the different forest biomes size, in order to estimate the annual marginal values per hectare, by forest biome and COPI region. For this purpose only the hectares

84 FAO/ForesSTAT is available online at: http://faostat.fao.org/site/381/default.aspx

actually designated to production are considered in order to estimate marginal values per hectare.

In the first valuation phase, the forest provisioning services are classified into two main categories: wood forest products (WFPs) and non-wood forest products (NWFPs), bearing in mind the relevant Millennium Ecosystem Assessment (MEA) classification (i.e. food, fiber, and fuel). Each of the two broad categories is further detailed in Table II.1, according to different industrial sectors.

Table II.1 The Provisioning Services Provided by Forest Ecosystem.

Wood forest products (WFPs)	Non-wood forest products (NWFPs)	
	Plant products	**Animal products**
• Industrial Roundwood • Wood pulp • Recovered paper • Sawnwood • Wood-based panels • Paper and paper board • Wood fuel	• Food • Fodder • Raw material for medicine and aromatic products • Raw material for colourants and dyes • Raw material for utensils, crafts & construction • Ornamental plants • Exudates • Other plant products	• Living animals • Hides, skins and trophies • Wild honey and beeswax • Bush meat • Other edible animal products

Sources: FAOSTAT and FAO/FRA 2005

For each forest product, the relevant market values (export values measured in 2005 US$) are taken from the FAO database (FAOSTAT) at the country level. These values are then adjusted for estimating total provisioning values, taking into account the domestic production, according to the following calculation:

(1) $$TV_i = EV_i \frac{Pq_i}{Eq_i}$$

Where:

TV_i = total forest provisioning value per year by country *i*

EV_i = export value per year by country *i*

Pq_i = domestic production quantity per year by country *i* (forest products produced within country *i*)

Eq_i = export quantity per year by country *i*

i = country

Domestic production and export values are available from FAO database and are measured in US$2005. From these values the net income is obtained based on the financial returns from wood forest production. Returns to the forest owner are made up of sales of timber and other wood forest products, increases in the value of the lands, less costs of production and any net Payments of taxes. The costs are employment costs and other purchases. The net return from forestry in the three-

year period 2003 to 2006 has been estimated equal to 8.2% per annum (Forestry Statistics 2007, UK[85]). This estimation has been applied to all the COPI regions.
Total values are then summed up across sectors and countries to get the aggregate gross benefits derived from forest provisioning services for each world COPI region and for each industrial sector:

(2) $$TV_{wr} = \sum_{wr=1}^{n} TV_{i \subset wr}$$

Where:

TV_{wr}	= total forest provisioning value per year by world COPI region *wr*, adjusted for profits
TV_i	= total forest provisioning value per year by country *i*, adjusted for profits
wr	= world COPI region
I	= country
n	= number of world COPI regions

In the second valuation step, total forest provisioning values per year by world COPI region *wr*, TV_{wr}, have been attributed to each forest biome proportionally to the forest area, and assuming a linear relationship between marginal values and forest biome size. The computation follows the formula below:

(3) $$V_{wr,b} = \frac{TV_{wr,b}}{Sp_{wr,b}}$$

Where:

$V_{wr,b}$	= value/ha/year by COPI region *wr* and forest biome *b*
$TV_{wr,b}$	= total provisioning value per year per COPI region *wr* by forest biome *b*
$Sp_{wr,b}$	= forest area size designated to production per COPI region *wr* by forest biome *b*
wr	= world COPI region
b	= forest biome

Results

Following the methodological approach illustrated above we are now able to calculate values of provisioning services, with special focus to WFPs and NWFPs). In particular we present:

- total values by COPI region and by forest product, adjusted for domestic production quantity (Table II.2)
- total values by COPI region adjusted for profits (Table II.3)
- marginal values by each forest biomes and COPI region (Table II.4)

Table II.2 illustrates the estimates of total provisioning values by forest product (WFPs and NWFPs), adjusted for domestic production quantity in 1,000 US$ 2005, not corrected for profits. As expected. wood forest products represent the most relevant part of total values. Table II.3 reports the results for total provisioning values for forest products, adjusted for profits. Differences across COPI regions depend on the type of wood forest products mainly produced within the region.

[85] http://wwww.forestry.gov.uk/website/ forstats.

Forest Products	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Ind roundwood	83,342,663	2,255,593	1,779,375	3,579,212	7,720,103	8,226,139	2,764,993	18,608,123	-	9,934,211	655,775	3,284,651	10,789,144	-
Wood pulp	42,861,176	6,164,150	5,139,208	1,054,996	4,635,531	2,740,455	1,491,691	2,214,555	-	2,636,578	5,206	2,045,074	1,353,314	-
Recovered paper	5,631,322	2,156,998	3,475,276	305,855	891,443	237,272	115,102	5,422,428	-	404,676	40,711	304,663	168,403	-
Sawnwood	56,949,028	11,660,170	7,379,062	2,605,018	5,595,130	2,878,806	4,982,985	3,487,331	-	3,471,241	710,280	2,614,348	4,697,444	-
Wood based panels	27,361,621	12,023,737	5,166,697	1,359,979	2,605,538	2,561,221	992,549	20,100,999	-	4,984,632	605,141	1,373,616	1,247,142	-
Paper&paperboard	80,416,491	55,230,449	31,880,141	2,239,490	5,741,127	3,507,696	4,085,311	37,471,909	-	10,004,712	1,081,522	3,615,331	2,652,787	-
Wood fuel	3,328,265	373,709	-	288,674	138	738,702	30,938,995	30,637,614	-	53,956,045	306,179	5,664,886	67,936,587	-
TOTAL WFPs	299,890,566	89,864,806	54,819,759	11,433,225	27,189,009	20,890,291	45,371,625	117,942,961	-	85,392,095	3,404,814	18,902,569	88,844,821	-
NWFPs	66,334	1,770,364	972,496	18,590	193,131	4,820	428,206	-	-	1,074,608	29,579	9,460	897,198	-
TOTAL WFPs+NWFPs	299,956,900	91,635,170	55,792,255	11,451,815	27,382,140	20,895,111	45,799,831	117,942,961	-	86,466,703	3,434,393	18,912,029	89,742,019	-

Table AII 2. Total production values by forest product and COPI regions (1000$, 2005) (calculated from FAOSTAT).

Table AII 3. Total production values by COPI regions, adjusted for profits (1000$, 2005).

Forest Products	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
TOTAL WFPs+NWFPs	24,596,466	7,514,084	4,574,965	939,049	2,245,335	1,713,399	3,755,586	9,671,323	-	7,090,270	281,620	1,550,786	7,358,846	-

Finally, Table II.4 reports the marginal values of provisioning services, estimated by world COPI region and forest biome, adjusted for profits, and converted in €2007. These estimated marginal values can thus be applied to derive total values attributable to forest areas actually designated to production.

Differences in marginal values across COPI regions and forest biomes can be interpreted as the result of the effect of the following factors:
- distribution of forest area across COPI regions;
- incidence of forest area designated to production in each COPI regions,
- distribution of forest production sectors across forest biomes and COPI regions.

Table II.4. Marginal value of provisioning services by COPI region and forest biome, adjusted for profits (2007€/ha/year).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	740	246	770	1,765	-	96	874	1,134	-	1,375	147	619	-	-
Tropical	10	-	2.4	126	368	-	59	17	-	916	-	300	1,886	-
Warm mixed	177	14	51	827	98	0.1	550	469	-	72	-	138	402	-
Temperate mixed	304	99	943	67	-	73	56	55	-	-	159	6	-	-
Cool coniferous	158	107	1,490	-	-	13	372	217	-	-	91	-	-	-
Temperate deciduous	155	142	631	252	-	4.9	231	431	-	1.9	12	1.8	15	-

For projections in 2050, values have been adjusted taking into consideration only PPPGDP projections in the future (from COPI), and assuming no real prices increase for wood forest products, as shown by some commentators in this literature (e.g. Clark, 2001).

II.3 Regulating services: carbon sequestration

Data availability

The economic value of the carbon sequestration is estimated as marginal value per hectare per year. In order to compute this estimate we use quantitative information about the tons of carbon sequestered by forest type and geographical region in the world, and monetary information on the value for each ton of carbon sequestered.

The quantity of carbon (measured in tons of carbon tC) stored by forest biome and geographical region has been taken from two studies, R.B. Myneni et al. (2001) and H.K. Gibbs (2007). The first study provides estimates of carbon stocks for temperate and boreal forest in Canada, US, Northern America, China, Japan, Russia, Finland, Sweden, Eurasia and South Eastern Asia. The second study provides estimates for carbon stocks for tropical and warm mixed forests in Brazilian Amazon, Latin America, Sub-Saham Africa and Tropical Asia. The monetary value per ton of carbon sequestered has been taken from the EU project CASES (Cost Assessment of

Sustainable Energy System[86]), which provide values for the baseline year of reference and for future period scenario. For the present report, values have been computed for year 2007 and year 2050.

Methodology

The methodological framework for carbon sequestration valuation is based on two main steps:

a) Identification of the capacity of carbon sequestration by forest biome and country (tC/ha).
b) Monetary estimation per COPI world region and forest biome.

Carbon stocks can vary mainly according to the following factors: (i) forest type (tree species having different biomass), and (ii) area of the forest. Following the simple equation below we can thus estimate annual marginal values of carbon sequestration per hectare:

(4) $$V_{wr,b} = (tC / ha_{wr,b}) * \$ / ha$$

Where:

$V_{wr,b}$ = value/ha/year by COPI region *wr-th* and forest biome *b-th*

$tC/ha_{wr,b}$ = tons of carbon stocked per hectare by world COPI region *wr* and forest biome *b*

$/ha = value per hectare of carbon stocked

wr = world COPI region

Marginal values of one ton of carbon have been taken from the EU-funded project CASES "Cost Assessment for Sustainable Energy Systems" that provides values estimated with Damage and Avoidance cost methods. In particular we consider lower and upper bound estimates of carbon. The lower estimate is based on the Marginal Damage Cost (MDC) approach. The high estimate is based on the Marginal Avoidance Cost (MAC) approach assuming the EU target of a 30 percent reduction in 2020 compared to 1990. This is the marginal economic cost of 30 percent carbon reduction[87]. Table II.5 reports the monetary values used for the years 2007 and 2050 under the two approaches.

Table II.5. Monetary values for carbon sequestration (Euro)[88].

Costs in Euro			
MDC (lower-bound)		MAC (upper-bound)	
Year 2007	Year 2050	Year 2007	Year 2050
6.43	23.11	15.8	179.6

86 CASES, Project No 518294 SES6, (2006-2008). http://www.feem-Project.net/cases/

87 See CASES deliverables for the valuation methodology: http://www.feem-project.net/cases/downloads_deliverables.php

88 Source: http://www.feem-project.net/cases/documents/deliverables/ExternalCosts_per_unit_emission_080313.xls

Results

Following the methodological approach illustrated above we are now able to show values of carbon sequestration.

Table II.6 shows the capacity of carbon sequestration by forest biome and COPI world regions. Some of the estimates displayed are taken from original studies which provide carbon capacity by forest type and geographical region (*), while others (**) have been estimated by transferring results from the original studies to similar COPI regions As expected, tropical forest and warm mixed forest are characterized by a higher carbon sequestration capacity .

Tables II.7 to Table II.10 show the estimated annual marginal values per hectare by COPI region and forest biome, using the above mentioned lower and upper bound scenarios considered in the CASES project. These estimated marginal values can thus be applied to derive total values attributable to natural and managed forest areas contributing to carbon sequestration.

Table II.6 Capacity of carbon sequestration in the world forests (tC/ha).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	37.37*	37.37*	37.37**	37.37**	-	37.37*	59.4**	25.77*	-	59.4**	37.98*	34**	-	-
Tropical	92**	-	149**	149**	186*	-	225*	96**	-	92*	-	149*	200*	-
Warm mixed	92**	92**	100**	134**	168*	92**	180*	78**	-	78**	-	134*	168**	-
Temperate mixed	51*	59.4*	47.35*	51**	-	37.98*	168**	25.77*	-	0	59.4*	59.4**	-	-
Cool coniferous	37.37**	37.37**	37.37**	-	-	37.37**	59.4**	25.77**	-	0	37.98**	-	-	-
Temperate deciduous	51*	59.4*	47.35*	51**	-	37.98*	168**	25.77*	-	59.4*	59.4*	34.88*	59.4**	-

Note: (*) Directly reported from the original studies by forest type and geographical region. (**) Transferred from the original studies to similar COPI regions.
Source: R.B. Myneni et al. (2001); H.K. Gibbs (2007)

Table II.7 Marginal value of carbon sequestration by COPI region and forest Biome (2007€/ha/year) - Lower bound estimates.

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	240	240	240	240	-	240	382	166	-	382	244	219	-	-
Tropical	592	-	958	958	1,196	0	1,447	617	-	592	-	958	1,286	-
Warm mixed	592	592	643	862	1,080	592	1,157	502	-	502	-	862	1,080	-
Temperate mixed	328	382	304	328	-	244	1,080	166	-	-	382	382	-	-
Cool coniferous	240	240	240	-	-	240	382	166	-	-	244	-	-	-
Temperate deciduous	328	382	304	328	-	244	1,080	166	-	382	382	224	382	-

Table II.8 Marginal value of carbon sequestration by COPI region and forest Biome (2007€/ha/year) - Upper bound estimates.

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	590	590	590	590	-	590	939	407	-	939	600	537	-	-
Tropical	1,454	-	2,354	2,354	2,939	-	3,555	1,517	-	1,454	-	2,354	3,160	-
Warm mixed	1,454	1,454	1,580	2,117	2,654	1,454	2,844	1,232	-	1,232	-	2,117	2,654	-
Temperate mixed	806	939	748	806	-	600	2,654	407	-	-	939	939	-	-
Cool coniferous	590	590	590	-	-	590	939	407	-	-	600	-	-	-
Temperate deciduous	806	939	748	806	-	600	2,654	407	-	939	939	551	939	-

Table II.9 Marginal value of carbon sequestration by COPI region and forest Biome, projections in 2050 (2050€/ha/year) - Lower bound estimates.

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	864	864	864	864	-	864	1,373	596	-	1,373	878	786	-	-
Tropical	2,126	-	3,443	3,443	4,298	0	5,200	2,219	-	2,126	-	3,443	4,622	-
Warm mixed	2,126	2,126	2,311	3,097	3,882	2,126	4,160	1,803	-	1,803	-	3,097	3,882	-
Temperate mixed	1,179	1,373	1,094	1,179	-	878	3,882	596	-	-	1,373	1,373	-	-
Cool coniferous	864	864	864	-	-	864	1,373	596	-	-	878	-	-	-
Temperate deciduous	1,179	1,373	1,094	1,179	-	878	3,882	596	-	1,373	1,373	806	1,373	-

Table II.10 Marginal value of carbon sequestration by COPI region and forest Biome, projections in 2050 (2050€/ha/year) - Upper bound estimates.

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	6,712	6,712	6,712	6,712	-	6,712	10,668	4,628	-	10,668	6,821	6,106	-	-
Tropical	16,523	-	26,760	26,760	33,406	0	40,410	17,242	-	16,523	-	26,760	35,920	-
Warm mixed	16,523	16,523	17,960	24,066	30,173	16,523	32,328	14,009	-	14,009	-	24,066	30,173	-
Temperate mixed	9,160	10,668	8,504	9,160	-	6,821	30,173	4,628	-	-	10,668	10,668	-	-
Cool coniferous	6,712	6,712	6,712	-	-	6,712	10,668	4,628	-	-	6,821	-	-	-
Temperate deciduous	9,160	10,668	8,504	9,160	-	6,821	30,173	4,628	-	10,668	10,668	6,264	10,668	-

II.4 Cultural services: recreation

Data availability
The literature retrieval process comprises checking several economic databases (among others EVRI - Environmental Valuation Reference Inventory - database), reference chasing, and approaching key scholars in the field. Several keywords, such as 'willingness-to-pay', 'biodiversity, 'forestry', 'recreation', were used in order to cover the multidimensionality of forest biomes.

Several of these studies do, however, not provide usable WTP estimates. Specifically, in some studies the estimates are not clearly related to a specific good to be valued, or they are expressed in un-inconvenient unit of measure. We report in the Annexes (Table AII 1) all the case studies used for the estimation process (based on travel cost methods, contingent valuation and choice experiments). All the estimates are computed in US$2000 (standardized WTP estimates per hectare per year) and then converted into €2007.

Methodology
The methodological framework is based on the following steps:
a) Creation of a database of all available case studies selected from a worldwide literature review
b) Estimation of a meta-regression function based on suitable values
c) Application of a two-step value transfer approach
   – transfer to UK recreational sites
   – transfer to the other world countries

Meta-regression[89]

Using the WTP estimates available worldwide, a simple meta-analysis has been performed to estimate the effect of two relevant variables expected to influence significantly the magnitude of WTP figures. According to what was already observed in previous meta-analyses of WTPs for environmental conservation, the main potential explanatory factors to be considered are:
– income level, and
– size of the forest recreational site.

A simple expected utility framework can be used to describe how individuals are willing to trade wealth for increases or decreases of forest services; under the conventional assumption that the estimated marginal valuation of forest cultural services (non market) decreases with an increase in the forest size, and increases with an increase of the income level (Hammitt, 2000).

[89] The meta-regression is based on the case studies reported in table 1 of the Annex. Part of the literature review and computations of standardized marginal values per hectare per year in US$2000 has been conducted within Ojea, E., Nunes, P.A.L.D. and M.L.G. Loureiro (2008) "Impacts of Climate Change and Biodiversity Effects: Evidence from a Worldwide Meta-analysis on Forest Ecosystem Values", mimeo, Fondazione ENI Enrico Mattei, Venice, Italy.

The meta-regression function can therefore be written in the following equation:

(5) $$V = f(S, I)$$

Where:

V	=	the marginal value (willingness to pay, WTP) of a given recreational site (*effect size*). Depending on the unit of measure used for the WTP estimation of the recreational site, V can be a WTP/household or a WTP/hectare.
S	=	the size of the recreational forest area [hectares]
I	=	the income level [measure as PPPGDP]

By running the regression function expressed by equation (5):

(6) $$\log V = \alpha + \beta \log S + \gamma \log I$$

we can therefore obtain an estimate of the marginal effect − on the recreational value of a given site, V − of the following factors:

- β : size of the forest recreational site, and
- γ : income level of the country where the site is.

These coefficients are used for the geographical as well as the inter-temporal value-transfer.

<u>Value transfer (two-step approach)</u>

(a) Value transfer to UK forest recreational sites

Building on the results of the meta-analysis, we can apply a simple value transfer exercise to measure the total annual value of a forest recreational site not estimated by previously performed original case-studies (named the 'policy site').

In doing this, we focus on one single exemplar country that provides a representative picture of forest recreation and consider all the existing recreational sites. Of all the countries the UK appears to be most suitable country for this purpose since it has many studies on the value of recreation for different forest types are already available in the economic literature. In addition, UK has a rich and completed database containing the information of protected habitats, so called Special Areas of Conservation (SACs) in the country. By definition, the SACs are strictly protected sites designated under the EC Habitats Directive. For the sake of present study, only the forest related SACs are considered as designated to recreational use.

The table below provides the valuation framework of the value-transfer for UK forest recreational sites. H denotes the size of the forest recreational site, and V denotes the marginal value of the site (per hectare).

Site	Size (ha)	Value
1	H_1	$V_{Policy-site1} = V_{study-site3}(H_{Ps1} / H_{Ss})^{\beta}$
2	H_2	$V_{Policy-site2} = V_{study-site3}(H_{Ps2} / H_{Ss})^{\beta}$
3	H_3	V_{Ss} (from an original case study, the so called *study site*)
..	...	....
..	...	...
N	H_n	
	$\sum_n H_n$	$\sum_n V_n$

Note: Sites not valued by previously performed studies are named *policy sites*; the site already valued is named *study sites*. In particular the study site used for this exercise is Scarpa, R., S. M. Chilton, W. G. Hutchinson, J. Buongiorno (2000).

The marginal annual value (WTP/ha/year, V_{UK}) of a recreational forest site in UK is estimated as follows:

(7)
$$V_{UK} = \sum_n V_n \Big/ \sum_n H_n$$

(b) Value transfer from UK to the other world countries

In the second step value transfer, we have used the γ income coefficient and the β forest recreation site coefficient to transfer the UK marginal value for forest recreation, V_{UK}, to each country *i* classified by the *r-th* OECD region considered in the COPI project. The transfer function is written in equation (8).

(8)
$$V_i = V_{uk}\left(\frac{N_i}{N_{uk}}\right)\left(\frac{Sr_{uk}}{Sr_i}\right)^{\beta}\left(\frac{PPPGDP_i}{PPPGDP_{uk}}\right)^{\gamma}$$

Where:

V_i	=	estimated value/ha/year for country *i*
V_{uk}	=	estimated value/ha/year for UK
Sr_i	=	forest area designated to recreation in country *i*
S_{uk}	=	forest area designated to recreation in UK
N_i	=	number of households in country *i*
N_{uk}	=	number of households in UK
$PPPGDP_i$	=	GDP adjusted for PPP (purchasing power parity) in country *i*
$PPPGDP_{uk}$	=	GDP adjusted for PPP (purchasing power parity) in UK
i	=	country

Information about forest areas (ha) designated to recreational activities are provided by country by FAO/FRA 2005.

For projections in 2050, values have been adjusted using population projections and *PPPGDP* projections and using the γ coefficient for income estimated in the meta-regression.

Results
The results of the meta-regression for recreational forest sites are reported in Table AII 11. A total number of 59 observations are used for the regression, as each case study might provide more observations. The β coefficient on forest recreation size (logSIZE) is negative and significant, showing that the estimated marginal value of recreation decreases with a marginal increase in forest area. The γ coefficient on income (logINCOME) is positive and significant, showing that the estimated marginal value of recreation increases with a marginal increase in income.

Table II.11 Results of the meta-regression function for forest recreational values.

Dependent variable	Coefficient (std.error)	T-value
LogWTP		
Independent variables (explanatory factors)		
constant	3.274 (3.698)	0.89
LogSIZE	-0.445 (0.073)	-6.14
LogINCOME	0.599 (0.352)	1.70
Nobs	59	
R^2	0.452	
Adj R^2	0.433	

Tables II.12 and II.13 show results for annual marginal values of forest recreational services by COPI region and forest biome, in €2007 and €2050 (not discounted). These estimated marginal values can thus be applied to derive total values attributable to forest areas designated to recreation.

II.5 Cultural services: passive use

Data availability
The literature retrieval process comprises checking several economic databases (among others EVRI - Environmental Valuation Reference Inventory), reference chasing, and approaching key scholars in the field. Several of these studies do, however, not provide usable WTP estimates. Specifically, in some studies the estimates are not related to a given forest typology as a whole, but they rather refer to some local plant species that grow in the forest area, and thus the related estimates can not be taken as estimates of passive use values in the conventional proper meaning.

We report in the Annexes to this COPI Annex all the case studies used for the estimation process (based on contingent valuation and choice experiments). All the estimates are computed in US$2000 (standardized WTP estimates per hectare per year) and then converted into €2007.

Table II.12 Marginal value (WTP estimates) of recreational forest services by COPI region and forest biome (2007€/ha/year).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	0.46	1.33	3.28	0.11	-	0.28	2.50	4.74	-	2.28	0.20	0.30	-	-
Tropical	0.46	-	3.28	0.11	0.32	-	2.50	4.74	-	2.28	-	0.30	0.57	-
Warm mixed	0.46	1.33	3.28	0.11	0.32	0.28	2.50	4.74	-	2.28	-	0.30	0.57	-
Temperate mixed	0.46	1.33	3.28	0.11	-	0.28	2.50	4.74	-	-	0.20	0.30	-	-
Cool coniferous	0.46	1.33	3.28	-	-	0.28	2.50	4.74	-	-	0.20	-	-	-
Temperate deciduous	0.46	1.33	3.28	0.11	-	0.28	2.50	4.74	-	2.28	0.20	0.30	0.57	-

Table II.13 Marginal value (WTP estimates) of recreational forest services by COPI region and forest biome, projections in 2050 (2050€/ha/year).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	0.94	2.74	6.75	0.22	-	0.58	5.15	9.76	-	4.70	0.41	0.62	-	-
Tropical	0.94	-	6.75	0.22	0.66	-	5.15	9.76	-	4.70	-	0.62	1.17	-
Warm mixed	0.94	2.74	6.75	0.22	0.66	0.58	5.15	9.76	-	4.70	-	0.62	1.17	-
Temperate mixed	0.94	2.74	6.75	0.22	-	0.58	5.15	9.76	-	-	0.41	0.62	-	-
Cool coniferous	0.94	2.74	6.75	-	-	0.58	5.15	9.76	-	-	0.41	-	-	-
Temperate deciduous	0.94	2.74	6.75	0.22	-	0.58	5.15	9.76	-	4.70	0.41	0.62	1.17	-

Methodology
The methodological framework is based on the following steps:

a) Creation of a database of all available case studies selected from literature review (world)
b) Selection of some representative case studies for each forest biome and for some COPI world region
c) Estimation of a meta-regression function based on usable values
d) Application of a two-steps value transfer approach:
   - transfer from country level to the corresponding COPI world region
   - transfer from the estimated COPI world regions to the other COPI regions

Meta-regression[90]

We select a set of studies that provide estimations of the passive value of a given forest type as a whole. We only select those studies that provide WTP per hectare or WTP per household. We thus collect a set of suitable values for each forest type and OECD world region. These studies have been used for the meta-regression function, in order to estimate the effect of income level and forest size designated to conservation of biodiversity, as in equation (9):

(9) $$\log V = \alpha + \beta \log S + \gamma \log I$$

Where:

V = the marginal value (willingness to pay, WTP) for passive use of a given forest site designated to conservation of biodiversity (*effect size*). Depending on the unit of measure used for the WTP estimation, V can be a WTP/household or a WTP/hectare.

S = the size of the forest area designated to conservation [hectares]

I = the income level [measure as PPPGDP]

By running the following regression function:

(10) $$\log V = \alpha + \beta \log S + \gamma \log I$$

We can therefore obtain an estimate of the marginal effect – on the passive use value of a given site, V – of the following factors:

- β : size of the forest area designated to conservation of biodiversity, and
- γ : income level of the country where the site is.

These coefficients are used for the geographical as well as the inter-temporal value-transfer.

[90] The meta-regression is based on the case studies reported in table 2 of the Annex. Part of the literature review and computations of standardized marginal values per hectare per year in US$2000 has been conducted within Ojea, E., Nunes, P.A.L.D. and M.L.G. Loureiro (2008) "Impacts of Climate Change and Biodiversity Effects: Evidence from a Worldwide Meta-analysis on Forest Ecosystem Values", mimeo, Fondazione ENI Enrico Mattei, Venice, Italy.

Value transfer (two-step approach)

The value-transfer exercise is based on a two-step approach.

(a) Value transfer–from country level to the corresponding COPI region

Table II.14 reports the original case studies selected for the first step value-transfer. When several representative case studies are available, the mean marginal value has been used.

Table II.14 Original studies selected for the first step value-transfer.

OECD world Region	Original case study	Reference study	Forest type
EUR	UK	Garrod, G.D. and Willis, K. G. (1997) Hanley, N., Willis, K, Powe, N, Anderson, M. (2002) ERM Report to UK Forestry Commission (1996)	Temperate
EUR	Finland	Kniivila, M., Ovaskainen, V. and Saastamoinen, O. (2002) Siikamaki, Juha (2007)	Boreal
EUR	Spain	Mogas, J., Riera, P. and Bennett, J. (2006)	Warm mixed
NAM	USA	Phillips, S., Silverman, R. (2007) Loomis and Ekstrand (1998) Walsh, R.G., J. B. Loomis and R. A. Gillman (1984)	Temperate
BRA	Brazil	Horton, B., Colarullo, G., Bateman, I., Peres, C. (2003)	Tropical
CHN	China	Kontoleon, A. and Swanson, T. (2003)	Temperate
AFR	Madagascar	Kramer, R.A., Sharma, N., and Munashinghe, M. (1995)	Tropical

We adjust the mean value taken from the above mentioned case studies, in order to take into account the effect of the size of the forest area under valuation, according to the following formula:

(11) $$V_{wr,b} = V_{i,b}\left(\frac{Sc_{i,b}}{Sc_{wr,b}}\right)^{\beta}$$

Where:

$V_{wr,b}$ = estimated value/ha/year by world COPI region *wr* and forest biome *b*

$V_{i,b}$ = value/ha/year for country *i* by forest biome *b* (from representative case studies for different forest biomes)

$Sc_{i,b}$ = forest area designated to conservation in country *i* by forest biome *b*

$Sc_{wr,b}$ = forest area designated to conservation in the world COPI region *wr* by forest biome *b*

i = country

wr = world COPI region

b = forest biome

For instance, for temperate mixed and temperate deciduous forests, we adjust the UK mean value to get a marginal value for the whole Europe. This has been done for each OECD region and forest biome for which some good valuation studies are available.

(b) Value transfer–from the estimated world COPI regions to the other regions

The estimated marginal values in the first step have been transferred to the other COPI regions according to the following transfer function:

$$(12) \qquad V_{WR,b} = V^*{}_{wr,b}\left(\frac{N_{WR}}{N_{wr}}\right)\left(\frac{S_{wr,b}}{S_{WR,b}}\right)^{\beta}\left(\frac{PPPGDP_{WR}}{PPPGDP_{wr}}\right)^{\gamma}$$

Where:

$V_{WR,b}$	=	estimated value/ha/year by region *WR* and forest biome *b*
$V^*_{wr,b}$	=	value/ha/year by region *wr* and forest biome *b* (first step estimation)
$Sc_{wr,b}$	=	forest area designated to conservation in region *wr* by forest biome *b*
Sc_{WRb}	=	forest area designated to conservation in region *WR* by forest biome *b*
N_{WR}	=	number of households in region *WR*
N_{wr}	=	number of households in region *wr*
$PPPGDP_{WR}$	=	GDP adjusted for PPP (purchasing power parity) in region *WR*
$PPPGDP_{wr}$	=	GDP adjusted for PPP (purchasing power parity) in region *wr*
$wr_{,b}$	=	world COPI region (first step valuation)
$W_{R,b}$	=	world COPI region (to be estimated)
b	=	forest biome

Information about forest areas (ha) designated to conservation of biodiversity are provided by country by FAO/FRA2005. For projections in 2050, values have been adjusted using population projections and PPPGDP projections (from COPI) and using the γ coefficient for income estimated in the meta-regression.

Results

The results of the meta-regression for forest passive use are reported in Table II.15.

Table AII 15. Results of the meta-regression function for forest passive use values.

Dependent variable	**Coefficient (std.error)**	**T-value**
LogWTP		
Independent variables (explanatory factors)		
constant	3. 972 (2.835)	1.40
LogSIZE	-0.603 (0.079)	-7.58
LogINCOME	0.889 (0.255)	3.49
Nobs	23	
R^2	0.797	
Adj R^2	0.797	

A total number of 23 observations are used for the regression. The β size coefficient (LogSIZE) on conservation forest area is negative and significant, showing that the estimated marginal value of passive use decreases with a marginal increase in forest area. The γ coefficient on income (logINCOME) is positive and significant, showing that the estimated marginal value increases with a marginal increase in income. If compared with the results obtained for recreational activities, these coefficients are higher, showing a higher sensitivity of forest area and income on marginal values.

Table II.16 presents the results from the first step value-transfer, estimating the marginal values from the original case study based on a country level to the corresponding COPI region.

Table II.16 Value transfer results of passive use values from country level to the corresponding COPI region (US$, measured in 2007).

Forest type	Original case study country	COPI region	Designated forest area for conservation in the studied country (ha)	Designated forest area for conservation in EU (ha) (FAO/FRA 2005)	Value transfer of marginal value by forest type for Europe (2007$/ha)
Temperate	UK	EUR	42,988	12,602,559	119
Boreal	Finland	EUR	267,455	7,022,622	99
Warm mixed	Spain	EUR	274,235	1,745,662	254
Temperate	USA	NAM	11,524,983	21,912,059	501
Tropical	Brazil	BRA	16,350,329	16,350,329	53
Temperate	China	CHN	210,908	449,327	203
Tropical	Madagascar	AFR	4,143,307	33,898,452	10

Tables II.17 and II.18 show final results about annual marginal values for forest passive use services by COPI region and forest biome, in €2007 and €2050 (not discounted). Some of the marginal values displayed have been estimated in the first step value-transfer, for which representative original studies exist (*), while the others (**) have been estimated by transferring these latter to the other COPI regions taking into account the forest type.

These estimated marginal values can be applied to derive total values of passive use applicable to forest areas designated to natural conservation. Note that some of the very high values per hectare arise when the forest areas of that type of biome are very small (e.g. "tropical biomes" in Japan).

II.6. Conclusions

This section reports the methodology and the estimation of some of the services provided by forest biomes in different world areas, by applying consolidated methods for the monetary valuation of market and non-market goods. The objective is to provide a methodological framework for estimating marginal values and an outline on how to use value-transfer techniques.

Table II.17 Marginal value (WTP estimates) of passive use by COPI region and forest biome (2007€/ha/year).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	22**	99*	855**	11**	-	2**	87**	113**	-	471**	14**	17**	-	-
Tropical	947**	-	7,404**	62**	53*	-	171**	847**	-	59**	-	30**	10*	-
Warm mixed	60**	254*	1,102**	3**	17**	243**	42**	108**	-	39**	-	7**	26**	-
Temperate mixed	501*	119*	293**	153**	-	8**	29**	203*	-	-	6**	8**	-	-
Cool coniferous	34**	99*	350**	-	-	3**	88**	185**	-	-	12**	-	-	-
Temperate deciduous	501*	119*	145**	46**	-	16**	42**	203*	-	207**	12**	57**	113**	-

Note: (*) First step value-transfer estimates. (**) Second step value-transfer estimates.

Table II.18 Marginal value (WTP estimates) of passive use by COPI region and forest biome, projections in 2050 (2050€/ha/year).

Forest Biomes	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
Boreal	59	212	1,482	30	-	7	579	678	-	2,107	61	53	-	-
Tropical	2,511	-	12,837	164	142	-	1,146	5,095	-	262	-	96	62	-
Warm mixed	159	546	1,910	8	46	1,028	279	648	-	175	-	22	160	-
Temperate mixed	1,328	256	508	404	-	35	193	1,221	-	-	28	25	-	-
Cool coniferous	90	212	607	-	-	13	589	1,113	-	-	50	-	-	-
Temperate deciduous	1,328	256	252	122	-	69	281	1,221	-	925	50	182	692	-

The forest area designated to conservation of biodiversity is reported in Table AII 19 (FAO/FRA2005), aggregating data by COPI region.

Table II.19 Designated forest area for conservation of biodiversity in % (FRA2005 DATA).

COPI Region	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	MEA	OAS	ECA	OLC	AFR	PLR
	10.5	10.2	7.5	23.9	8.1	8.7	21.9	2.7	-	30.6	17.5	24.29	18.11	-

Source: FAO/FRA2005 DATA

The valuation framework has been applied to forest biomes, and specifically to key ecosystems services identified following the Millennium Ecosystem Assessment (MEA, 2005) taxonomy: provisioning services (wood forest products and non-wood forest products), regulating services (carbon sequestration), and cultural services (recreation and passive use values). This selection has been based on the availability of data and on their relevance to decision-making. The estimation of such services, although not covering the full range of forest instrumental values, will allow the quantification of those values which are expected to be relevant to context where it is necessary to make decisions and trade one value against the other. Other economic values of similar importance have not been covered here due to data and time constraints. Both market and non-market valuation techniques can be applied; however, the COPI project mainly relies on the existing body of knowledge already available in the literature to draw suitable marginal values for forest services, to be scaled up at the global (OECD regions) level using proper transfer protocols.
Based on the nature of the ecosystem service of concern, we have identified the valuation methodologies already available in the literature for the monetary estimation. Provisioning services have been valued using a market-based approach (based on market prices). Carbon sequestration valuation is based on the Marginal Damage Cost (MDC) approach and the marginal avoidance cost (MAC), with the latter resulting in higher estimates then the first. Finally, cultural services are estimated using non-market valuation methods, based on both stated and revealed preferences approaches (travel cost method, contingent valuation and choice experiments). The valuation framework has been built on the COPI's global perspective, according to which the estimates should cover, for each ecosystem service, the highest variability in terms of geographical regions and forest biomes. In this context meta-analysis and value-transfer techniques appear to be the most suitable for cultural services valuation.
Regarding provisioning services, the valuation framework is comprised of two main phases: (i) calculation of total annual values, based on FAO export values at country level by different industrial sectors, and adjusted for domestic production and profits, and (ii) calculation of marginal values taking into account the forest size designated to production only. Marginal values for forest provisioning services have been therefore estimated taking into account the industrial sector (product category, wood forest products and non-wood forest products), the country of production, the forest type, and the size of the forest designated to production (plantations).
Carbon stocks have been estimated by identifying the capacity of carbon sequestration by forest type and country, and applying the monetary value estimated in the EU project CASES (Cost Assessment of Sustainable Energy System), based on damage and avoidance cost methodologies.

For cultural values, the meta-analysis has produced significant results in terms of the marginal effect of forest size and income level on the marginal value of the forest site, showing, as expected under the conventional assumptions, that the estimated marginal non-market value of forest cultural services decreases with an increase of the forest size, and increases with an increase of the income level. Value-transfer methodologies have been applied in order to transfer the estimates available from the original studies to the new policy contexts for which no original study exist. The value-transfer exercise has been developed based on a two-step approach. For recreational values we have first estimated marginal values for United Kingdom which provides a representative picture of forest recreation (value-transfer to UK forest recreational sites). The marginal value estimated for UK has been transferred to all the other COPI regions in the second step of the calculation. For passive use values, in the first step we estimated the marginal values by forest biome in some COPI regions (by transferring the values from country level to the corresponding COPI region), while in the second step we transferred these values from the estimated COPI regions to the other COPI regions. This approach has been applied taking into account not all the forest area, but only those forest sites designated to recreation or conservation of biodiversity.

Final results show that marginal values are higher for provisioning and carbon sequestration services, compared to cultural services, the latter being based on willingness to pay estimates which are subject to individual budget constraint.

Our work suggests that any attempt to provide a monetary estimation of the services provided by biodiversity - here seen in terms of biomes- still represents a very challenging task for researchers. On the one hand this task is made difficult due to the partial lack of original valuation studies providing reliable estimates of the WTP for forest biodiversity values. On the other hand, the worldwide approach adopted here, will need to be reinforced by taking into consideration uncertainty and a lack of information on local biodiversity conditions, that are expected to influence the results of the valuation process.

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Annex II Table A1. A review of the relevant studies on recreational use of forest

Authors	Paper year	OECD regions	Country	Forest type	Standardized 2000 US$ (WTP/ha/yr)	Standardised 2000 US$ (WTP/hh/yr)
Bienabe, E. and Hearne, R.R	2006	AFR	Costa Rica	Tropical	–	$2.93-$3.28
Chase, L. C., D. R. Lee, W. D. Schulze and D. J. Anderson	1997	AFR	Costa Rica	Tropical	$4,173.10	$45.18
Emerton, L.	1999	AFR	Kenya, Mount Kenya Forest Reserve	Dry mountain and mountain rainforest	$3.84	–
Maille and Mendelsohn	1991	AFR	Madagascar	Tropical	$360-$468	–
Kramer, R.A., Sharma, N., and Munashinghe, M.	1995	AFR	Madagascar	Tropical	$10.73-$29.04	–
Naidoo, R. and Adamowicz, W.L.	2005	AFR	Uganda	Tropical	$0.59-$1.32	$46
Zandersen, M., Termansen, M., Jensen, F.S.	2005	EUR	Denmark	Temperate	$2083 (115-23,334)	$3.47
Dubgaard, A.	1998	EUR	Denmark	–	$148.99	$23.03
Kniivila, M., Ovaskainen, V. and Saastamoinen, O.	2002	EUR	Finland	Temperate	$2.60	$0.39
Clinch	1999	EUR	Ireland	Temperate	$250	$16
Scarpa, R., S. M. Chilton, W. G. Hutchinson, J. Buongiorno	2000	EUR	Ireland	Temperate	$2009.97	$455.5
Bellu and Cistulli	1997	EUR	Italy, Liguria forests	Temperate	$77-$85	–
van der Heide, C.M., van den Bergh, J.C.J.M, and Nunes, P.A.L.D.	2005	EUR	Netherlands	Temperate	$79.41	$0.22
Mogas, J., Riera, P. and Bennett, J.	2006	EUR	Spain	Mediterranean	$360.73	$54.5
Campos, P. and P. Riera	1996	EUR	Spain	Mediterranean	–	$9.05
Bostedt, G. and L. Mattsson	2006	EUR	Sweden	Boreal	$16.82	$349.4151
Bann	1998	EUR	Turkey	Temperate	$0.4	–
Gurluk, S.	2006	EUR	Turkey	Temperate	–	$62.07
Hanley, N., Wright, R.E., Adamowicz, W.L.	1998	EUR	UK	Temperate	–	$20.09
Scarpa, R., S. M. Chilton, W. G. Hutchinson, J. Buongiorno	2000	EUR	UK	Temperate	$783.74	$313.48
Bateman *et al*	1996	EUR	UK-England, Oxfordshire	Temperate	$2290	–

Annex II Table A1. A review of the relevant studies on recreational use of forest (cont.)

Authors	**Paper year**	**OECD regions**	**Country**	**Forest type**	**Standardised 2000 US$ (WTP/ha/yr)**	**Standardised 2000 US$ (WTP/hh/yr)**
Adger et al	1995	NAM	Mexico	Tropical	$1	–
Phillips, S., Silverman, R.	2007	NAM	USA, Alaska	Temperate	$8.84	–
Gilbert et al	1992	NAM	USA, Vermont	Temperate	–	$9.04-$10.42
Bann	1999	OAS	Malaysia	Tropical	$3	–
van Beukering, P.J.H., Cesar, H.S.J., Janssen, M.A.	2003	OAS	Indonesia	Tropical	$0.04	–
Hodgson and Dixon	1988	OAS	Philippines	Tropical	$650	–
Shultz, Pinazzo and Cifuentes	1998	OLC	Costa Rica	Tropical	$950-$2305	–
Tobias and Mendelsohn	1991	OLC	Costa Rica, Monteverde rainforest	Tropical	$160	–
Ammour et al	2000	OLC	Nicaragua	Tropical	$70-$130	–
Verma, M.	2000	SOA	India, Himachal Pradesh	Varied (tropical, sub-tropical, montane temperate, sub –alpine and alpine)	$391	–

Annex II Table A2 A review of the relevant studies on passive use of forest valuing biodiversity conservation programs

Authors	Paper year	OECD regions	Country	Forest type	Does the forest have special status?	Standardised 2000 US$ (WTP/ha/yr)	Standardised 2000 US$ (WTP/hh/yr)
Kramer, R.A., Sharma, N., and Munashinghe, M.	1995	AFR	Madagascar	Tropical	Protected area and biodiversity hotspot	$29.04	–
Horton, B., Colarullo, G., Bateman, I., Peres, C.	2003	BRA	Brazil, Amazon -	Tropical	NO	$43	–
Kontoleon, A. and Swanson, T..	2003	CHN	China, Sichuan Province	Temperate	Protected area and biodiversity hotspot	$259	$15.40-$6.67
Siikamaki, Juha	2007	EUR	Finland	Temperate	Biodiversity hotspots	$667.74-697.42	$45-47
Kniivila, M., Ovaskainen, V. and Saastamoinen, O.	2002	EUR	Finland, North Karelia Province	Old growth, temperate	NO	$337	$50
Mogas, J., Riera, P. and Bennett, J.	2006	EUR	Spain, Catalonia	Mediterranean	NO	–	$39-64 CVM and $59-65 CE
Hanley, N., Willis, K, Powe, N, Anderson, M.	2002	EUR	UK	Temperate	NO	Upland conifer: $943; Lowland conifer: $891; Lowland ancient semi-natural broadleaved: $3048; Lowland new broadleaved: $2265; Upland native broadleaved: $2427; Upland new native broadleaved: $1645.	Upland conifer: $.49; Lowland conifer: $.41; Lowland ancient semi-natural broadleaved: $1.59; Lowland new broadleaved: $1.18; Upland native broadleaved: $1.27; Upland new native broadleaved: $.86.

Annex II Table A2 A review of the relevant studies on passive use of forest valuing biodiversity conservation programs (contd).

Authors	Paper year	OECD regions	Country	Forest type	Does the forest have special status?	Standardised 2000 US$ (WTP/ha/yr)	Standardised 2000 US$ (WTP/hh/yr)
ERM	1996	EUR	UK (all forests)	Temperate	NO	$846-1685	$11.04-21.99
Garrod, G.D. and Willis, K. G.	1997	EUR	UK (remote forest areas: rarely visited)	Temperate	NO	$3899 - 4299	$0.506-0.558
Loomis and Ekstrand	1998	NAM	USA	Temperate	unknown	$4,400	$102
Phillips, S., Silverman, R.	2007	NAM	USA, Alaska	Old-growth temperate	Protected areas	$24	–
Walsh et al	1984	NAM	USA, Colorado	Temperate	unknown	$12-45	–
Verma, M.	2000	SOA	India, Himachal Pradesh	Varied (tropical, sub-tropical, montane temperate, sub -alpine and alpine)	NO	$435	–

Annex III Invasive alien species and their global impacts

Patrick ten Brink, Niele Peralta-Bezerra and Marianne Kettunen

III.1 Introduction

Invasive Alien Species (IAS) are '*non-native species that are introduced deliberately or unintentionally outside their natural habitats where they become established, proliferate and spread in ways that cause damage to human interests*' (Convention on Biodiversity, CBD)[91].

IAS occur in all major taxonomic groups. They include viruses, fungi, algae, mosses, ferns, higher plants, invertebrates, fish, amphibians, reptiles, birds and mammals (see Box III. 2 for details of 100 of the most important IASs). The invasive alien species can travel from a source country to their destination (affected area) via a range of pathways including via land (e.g. car, truck or migration), sea or river (e.g. via ballast water, or hull fouling, or escapee fish) and air (e.g. air traffic or airborne IAS) using a range of different vectors (e.g. being carried by animals, humans or different vehicles). Some are introduced intentionally and some unintentionally (see Box III.1).

Box III.1: Introduction of IAS

Intentional introduction, i.e. the deliberate movement and/or release by humans of an alien species outside its natural range (COP 6, decision VI/23);

- The intentional release of IAS into the wild for economic needs (e.g. bio-control agents for control or eradication of invasive alien species, weeds, horticulture, trade in pets and aquarium species)
- Import of species and trade of IAS (e.g. as ornamental plants, pets).
  Unintentional introduction, i.e. all other introductions which are not intentional (COP 6, decision VI/23)
- Unintentional introduction includes a large number of sectors, such as fisheries, agriculture, forestry, horticulture, shipping, ground and air transportation, construction projects, landscaping, aquaculture, tourism, the pet industry, game-farming.

The growth of global trade and the increased mobility of people are directly contributing to the mixing of wildlife across bio-geographical boundaries. Species that appear in new environments may fail to survive, but in a number of occasions they thrive, and become invasive. IAS are currently considered to be the second most important threat to biodiversity at the global level and it has been estimated that 480,000 IAS have been introduced into different ecosystems on earth (Pimentel *et. al*., 2001). Invasive alien species have invaded and affected virtually every ecosystem type across the regions on Earth (see Table III.1). Most nations are already struggling with complex and costly invasive species problem (GISP, 2001). Addressing the problems of invasive alien species is vital because the threat is constantly growing and the economic and environment impact are known to be severe. In general, the cost of early action is generally less that that of delayed action. Similarly, benefits of

[91] See http://www.biodiv.org/programmes/cross-cutting/alien/default.shtml

action are generally greater – often by several orders of magnitude – than the costs (see chapter 4).

Box III.2: List of the most invasive species around the World

It is very difficult to identify the 100 worst IAS from around the world. Species and their interactions with ecosystems are very complex and have different impacts. For example, some species may have invaded only a restricted region, but have a high probability of expanding and causing further great damage (e.g. see *Boiga irregularis*: the brown tree snake). Other species may already be globally widespread and causing cumulative but less visible damage. However, this list illustrates the variety of species that have the ability, not just to travel in ingenious ways, but also to establish, thrive and dominate in new places. This is a selection from the global invasive species database (IUCN, 2005).

100 OF THE WORLD'S WORST INVASIVE ALIEN SPECIES

MICRO-ORGANISM

avian malaria	*(Plasmodium relictum)*
banana bunchy top virus	*(Banana bunchy top virus)*
rinderpest virus	*(Rinderpest virus)*

MACRO-FUNGI

chestnut blight	*(Cryphonectria parasitica)*
crayfish plague	*(Aphanomyces astaci)*
Dutch elm disease	*(Ophiostoma ulmi)*
frog chytrid fungus	*(Batrachochytrium dendrobatidis)*
phytophthora root rot	*(Phytophthora cinnamomi)*

AQUATIC PLANT

caulerpa seaweed	*(Caulerpa taxifolia)*
common cord-grass	*(Spartina anglica)*
wakame seaweed	*(Undaria pinnatifida)*
water hyacinth	*(Eichhornia crassipes)*

LAND PLANT

African tulip tree	*(Spathodea campanulata)*
black wattle	*(Acacia mearnsii)*
Brazilian pepper tree	*(Schinus terebinthifolius)*
cogon grass	*(Imperata cylindrica)*
cluster pine	*(Pinus pinaster)*
erect pricklypear	*(Opuntia stricta)*
fire tree	*(Myrica faya)*
giant reed	*(Arundo donax)*
gorse	*(Ulex europaeus)*
hiptage	*(Hiptage benghalensis)*
Japanese knotweed	*(Fallopia japonica)*
Kahili ginger	*(Hedychium gardnerianum)*
Koster's curse	*(Clidemia hirta)*
kudzu	*(Pueraria montana var. lobata)*
lantana	*(Lantana camara)*
leafy spurge	*(Euphorbia esula)*
leucaena	*(Leucaena leucocephala)*
melaleuca	*(Melaleuca quinquenervia)*
mesquite	*(Prosopis glandulosa)*
miconia	*(Miconia calvescens)*
mile-a-minute weed	*(Mikania micrantha)*
mimosa	*(Mimosa pigra)*
privet	*(Ligustrum robustum)*
pumpwood	*(Cecropia peltata)*
purple loosestrife	*(Lythrum salicaria)*
quinine tree	*(Cinchona pubescens)*
shoebutton ardisia	*(Ardisia elliptica)*

LAND PLANT (CONTINUED)

Siam weed	*(Chromolaena odorata)*
strawberry guava	*(Psidium cattleianum)*
tamarisk	*(Tamarix ramosissima)*
wedelia	*(Sphagneticola trilobata)*
yellow Himalayan raspberry	*(Rubus ellipticus)*

AQUATIC INVERTEBRATE

Chinese mitten crab	*(Eriocheir sinensis)*
comb jelly	*(Mnemiopsis leidyi)*
fish hook flea	*(Cercopagis pengoi)*
golden apple snail	*(Pomacea canaliculata)*
green crab	*(Carcinus maenas)*
marine clam	*(Potamocorbula amurensis)*
Mediterranean mussel	*(Mytilus galloprovincialis)*
Northern Pacific seastar	*(Asterias amurensis)*
zebra mussel	*(Dreissena polymorpha)*

LAND INVERTEBRATE

Argentine ant	*(Linepithema humile)*
Asian longhorned beetle	*(Anoplophora glabripennis)*
Asian tiger mosquito	*(Aedes albopictus)*
big-headed ant	*(Pheidole megacephala)*
common malaria mosquito	*(Anopheles quadrimaculatus)*
common wasp	*(Vespula vulgaris)*
crazy ant	*(Anoplolepis gracilipes)*
cypress aphid	*(Cinara cupressi)*
flatworm	*(Platydemus manokwari)*
Formosan subterranean termite	*(Coptotermes formosanus shiraki)*
giant African snail	*(Achatina fulica)*
gypsy moth	*(Lymantria dispar)*
khapra beetle	*(Trogoderma granarium)*
little fire ant	*(Wasmannia auropunctata)*
red imported fire ant	*(Solenopsis invicta)*
rosy wolf snail	*(Euglandina rosea)*
sweet potato whitefly	*(Bemisia tabaci)*

AMPHIBIAN

bullfrog	*(Rana catesbeiana)*
cane toad	*(Bufo marinus)*
Caribbean tree frog	*(Eleutherodactylus coqui)*

FISH

brown trout	*(Salmo trutta)*
carp	*(Cyprinus carpio)*
large-mouth bass	*(Micropterus salmoides)*

FISH (CONTINUED)

Mozambique tilapia	*(Oreochromis mossambicus)*
Nile perch	*(Lates niloticus)*
rainbow trout	*(Oncorhynchus mykiss)*
walking catfish	*(Clarias batrachus)*
Western mosquito fish	*(Gambusia affinis)*

BIRD

Indian myna bird	*(Acridotheres tristis)*
red-vented bulbul	*(Pycnonotus cafer)*
starling	*(Sturnus vulgaris)*

REPTILE

brown tree snake	*(Boiga irregularis)*
red-eared slider	*(Trachemys scripta)*

MAMMAL

brushtail possum	*(Trichosurus vulpecula)*
domestic cat	*(Felis catus)*
goat	*(Capra hircus)*
grey squirrel	*(Sciurus carolinensis)*
macaque monkey	*(Macaca fascicularis)*
mouse	*(Mus musculus)*
nutria	*(Myocastor coypus)*
pig	*(Sus scrofa)*
rabbit	*(Oryctolagus cuniculus)*
red deer	*(Cervus elaphus)*
red fox	*(Vulpes vulpes)*
ship rat	*(Rattus rattus)*
small Indian mongoose	*(Herpestes javanicus)*
stoat	*(Mustela erminea)*

Species were selected for the list using two criteria: their serious impact on biological diversity and/or human activities, and their illustration of important issues of biological invasion. To ensure a wide variety of examples, only one species from each genus was selected. **Absence from the list does not imply that a species poses a lesser threat.**

Development of the *100 of the World's Worst Invasive Alien Species* list has been made possible by the support of the Fondation d'Entreprise TOTAL (1998 - 2000).

For further information on these and other invasive alien species consult The *Global Invasive Species Database*:

www.issg.org/database

More information on the IAS list of "*100 of the World's Worst Invasive Alien Species*" is available at http://www.issg.org/database/welcome/

Table III.1: Invasive Alien Species - Examples from across the world and across ecosystems

		Forest and Woodland		**Savannah, Grassland, scrubland and steppe**		**Aquatic**	**Marine and Coastal**	**Urban**
	Continents/Countries	**Natural Forest**	**Management Plantation Forest**	**Natural**	**Agriculture**	**Rivers/lakes - fresh water**	**Saline (includes fisheries, marine ecosystems, coral reefs)**	**Parks, gardens, etc**
	North America	Insect: Thai scale *Aulacaspis yasumatsui* (e.g. Florida)	Plant: Garlic Mustard *Alliaria petiolata* Herb: fig buttercup *Ranunculus ficaria*	Shrub: *Euonymus alata* (e.g. Florida)	Weed: Japanese Knotweed *Fallopia japonica*	Reptile: Northern snakehead. *Channa argus*	Crustacea: Chinese mitten crab. *Eriocheir sinensis*/ Zebra mussel. Dreissena polymorph	Tree: Japanese camphor: *Cinnamomum camphora*
	Europe	Shrub: *Berberis thunbergii* (e.g. Poland, Finland, Italy, Austria, Denmark, Germany, Netherlands)	Mammal: Grey Squirrel. *Sciurus carolinensis* (e.g. UK)	Grass: smooth brome *Bromus inermis*	Herb: *Ambrosia artemisiifolia Linnaeus*	Mammal: *Myocastor coypus*/ Bird: Ruddy duck. *Oxyura jamaicensis*	Sea Weed: *Caulerpa taxifolia*	Insect: ladybird. *Harmonia axyridis* (e.g. UK)
	Asia (Japan & Korea)	Mammal: Indian musk *Suncus murinus* Philippines, Japan and Singapore	Insect: Formosan subterranean termite *Coptotermes formosanus*	Shrub: *Abelmoschus moschatus* (e.g. Fiji and Tonga)	Grass: *Urochloa maxima* or *Panicum maximum*	Amphibian: giant American toad. *Bufo marinus*	Mollusc: The European flat oyster. *Ostrea edulis* (e.g. Japan)	Mammal: Pacific rats *Rattus exulans*
	Pacific (Australia & New Zealand)	Reptile: ambon lizard Varanus indicus	Tree: wait-a-bit *Caesalpinia decapetala*	Mammal: Old World rabbit *Oryctolagus cuniculus*	Herb: musk thistle. *Carduus nutans*	Aquatic Plant: reed sweet grass. *Glyceria maxima*	Fish: Japanese river goby *Acanthogobius flavimanus*	Bird: Indian myna *Acridotheres tristis*
	Brasil	Tree: black plum *Syzygium cumin mammal: Lepus europaeus*	Tree: *Pinus spp.* Tree: Japanese raisin tree. *Hovenia dulcis*	Grass: South African weeping grass	Grass: brachiaria grass *Brachiaria spp*	Weed: Brazilian waterweed. *Egeria densa*	Mussels: Golden mussels *Limnoperma fortunei*	Snail: African snail *Achatina fulica* *Bird:Mimosa caesalpiniifolia*
		Herb: wandering willie *Tradescantia fluminensis*	Mammal: American beaver. *Castor canadensis*	Grass: cheatgrass **Bromus tectorum**	Grass: cheatgrass *Bromus tectorum* (e.g. southern Russia)	Fish: eastern snakehead *Channa argus*	*Crustacea: fishhook waterflea. Cercopagis pengoi*	Insect: khapra beetle (Trogoderma granarium)
		Tree: sissoo *Dalbergia sissoo* (e.g. Malaysia, Indonesia, Thailand, Sri Lanka)	Herb: bitter bush *Chromolaena odorata (e.g. Indonesia)*	Tree: sweet acacia *Acacia farnesiana*	Insect: cotton whitefly *Bemisia tabaci*	Aquatic plant: alligator weed *Alternanthera philoxeroides*	Coral: coral-eating starfish *Acanthaster planci*	Herb: sensitive grass *Mimosa pudica*

		Forest and Woodland		**Savannah, Grassland, scrubland and steppe**		**Aquatic**	**Marine and Coastal**	**Urban**
	Continents/Countries	**Natural Forest**	**Management Plantation Forest**	**Natural**	**Agriculture**	**Rivers/lakes - fresh water**	**Saline (includes fisheries, marine ecosystems, coral reefs)**	**Parks, gardens, etc**
		Insect: pine mealybug *Oracella acuta*	Nematode: pinewood nematode *Bursaphelenchus xylophilus*	Grass: missiongrass *Pennisetum polystachion*	Mollusc: apple snail *Pomacea canaliculata* (e.g. southern China)	Aquatic plant: hornwort *Ceratophyllum demersum*	Algae: naked dinoflagellate *Gymnodinium catenatum*	climber: cat-claw creeper/ *Macfadyena unguis-cati*
	Middle East	Bird: red-whiskered bulbul	Insect: white-footed ant. *Technomyrmex albipes*	Bird: Colombo crow *Corvus splendens* (e.g. Israel and Jordan	Tree: black locust *Robinia pseudoacacia* (e.g.Cyprus) Grass: Aleppo grass *Sorghum halepense*	Fish: largemouth bass *Micropterus salmoides*	Mollus: senhouse mussel *Musculista senhousia* (e.g. Israel, Egypt)	Insect: Khapra beetle *Trogoderma granarium* (e.g. Syria, Tunisia)
	Other Asia	Tree: red sandalwood tree *Adenanthera pavonina* (e.g.Malaysia, Philippines, Taiwan)	Insect: ambrosia beetle *Xylosandrus compactus* (e.g. Malaysia, Java, Sumatra, Fiji)	Shrub*: Prosopis juliflora*	Vine, climber: passionflower *Passiflora foetida*	Fish: Chinese schemer *Hypophthalmichthys molitrix*	Herb: joyweed *Alternanthera sessilis* (e.g. Fiji)	Bird: Japanese white-eye *Zosterops japonicus*
	Eastern Europe & Central Asia	Tree: silverberry *Elaeagnus umbellata* (e.g. Afghanistan)	Tree: sissoo *Dalbergia sissoo*	Tree: silverberry *Elaeagnus umbellate* (e.g. Afghanistan)	Tree: Indian jujube *Ziziphus mauritiana* (e.g. Afghanistan)	Algae: rock snot *Didymosphenia geminata*	Fish: sea trout *Salmo trutta*	Herb: field thistle *Cirsium arvense*
	Other Latin America & Caribbean	Herb: kahili ginger *Hedychium gardnerianum*	Tree: *Dichrostachys cinerea (e.g. Jamaica)*	Tree*:* algaroba *Prosopis* spp	Tree: oleaster *Elaeagnus angustifolia L.*	Crustacean: virile crayfish *Orconectes virilis*	Mollusc: ribbed mussel *Geukensia demissa*	Insect: Asian Lady Beetle *Linepithema humile*
	Africa	Shrub: soap bush *Clidemia hirta* (e.g. Tanzania)	Vine, climber: *Anredera cordifolia*	Rinderpest (via infected cattle)	Crop weed: Trffid weed *Chromolaena odorata*	Fish: Nile perch *Lates niloticus* (e.g.Lake Victoria in East Africa)	Fish: Nile Tilapia *Oreochromis niloticus*	Tree: Black wattle *Acacia mearnsii*
		Tree: black plum *Syzygium cumini*	Tree: Blackwood *Acacia melanoxylon*	Mammal: Sheep *Ovis aries*	Insect: Argetina Ant *Linepithema humile*	Fish: goldfish. *Carassius auratus* Fish: rainbow trout *Oncorhynchus mykiss*	Algae: red alga *Acanthophora spicifera*	Snail: giant African land snail. Achatina fulica

III.2 Impacts of invasive alien species

Types of impacts

Invasive alien species have led and continue to lead to a wide range of impacts ecological and socio-economic impacts including changes in species composition and dynamics, habitat characteristics, provisioning of ecosystem services (e.g. provision of food, water retention and regulation of erosion and forest fires). IAS also have negative impacts on health and they cause damage to infrastructure. Box III. 3 presents the list of ecological problems IAS are known to cause.

Box III. 3: **List of IAS negative ecological impacts**

- **Competing with other organisms** (e.g. plants like Japanese knotweed - *Fallopia japonica* or the Giant hogweed - *Hercleum mantegazzianum*) and change habitat structure
- **Predating** on native organisms (e.g. the fish Nile perch - *Lates niloticus* causing the extinction or near-extinction of several hundred native species in Africa)
- **Hybridising** with a related species or varieties, such as the North American grass *Spartina alterniflora* which hybridized with the European *Spartina maritima* and produced the very invasive hybrid *Spartina anglica*, which has radically changed coastal mudflat habitats in Great Britain, Denmark and Germany
- **Causing extinction** of native species, e.g. displacement of native species is known for the invasive multicoloured Asian ladybeetle (by intra-guild predation) and the Argentine ant (superior competitiveness)
- Being **toxic** (toxic algae blooms caused by alien phytoplankton such as *Chattonella verruculosa* and *Alexandrium* species)
- Being a reservoir for **parasites** or a **vector** for pathogens (rainbow trout which is a host for the salmon parasite *Gyrodactylus salaris* , signal crayfish which is a carrier and host of the crayfish plague)
- **Disrupting pollination** (e.g. *Impatiens glandulifera*. The alien plant competes for pollinators such as bumblebees with the native riverbank species, and so reduces seed set in these other plants)
- **Altering energy and nutrient flows**, as well as physical factors in habitats and ecosystems (freshwater plants like the Canadian waterweed (*Elodea canadensis*) and the Nuttall's waterweed (*Elodea nuttallii*)
- **Altering the local food web**, e.g. alien plants alter nutrient availability (e.g. nitrogen-fixing *Robinia pseudacacia*, *Lupinus polyphyllus*)
- **Altering the composition and functioning habitats and ecosystems**. E.g. alien tree (Snichona pubescens) covering originally treeless highland of Santa Cruz island, Galapagos.

Invasive alien species, together with habitat destruction, has been a major cause of **extinction of native species** throughout the world in the past few hundred years. For example the introduction of the Nile perch (Lates nilotica) into lake Victoria in 1954 resulted in the extinction of over 200 endemic species of fish. In China's Dianchi Lake, the number of native species fell from 25 to 8 over a 20 year period that coincided with the introduction of 30 alien species of fish McNeely et al (2001). The Indian mongoose, introduced to Fiji, West Inies, Mauritius and Hawaii to control rats has led to the extinction of several endemic species of birds, reptiles and amphibians (McNeely et. al. (2001).

Additionally, it has been suggested that 80% of **endangered species** worldwide could suffer losses due to competition with or predation by IAS (Pimentel *et. al.*, 2005). For example, the grey squirrel (*Sciurus carolinensis*), the Asian lady beetle

(*Harmonia axyridis*) and the Argentine ant (*Linepithema humile*) are known to out-compete and displace native species in several parts of the world. The European Mink (*Mustela lutreola*) - one of the only two endemic carnivores in Europe - is at risk of extinction from competition with the America mink (*M. vison*).

In addition to threatening native species, the introduction of IAS between continents, regions and nations has often had significant impacts on the **structure and functioning of the recipient ecosystems** (Hulme, 2007). For example, the invasion of alien shrubs and trees in the South-African native fynbos ecosystem and the consequent increase in vegetation biomass has resulted in a significant decrease of the overall water supply in the area (Daily, 2007).

IAS are also increasingly seen as a **threat to ecosystem services** and negatively affecting economic development and human well-being. For example, a number of human health problems, e.g. allergies and skin damage, are caused by IAS. The economic effects are related to the negative impacts of IAS on various human activities, such as hindering navigation by blocking waterways, and causing damage to forestry and crops (see Table 1). For example, the rapid invasion of zebra mussels (*Dreissena polymorpha)* throughout different EU water bodies has resulted in significant economic and environmental damage.

Furthermore, increasing pressures on ecosystems, caused mainly by destruction of habitats, spread of IAS, over-exploitation and pollution, are weakening ecosystem resilience and ability to adapt to new conditions. The ability to adapt to climate change is weakening with biodiversity loss, and there is also a continuously declining capacity for providing ecosystem services.

The impacts of IAS affect a range of different ecosystem services. While a comprehensive survey has not been carried out, Table III.2 shows examples of IAS impacts across the ecosystem service types, demonstrating that virtually all ESS are affected by IAS.

Table III.2: Impacts of IAS on Ecosystem Services

TYPE OF ECOSYSTEM SERVICE LOST	Examples of the service being lost (no of examples where mentioned)
Provisioning Services	
Food and fibre	• Agricultural losses – e.g. Colorado potato beetle (Finland) • Food: comb-jellyfish reduces anchovy catch (e.g. Black Sea) • Forestry losses - black locust (e.g. Cyprus) • Food security: destroy rice field: Golden apple snail (*Pomacea canaliculata*), Rats (*Rattus spp.*); invasive fish (e.g., *Oreochromis niloticus, Cyrpinus carpio*)
Fuel	
Biochemicals, natural medicines, and pharmaceuticals	
Ornamental resources	• *Rhododendron ponticum* displaces other plants in natural areas (e.g. Australia)

TYPE OF ECOSYSTEM SERVICE LOST	Examples of the service being lost (no of examples where mentioned)
Provisioning Services	
	• The common broom *Cytisus scoparius* has become a pest in production forest and nature reserves, destroying open land-scapes and threatening endangered plant species
Fresh water	• Algae blooms caused by alien phytoplankton such as Chattonella verruculosa and Alexandrium species can be toxic
Other	• Irrigation and drainage: Aquatic weeds (e.g., *Eichhornia crassipes*, S*alvinia molesta*, *Mimosa pigra, Pistia stratiotes.*)
Regulating services	
Air quality maintenance	
Climate regulation (eg temperature and precipitation, carbon storage)	• Carbon storage can be reduced by damage / death to trees in forests due to beetles (e.g.….)
Water regulation (eg flood prevention, timing and magnitude of runoff, aquifer recharge)	• Decrease water levels (e.g. due to Japanese Knotweed or in South African native Fynbos ecosystem) • Hydroelectric: Aquatic weeds (e.g., *Eichhornia crassipes*, S*alvinia molesta*, *Mimosa pigra,Pistia stratiotes.*)
Erosion control	• Erosion of river banks and embankments by invasive weed (eg *Fallopia in* Germany) • The rabbit in Australia, causing soil erosion – impediment of the regeneration of forests and shrubs that prevent soil erosion
Water purification and waste management	• Depletes oxygen (water hyacinth)
Regulation of human diseases	• Invasive can bring in disease (influenza, small pox, dengue fever, malaria, bubonic plague)
Biological control (eg loss of natural predator of pests)	
Pollination	• Competing for pollinators such as bumblebees with the native riverbank species, and so reduces seed set in these other plants (*Impatiens glandulifera*)
Storm protection (damage by hurricanes or large waves)	
Fire resistance (change of vegetation cover leading to increased fire susceptibility)	• Increased fire risk due to drying of land (eg South African fynbos ecosystem) or due to less species diversity and higher ratio of easily flammable trees (eg Portugal due to eucalyptus) • Increase fuel loads, leading to changes in fire regimes *Andropogon gayanus* (Gamba grass) e.g. Australia, Brazil
Avalanche protection	
Other	• Cockroaches (50% exotic) causing asthma
Cultural services	
Cultural diversity, spiritual and religious values, educational values, inspiration, aesthetic values, social relations, sense of place and identity	• Change in landscape via invasive alien trees can lead to change of sense of place and identity – (e.g. alien trees covering originally treeless highland of Santa Cruz island, Galapagos)

TYPE OF ECOSYSTEM SERVICE LOST	Examples of the service being lost (no of examples where mentioned)
Provisioning Services	
Cultural heritage values	
Recreation and ecotourism	• Salmon parasite leads to reduction in value of recreational fishing (eg Norway) • *Chromolaena odorata*, affects the nesting sites of crocodiles (a focus of tourism in South Africa), directly placing these populations at risk • Toxic algae harming tourism (e.g.) • Rabbit haemorrhagic disease harming rabbit hunting e.g. Australia
Other	
Supporting services	
Primary production	
Nutrient cycling	• When the shrub bush honeysuckle *(Lonicera maackii)* becomes dominant, tree seedlings and herbaceous plants become less abundant (e.g. USA), creating a near monoculture of honeysuckle
Soil formation	
Other	

Scale of impacts

The impacts of IAS on ecosystems vary significantly depending upon the invading species, the extent of the invasion, and the vulnerability of the ecosystem being invaded. Some impacts are global and of headline importance (see Box AIII. 4 for some headline cases) whereas some effects take place at national, regional or local level. The latter are also often of fundamental importance to the areas and ecosystems in question, e.g. affecting the flow of ecosystem services to several beneficiaries. Additionally, some species may have invaded only a restricted region, but have a high probability of expanding and causing further great damage (e.g. see *Boiga irregularis*: the brown tree snake). Other species may already be globally widespread and causing cumulative but less visible damage (IUCN, 2005).

Box III. 4: IAS – some major impacts (examples from major health impacts)

- An invasive species of rat, carrying a flea, was a vector for the bubonic plague that spread from central Asia through North Africa, Europe and China.
- Smallpox and measles were spread from Europe to the Americas, leading to major illness, mortalities and ultimately the fall of the Aztec and Inca empires.
- Infected cattle introduced into Africa carried the Rinderpest in the 1890s. This spread to domesticated and wild herds of bovids throughout the Savannah regions of Africa. Many cattle populations were decimated and it was estimates that 25% of the cattle-dependent pastoralists may have starved to death in the early 20th century due to this.
- The influenza virus, with its origins in birds, passed on to pigs, and then to humans

Source: McNeely et al (2001)

III.3 Drivers of and policy responses to the spread of IAS

Globalization can be seen as the underlying driver behind the increasing risks of IAS. The spread of IAS is closely linked to the **increasing volume of trade**. Free trade is perceived as problem for control of import of IAS at all levels as it increases the probability of introducing alien species into the environment. Additionally, explosive **movement of people**, **growth of transport and tourism** are also responsible for increased movement of IAS. The introductions can take place either deliberately in the form of trading commodities such as livestock, pets, nursery stock, and produce from agriculture and forestry. Further introductions occur inadvertently as species are transported in packaging, ballast water, and on the commodities themselves (GISP, 2001).

This does not say, of course, that trade, mobility and globalisation are bad things, simply that with these come with additional and important risks of IAS and hence there is a need for a policy response to address this (see Box III. 5). Where to focus efforts and which instrument, will depends on the potential benefits of action and the costs of action (see Chapter 4 on this).

Box III. 5: Policy Response – when and where to act

Policy responses to IAS can usefully be categorised according to prevention, early detection and rapid eradication and containment and long-term control.

Prevention – to prevent the introduction and spread of alien species in ecosystems is a vital element of management. It is generally far more cost effective and environmentally desirable than measures taken following introduction and establishment of IAS (e.g. the use of list for species "*black list*", "*white list*" and '*grey list*', surveillance, import restriction, labelling).

Early detection and rapid eradication (eliminating the IAS completely) - if an invasive specie has been introduced, early detection and rapid eradication is the most cost effective way of preventing its establishment and wider spread.

Long-term control and containment (reducing population levels of the IAS to an acceptable threshold and keeping the IAS within regional barriers) – if eradication is not feasible, IAS population should be controlled in order to prevent further spread.

III.4 Invasive alien species (IAS) - monetary impacts

Overview of what is known about the economic impacts of IAS

Alien species can offer increased economic returns (e.g. plantations of fast-growing non-native conifers), satisfy demand for exotic products (e.g. fur trade), feed on and suppress other species (e.g. biological control agents) or simply fulfil a domestic need (e.g. pets and many garden plants) (Hulme, 2007). However, apart from their threat to biodiversity and ecosystem services, IAS have a significant economic impact. They reduce yields from agriculture, forestry and fisheries, decrease water availability, cause costly land degradation, and block transport, among other economic impacts. There is growing evidence of the economic impacts.

Over 120,000 invasive species of plants, animals and microbes have invaded the United States, United Kingdom, Australia, South Africa, India, and Brazil, and many have caused major economic losses in agriculture (Pimentel, *et. al.*, 2001) – see further below for values. Furthermore, a recent European commission supported study shows that 1,347 alien species invading Europe are known to have an economic impact (DAISIE, 2008), and offer valuable cost impact data. A number of studies provide a good overview of the IAS economic costs by classifying the impacts of invasive species into five types. These types related to production, price and market effects, trade, food security and nutrition, and financial costs (e.g. Evans, 2003; Pimentel et. al., 2001; DAISIE, 2008). This evidence is, however, still incomplete. For example, of the estimated 10 million species on earth, only 1.5 million species have been identified and described (Pimentel, *et. al.*, 2001) and far fewer have been the focus of evaluation studies. Furthermore, studies of impacts of IAS have to date, focused more on some countries than others. Most studies appear to focus on America. The review of invasive species impact by Levine *et. al.* (2003) shows that nearly 60% studies come from America, more than 20% from Oceania and less than 10% studies have been carried out in Europe. Similarly, in a recent review of the impact of invasive alien insects worldwide, only 3 out of the 50 species studied have been considered for Europe (DAISIE, 2008). Box III.6 provides a selection of key studies on invasive alien species and their monetary impacts.

Box III. 6: Key Studies on monetary impacts of invasive aliens

- Cost of introduced pests in the USA - Pimentel *et. al.* (2001)
- Economic evaluation of biological invasions – Born, *et. al.* (2005)
- Characterised and projected costs of non-indigenous species in Canada – Colautti, *et. al.* (2006)
- Conflicts of interest in environmental management: estimating the costs and benefits of a tree invasion – De Wit. *et. al.* (2004)
- Analysis of the Colorado potato beetle protection system in Finland – Heikkila and Peltola (2004)
- Update on the environmental and economic costs associated with alien-invasive species in the United States – Pimentel *et. al.* (2005)
- Economic Impacts of Invasive Alien Species: A Global Problem with Local Consequences - GISP
- Eradications of invasive alien species in Europe: a review – Genovesi (2005)
- Costs and benefits of stock enhancement and biological invasion control: the case of the Bay of Brest scallop fishery - Frésard and Boncoeur (2006)
- Biotic invasions: Causes, epidemiology, global consequences, and control - Mack *et. al.* (2000)
- Socioeconomic impacts and assessment of biological invasions - Binimelis *et. al.* (2007)
- Biological Invasions in Europe: Drivers, Pressures, States, Impacts and Responses - Hulme (2007)
- Reassessing the cost of biological invasion: *Mnemiopsis leidyi* in the Black Sea - Knowler (2005)
- State of the art review of the environmental and economic risks posed by invasive alien species in Europe – European database on invasive alien species DAISIE (2008)
- Invasive alien species and ornamental generally – Perrings et. al. (2005)
- Biological Invasion - Mark Williamson (1996)
- Biological Globalisation: Bio-invasions and their impacts on nature, the economy and public health – Weijden *et. al.* (2007)

Known examples on the IAS monetary impacts

A wide number of examples of monetary impact across the world exist in the literature, and a summary is presented in Annex 1. Some of the cost examples focus on the costs of the impacts – e.g. the damage caused. Others focus on the cost of eradication. A number of others focus on control cost and one costs of prevention. The former two are physical impacts or processes, and the latter two more costs of administrative/control measures. Examples of monetary impacts are presented below. A key study on the costs of IAS (Pimentel, *et. al.*, 2001), showed that the IAS can lead to very significant cost of impact on the economy. It has been estimated that invasive species in six nations (USA, UK, Australia, South Africa, India and Brazil) are causing more than US$ 314 billion per year in damages.
Most of these monetary costs and estimations refer to management costs, such as eradication, control and monitoring (DAISIE, 2008). Details include:

- For example, in the **United States**, invasive species cause environmental damages and losses adding up to almost $120 billion per year (*ibid.*:16.). Pimentel *et. al.* (2001) report that 88 species of molluscs have been introduced and become established in US aquatic ecosystems. Two of the most serious pests are the zebra mussel (*Dreissena polymorpha*) and the Asian clam (*Corbicula fluminea*). Zebra mussels, for example, colonize docks, locks, ship hulls, water intake pipes, and other mollusks, and cause great damage to power plants and water treatment facilities (e.g. causing US$ 5 billion per year in damages and associated control costs in USA).
- In **the UK** about US$ 3.2 billion in total potential crop production is lost annually because of weed infestations (Pimentel, *et. al.*, 2001). Similarly, the crop losses in the UK due to alien arthropods has been estimated to be 2800 million € per year which together with the impact inflicted by pathogens and vertebrates reach a total cost on crops reaching 3800 million € per year (Pimentel *et. al.*, 2001). Invasive species can costs the British economy an estimated £2bn per year (DEFRA, 2007).
- In **New Zealand**, the varroa mite is a series pest in honeybee hives and is expected to have an economic cost of US$267-602 million, and force beekeepers to alter the way that manage their hives. Beekeepers argue that had border rules been followed or had surveillance detected the mite earlier, the problem could have been avoided entirely. It appears too late to eradicate the mite. (Wittenberg et al, 2001, cited in McNeely et al (2001)

Other examples of costs include (see also Annex III table 1 to this COPI Annex):

- The zebra mussel has led to damage to US and European industrial plant. Cumulative costs for the period 1988-2000 have been estimated at between $750milllion to $1 billion (National Aquatic Nuisances Species Clearinghouse, 200 in McNeely et al (2001).
- Rabbits in Australia, have led significant agricultural losses in Australia. An early estimate put this at $373 million/year. Wilson, 1995, cited in White and Newton-Cross, 2000, cited in McNeely et al (2001)

- The introduced comb-jellyfish caused losses to the anchovy fisheries in the Black Sea estimated at $17 million annually (Knowler and Barbier, 2000).
- The introduction of the salmon parasite *Gyrodactylus salaries* to more than 46 rivers and 37 aquaculture facilities in Norway has decreased the density of salmon by 86% in infected rivers. Losses of income and opportunities for recreational fishing due to *Gyrodactylus salaries* have been calculated to about 20 million € (Johnsen, 2006).
- In Germany's inland water systems from erosion of river banks and embankments is estimated at 32 million € per year for *Fallopia japonica* (causes blockages to rivers in autumn when dry stems are carried by the current) species and 12 million € per year for *Heracleum mantegazzianum* (Hogweed related illnesses cost in terms of medical treatment) (SBSTTA 2005). Similarly, the mammal *Ondatra zibethicus* is causing potential impact on aquaculture industry estimated at € 12,4 million/year (€ 4.6 mln/yr for sanitary aspects, € 2.3 million/year for maintenance of waterways, € 1.9 million/year for impacts to hatcheries and fish breeders by damaging ponds and dams). (DAISIE, 2008).

Some numbers are very large and significant at national levels, others are important at local levels, whether for those directly affected by the loss, or those responsible for responding to the loss.

AIII.5 Interpreting and building on the existing information on IAS monetary impacts

As for the more detailed monetary impacts of IAS invasions, the costs of IAS in different studies are often of different nature. Some studies report costs of damages, including costs arising from the preparation of damages, (e.g. insurance losses, restoration or clean-up costs) whereas others document the loss of economic output due to IAS invasion (e.g. lost agricultural and fisheries output, loss of tourism).On the other hand, a number of studies also provide information on the costs of eradication and control, hence can be classified as "costs of action" (See below). Table III.3 below classified a number of examples on monetary costs according to their different nature.

Table III.3: IAS costs - categorised by different type of cost

Type of costs	**Examples**
Damage costs	• Damage to US and European industrial plant from the zebra mussels: cumulative costs 1988-2000 of between \$750 million to \$1 billion. • Restoration costs: Returning South African Floral Kingdom to pristine state costs \$2billion. • The total annual costs of damages & losses in Netherlands were € 673-1945 million
Ecosystem service losses	• Food: comb-jellyfish led to losses to the anchovy fisheries of about \$17 million annually in the Black Sea • Food: Weeping grass led to reduced output from cattle rearing – estimated at US\$ 29 million for the period between 1995 and 2005 (see Box AIII. 5) • Recreation: Salmon parasite leads to reduction in value of recreational fishing of about 20 million €/year in Norway • Tourism: losses of tourism visits and revenue from crocodile nesting sites being compromised. In Netherlands the foot-and-mouth disease harming hotels & catering in € 5-21 million.
Eradication	• Cost of eradication efforts in Germany estimated at over € 3 million/year.
Control and containment	• Cost of control BSE - mad-cow disease (1997-2005) in Netherlands were €519-769 million and the total cost were € 461-1044 million[92]

Given the partial picture of the overall IAS impacts and the differences in existing costs information it is naturally perilous to try to derive any global estimates for the scale of the IAS impacts. However, it is valuable to try as it can help highlight the importance of the impact in a language that will reach a wider audience. Pimental et al carried out such a calculation (Pimentel, *et. al.*, 2001). He calculated the per capita costs for the losses incurred due to biological invaders in the six nations investigated as being approximately \$240 per year. Assuming similar costs worldwide, damage from invasive species would be more than \$1.4 trillion per year, representing nearly 5% of the world economy (*op. cit.*). Using the Pimentel et al. information for a basis of a generic transfer of insights from one set of countries to another (e.g. to the developing world) could be broadly considered justified. This has been supported, for example, by McNeely et al (2001) stating that "*There are strong indications that the developing world is experience similar if not proportionally greater, losses"*. McNeely's statement basis itself, for example, on the knowledge that IAS pose a threat to the success of 13 billion dollars investment dedicated to current or planned World Bank funded projects in the developing countries (e.g. due to risks to irrigation, water supply, sanitation and power sectors) and the threat that the white cassava mealy bug and larger grain bored are posing to food security in Africa (Joffe and Cooke, 1998 cited in McNeely et al (2001). Nevertheless, the existing information provides clear evidence that IAS are an issue across the world and are leading to real costs to national economies. The benefits of addressing the problem are very significant and the next section looks at the costs of action, and how the costs of action relate to the benefits.

[92] See Van der Weijden*, et. al.* (2007)

III.6 Costs of action to prevent, eradicate and control IAS

Different actions have been developed and used world wide against invasive alien species. Local, national and regions suggest that there are different best solutions for different localities and different problems. However, it is generally acknowledged that the costs of later eradication or control (as in some cases only control is possible beyond a certain state of invasion) are much higher than the costs of early eradication as demonstrated in the case study below (See Box III. 7). It is also the case that often the costs of prevention (action) can be lower than the cost of responding to the problem. These issues are discussed further in the next section on the costs of action.

Box III.7: Case Study: Weeping Grass (*Eragrostis plana*) Invasion in the Southern Grasslands of Brazil

Weeping grass (*Eragrostis plana*) is native to South Africa, where it does not have wide expression, and is not a dominant species.

E. plana was accidentally introduced into Rio Grande do Sul state, in the south of Brazil, as a contaminant of seeds of an African forage grass, *Chloris gayana*, in 1969, imported from South Africa. By 1979 it had been widely recognized as a very poor forage grass, as the cattle either would not graze on it or would not gain weight, and its use was prohibited by the Ministry of Agriculture. At that time it occupied 20,000 ha. As no control programs were implemented, it grew to 400,000 ha in 1993 and to about 2,000,000 ha in 2007, covering about 20% of the natural ecosystem. Predictions for 2015 are 4,480,000 ha invaded.

E. plana is strongly dominant and eliminates all other plants from the land it occupies. It is allelopathic, releasing chemicals in the soil to inhibit the germination and growth of native species. It impacts wildlife by not providing food or habitat, and totally changing the natural composition of the grasslands and savannas. Weeping grass invades the most traditional lands in Brazil for cattle farming. When the land is not viable for cattle, farmers often rent the property for alien invasive forest plantations (pines, eucalypts and acacias) or convert to agriculture, destroying biodiversity and the possibility of future restoration.

Estimates are that the economic impact of weeping grass invasion on cattle farming leads to a loss of US$ 38.91 per hectare, while non-invaded areas yield a gain of US$ 17.15. The total production losses to the state of Rio Grande do Sul are estimated at US$ 3.4 million in 2005, totalling US$ 29 million between 1995 and 2005. If no control is undertaken, total losses between 1995 and 2015 will total US$ 600 million.
Sources: Coelho, R. and Kissmann (1997)

As noted above, in the UK, crop losses due to alien arthropods has been estimated to be 2800 million € per year which together with the impact inflicted by pathogens and vertebrates reach a total cost on crops reaching 3800 million € per year (Pimentel *et. al.*, 2001). To contrast this - the cost of control most invasive alien plants (e.g. using herbicide) in UK (1983-92) was 344 million/year for 12 species (Williamson, 1998).

In the above New Zealand bee example, the costs of a mitigation plan is expected t be $US1.3million in the first phase, compared to expected losses if no action of between US$267-602 million.

In the South African Cape Floral Kingdom, the establishment of invasive tree species has decreased water supplies for nearby communities, increased fire hazards, and threatens native biodiversity justifying government expenditures of US$40 million per year for manual and chemical control (GSC, 2001). These costs of action due to invasive species have become important concerns of many governments future.

The type of the action differs depending upon species and requires different management such as integrated control methods which involve combinations of actions (GISP, 2001). For example, in Germany it has been estimated that the minimum costs to losses in stored grain added to managing three of the most damaging arthropods might be €12 million per year (Reinhardt *et. al.*, 2003). Thus, depending on the invasive alien species, any preventative measures, eradication or management actions should be straightforward to monitor and regulate but, in practice, developing legislation has proved difficult. New invasive alien species continue to occur through contaminant, stowaway, corridor and unaided pathways. Furthermore, the benefits of addressing the IAS can lead to very significant benefit/cost ratios – as the cost of action can be significantly less that the cost of inaction (IAS impacts). Benefit cost rations vary considerably depending on the time of action, the IAS in question, and the nature and locality of the impacts. The Global Strategy Catalogue gives a range of benefit costs of between around 10 to 1 (case of the tree *Melaleuca quinquenervia*), to 20 to 1 (the insect *Ceratitis capitata*, Mediterranean fruit fly), to 30 to 1 (fish sea lamprey, *Petromyzon marinus*), and up to 1659 to 1 for Siberian log impacts (tree, *Larix spp*).

III.7 Future trends and development needs

For the future, there are currently no scenarios or models of future likely risks or expected impacts from IAS. We can, however, expect that the risk of IAS occurrence and IAS impact to depend on the probability of AS arrival, likelihood of successful invasion, likelihood of impact, and expectations of policy response. From the knowledge of the past (IAS pathways, affected areas and impacts), we know that IAS risk relate grows with increasing volume of trade (and hence shipping, road and aviation transport), the increased movement of people (where for trade, migration or tourism). We can also expect IAS to increase with climate change.

While one could, in principle, look at future scenarios for trade volumes, tourism levels, migration and climate change, and clarify links to IAS risks so as to get a basis for an estimate of future IAS and impacts, this is too difficult to do at present. It would likely require significant new primary research.

At a very pragmatic, and probably very conservative level, one can assume that the risks will grow at least in line with GDP (as we can expect trade to at least grow as fast as GDP; trade has far outstripped GDP growth over the last 100 years) and in line with population (as we can broadly expect international mobility to grow, and also expect that the impacts will affect more people as the population rises). From the OECD/Globio work, we know that from 2000 to 2050, GDP grows from

41.4$trillion (in PPP) in 2000 to 195.5 $trillion (in PPP) in 2050 – a 4.7 fold increase. Furthermore, population is expected to grow from 6.1 billion in 2010 to 9.1 billion by 2050 – a 1.5 fold increase. Combined this represents a 7 fold increase.

While only an order of magnitude estimate, used to highlight the likely importance of action on IAS, if the $1.4 trillion per year current impact (as derived based on Pimentel et al. 2001 above) were to grow in line with GDP and population, it would rise to nearly $9trillion, and in percentage GDP from circa 5% of GDP to circa 7.5% of GDP. These numbers can be taken as working COPI values for costs of IAS. In reality, the increased trade, travel and climate change can be expected to lead to a higher risk of impact – in the context of no additional policy action. That said, while this risk and scale of impacts is expecting to increase, so is the realisation of the need for effective policy response. The final impact can be expected to be less as policy responses are implemented.

To conclude, it is critical that information on IAS negative impacts and the benefits of prevention and early action can be expanded. Additionally, methodological tools should be disseminated to provide the basic data and information necessary for informed decision-making on the prevention, eradication and control of invasive species.

Based on the analysis of the existing information on IAS monetary costs and with a view to develop more complete regional and global estimates of IAS costs, the following suggestions for analysis for the phase two of the Global Review of Economics of Biodiversity Loss have been identified:

- IAS is a global problem, so **involving more nations is urgent** (e.g. more information in other countries apart from USA, New Zealand, etc.) A good operational data between countries. National, trans-border, regional and international level are required, based on a proactive rather than reactive approach
- Carry out **more monetary studies** and **studies on the relation of economic impacts with environment impacts** (normally production impacts/services)
- It will be valuable to **find more monetary impact studies** for **different IASs** and **different geographic areas** affecting **different stakeholder groups** to underline that the issue affects all.
- **Use of tools** (e.g. use of risk assessment) and **polices** that could help address the problem.

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Annex III Table A1: Examples of Monetary Impacts across the World

Countries Known introduced range	Type of Species	Area Affected	Economic Impacts of IAS
Mexico	Insect: Cactus moth (*Cactoblastis cactorum*)	Island	The cost of insecticide treatments in affected zones could reach US$ 620,000 for nopal and US $2.9 million for cactus fruit.
Brazil	Seed: Weeping grass (*Eragrostis plana*)	Southern grasslands. Occupied about 2,000,000 ha in 2007, covering about 20% of the natural ecosystem. Predictions for 2015 are 4,480,000 ha invaded.	The grass invasion on cattle farming leads to a loss of US$ 38.91 per hectare, while non-invaded areas yield a gain of US$ 17.15. The total production losses to the state of Rio Grande do Sul are estimated at US$ 3.4 million in 2005, totalling US$ 29 million between 1995 and 2005. If no control is undertaken, total losses between 1995 and 2015 will total US$ 600 million.
United Kingdom	Mammal: Coypu (*Myocastor coypus*) large South American rodent	Native wetlands – damage to agriculture and river banks	The species is considered a pest for its feeding on crops, such as sugar beets and maize, and for its burrowing activity that disrupts riverbanks and dikes. In Italy during 1995-2000, despite control activities involving the removal of 220,688 coypus with a cost of 2,614,408 €, damage to the riverbanks exceeded 10 million € and impact on agriculture reached 935,138 €.
Mediterranean Sea	Marine alga: (*Caulerpa taxifolia)*	Marine habitats	Economic impacts resulting from the cost of eradication included approx $US 6 million spent in Southern California up to 2004 and $AUS 6-8 million in South Australia.
Europe, the former Soviet Union, and in the most southern countries of South America	Mammal: American mink (*Mustela vison*)	Coastland, estuarine habitats, lakes, natural forests, planted forests, riparian zones, water courses, wetlands	Can inflict damage to free ranging chickens, reared game birds, fisheries (salmon farming) and the eco-tourist industry through predation on ground nesting birds. Germany estimates the costs of impacts to be 4,200,000 €.
Australia	Mammal: *Oryctolagus cuniculus*	Agriculture, forestry, tree plantations, grassland	The costs amounted to some $600 million per year in agriculture damage by 1997, plus $20 million in pest control and another $million in research costs.
Netherlands	*Phytophthora* plants genus)	Agriculture	Total costs of pest and weed control in agriculture and horticulture are an estimated €156-240 million per year. In forestry, the costs of combating the black cherry are € 2 million per year.

Countries Known introduced range	Type of Species	Area Affected	Economic Impacts of IAS
Netherlands	*Virus: hog cholera virus* (classical swine fever)	Livestock husbandry	Costs were €1.5-1.9 billion
Europe, North America	Herb: Giant hogweed *(Heracleum mantegazzianum)*	Riparian zones, ruderal/disturbed, water courses	Costs are incurred therefore both for medical treatment and in implementing to keep the plant under control. For example, Mainz-Bingen (Germany) eradication efforts in this district have cost from 42,000 to 100,000 Euros annually. Hogweed related illnesses cost in terms of medical treatment. Clinics have reported about 1- 5 patients every year per 1.5 million inhabitants, whilst most of the cases are outpatients 1-5% cases are severe enough to cause hospitalization (Germany)
From Belgium across to Turkey, south to Spain, Portugal, Italy and Morocco and north to Norway; Iceland. The UK has the largest population with around 5,000 individuals followed by France with 50 breeding pairs	Bird: Ruddy duck (*Oxyura jamaicensis*)	Estuarine habitats, lakes, water courses, wetlands	Costs of eradication are considerable. There is an ongoing eradication program in the UK since 1992 with the goal of reducing the population to less than 175 birds or 5% of the 1999 population at an estimated cost of 3.6 million GB Pounds or 4.4 million Euros over a 4-6 year period. By 2004, at least 15 countries in the Western Palearctic were taking actions to control populations. Approximately 5,500 individuals have been controlled in various countries, particularly the UK (5,100), France (246) and Spain (217).
Most European countries, Canada and USA, and reported from Australia and New Zealand	Herb: Japanese Knotweed (*Fallopia japonica*)	Coastland, riparian zones, urban areas, water courses, wetlands	Prolific rhizome and shoot growth can damage foundations, walls, pavements, and drainage works, and causes flood hazards by increasing resistance to water flow and damaging flood prevention structures. Secondary compounds isolated from F. japonica include the anti-cancer phytoalexin resveratrol.
European countries and USA	Mollusc: Zebra mussel *Dreissena polymorpha*	Industrial plants	Cumulative costs 1988-2000 National Aquatic Nuisances industrial plants = $750 million to 1 billion. Source: National Aquatic Nuisances Clearinghouse, 2000
Italy, England, Ireland,	Mammal: grey squirrel (*Sciurus carolinensis*)	Agricultural areas, natural forests, planted forests, ruderal/disturbed, scrub/shrublands, urban areas	Severe damage to trees by bark stripping, that exposes the timber to fungal and insect attack, disrupts the flow of nutrients up the tree, and weakens the stem. They cause local damage to fruit orchards and nut growers.

Countries Known introduced range	Type of Species	Area Affected	Economic Impacts of IAS
South Africa	Tree: Black wattle (*Acacia mearnsii*)	Grasslands, riparian zones, urban areas, water courses	Losses due to invasive wattles were estimated to amount to 577 million cubic metres of water annually. This corresponds to an economic loss of about $1.4 billion annually.
Asia	Plant: giant sensitive plant (*Mimosa pigra*)	Farms, livestock, tourist operators and conservation agencies. Invasion of at least 100,000 Km² at least 9 countries	The monetary impact of this invasion was in excess of US$ 1,350 per hectare to users of the floodplain. Management (reasonable control using mechanical, chemical and biocontrol options) of such an infestation would cost between zero and US$ 7,600 per km². Prevention of spread of mimosa, on the other hand, would cost in the region of US$ 200 km².
India, China, Indonesia, East Timor and the Philippines	Crop weed: Trffid weed (*Chromolaena odorata*)	Agriculture and grazing	The control of triffid weed in natural areas are estimated at US$ 151 to 164 per hectare, depending on the scale of the work. It would therefore take US$ 2 million to clear 4,000 hectares, and up to US$ 24 million to clear 57,000 hectares of natural areas. E.g. SA on a 13,000 ha government cattle farm with more than 8,000 ha invaded, conservative estimates relating only to clearing the weed for cattle production reach US$ 180 million. This includes controls undertaken over a period of 30 years.
South Africa	Water hyacinth (*Eichhornia crassipes*)	Aquatic weed. It impacts all aspects of water resource utilization i.e. fisheries, transport (including the collection of palm wine) and hydropower generation, as well as water supplies (potable water), flood control, irrigation, health (e.g. malaria, bilharzia)	In South Africa, estimated losses in income from activities impacted by E. crassipes total US$ 58,195 annually. These decreased to US$ 7,000 with the immediate implementation of an integrated control programme (i.e., a benefit-cost ratio of 31:1).
China, USA, South America, South Africa	Tree: Black wattle (*Acacia mearnsii)*	Grasslands, riparian zones, ruderal/disturbed, urban areas, water courses	Commercial plantations and invasive stands of A . mearnsii in South Africa reduce surface runoff and decrease water ability, causing an estimated annual economic loss of $US 2.8 million.

Countries Known introduced range	Type of Species	Area Affected	Economic Impacts of IAS
Saipan and other Pacific Islands	Snake: brown tree snake (*Boiga irregularis*)	Agricultural areas, coastland, natural forests, planted forests, range/grasslands, riparian zones, ruderal/disturbed, scrub/shrublands, urban areas, wetlands	Masonry barriers use a pre-stressed moulded concrete design which is 100% successful in keeping snakes out and is not vulnerable to rat or typhoon damage. However, it has a high initial cost of approximately US$300 per metre. Marianna Naval Base in Guam has caused electrical problems on the island by simultaneously touching live and grounded conductors (creating short circuits resulting in power loss and have caused losses of up to $US4 million per year.
World (e.g. Brazil e Florida)	Mollusc/Snail: Giant African land snail (*Achatina fulica)*	agricultural areas, coastland, natural forests, planted forests, riparian zones, ruderal/disturbed, scrub/shrublands, urban areas, wetlands	e.g. Control costs can range from $US 60,000 dollars for a 7-month procedure, to over $US 700,000 dollars for the eradication in Florida.
USA	Mammal: pig (*Sus scrofa*)	agricultural areas, coastland, natural forests, planted forests, range/grasslands, riparian zones	In one study conducted in 40 counties of California an economic loss of approximately US$ 1 730 000 was recorded due to pigs.

Source: http://www.europe-aliens.org and http://www.issg.org/database