CHAPTER 7

Conclusions and recommendations

Leon Braat & Patrick ten Brink

Building on the work of the COPI team:

J. Bakkes, I. Braeuer, B. ten Brink, A. Chiabai, H. Ding, H. Gerdes, M. Jeuken, M. Kettunen , U. Kirchholtes, A. Markandya, P. Nunes, M. van Oorschot, N. Peralta Bezerra, M. Rayment and C. Travisi.

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.
Nature|Vol 415 | 3 January 2002[1]

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[2] in the line of major global species extinctions[3]. 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. The chapter addresses:

- The changes in biodiversity – past and expected future (Section 7.2)
- Changes in ecosystem services (section 7.3)
- The value of ecosystem services loss – both the core COPI landuse based analysis for 2050 and the exploration of values for the wider set of ecosystems and biomes (section 7.4)
- Conclusions on and discussion of the methodology applied (section 7.5)
- Recommendations on policy response (section 7.6), and
- Recommendations on methodological development and areas of further study (section 7.7).

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

[1] NATURE|VOL 415 | 3 JANUARY 2002 |www.nature.com
[2] 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)
[3] http://www.newscientist.com/channel/life/dinosaurs/mg16422167.700

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

7.2.1 The past

The facts with respect to 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[4].
- 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[5].
- 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.[6]
- In the past two decades, 35% of mangroves have disappeared. Some countries have lost up to 80% through conversion for aquaculture, overexploitation and storms.[7]
- 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.[8]
- 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

[4] United Nations Forest and Agriculture Organisation, 2001.
Global Forest Resources Assessment 2000
2 United Nations Forest and Agriculture Organisation, 2006 *Global Forest Resources Assessment 2005.*
[5] http://www.ramsar.org/about/about_wetland_loss.htm
[6] Wilkinson C., 2004: *Status of Coral Reefs of the World: 2004 report*
[7] 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
[8] Millennium Ecosystem Assessment, 2005 *Living Beyond Our Means: Natural Assets and Human Well-being*. Island Press, Washington DC. Page 15

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[9].

- 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[10].

7.2.2 The near future

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 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

[9] Caldecott, J & Miles L (eds) 2005 World atlas of great apes and their conservation UNEP-WCMC, U of C , Berkeley Press, Berkeley CA, USA

[10] Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis.* Island Press, Washington DC.

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)[11] 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, many protected areas are nothing more than 'paper parks', and many of the world's flagship protected areas are threatened by external pressures and lack of adequate protection.

7.3 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 (eg water, climate, and disease regulation), and supporting services (eg biomass production, soil formation and retention, nutrient cycling, water cycling) 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

[11] http://www.cbd.int/gbo2/

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 (ESS) 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.

7.4 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 that significant gaps remain in our knowledge, 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 first scoping 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)[12], 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 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. Examples are available in Chapter 6. A few observations:

- A recent review by the French Government[13] 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.

[12] 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

[13] 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[14], 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. For example, the economic impact of forest recreation in national forests in the USA, was valued[15] at $6.8 billion in 1993 and 139,000 jobs in 1996. The wider contribution to GDP was estimated at $110 billion/year. The total economic value of fishing in national forests was estimated at $1.3-2.1 billion in 1996.
- Pollination: Ricketts et al. (2004) found the value of bee pollination for coffee production to be worth US$ 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[16])* is a serious pest in honeybee hives and is expected to have an economic cost of US$267-602 million[17]. 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[18]). Cumulative costs for the period 1988-2000 have been estimated at between $750 million to $1 billion[19]. Both example 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[20] at ranging from $1/ha to $265/ha when employing a random search, including locations with the highest biodiversity. There is a high variation of values within one study. This is once again a good example of the site dependency of values. Even though all tropical forests are rich in biodiversity not each tropical forest is (already) a recognised hot spot region for genetic material.
- Marine capture fisheries are an important source world wide of economic benefits, with an estimated first-sale[21] value of *$ 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 COPI analysis demonstrated the ranges of the potential losses of carbon storage from land use changes.

---

[14] 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.
[15] Moskowitz and Talberth (1998)
[16] http://en.wikipedia.org/wiki/Varroa_destructor
[17] Wittenberg et al, 2001
[18] http://nationalatlas.gov/articles/biology/a_zm.html
[19] National Aquatic Nuisances Species Clearinghouse, 2000 in McNeely et al (2001)
[20] Costello & Ward (2006)
[21] Value to fishermen, so does not include the value added along the retail chain.

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 COPI results for value of loss of ecosystem services from land based biomes

The results include:

- The loss of welfare in the year 2050, from the cumulative loss of ecosystem services between 2000 and that year, amounts to $14 trillion (10^12 or million * million) Euros under the fuller estimation scenario[22] – 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 (eg 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.
- These losses continue to increase annually 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.

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;

[22] As noted in Chapter 6, two scenarios were developed – a partial evaluation scenario, that left a number of gaps unfilled to avoid the influence of "too much gap filling" – and a fuller evaluation scenario – that filler more (but not all) of the gaps, so as to enable an aggregate picture to be developed.

- 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 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 are given on the forestry biomes. The losses of services from the change in landuse and biodiversity 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) 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. 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.

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 (eg tundra and wooded tundra), where some benefits transfer from biome to biome was carried out (eg 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 (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.

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, For example for the fuller estimation scenario the value of the loss of ecosystem services in 2050 from the cumulative loss of biodiversity over the period 2000 to 2050 was estimated at around 6,734 billion (10^9) EUR/year for land use changes and 8,834 billion EUR./yr for quality changes However quality losses are generally negative across all land-use types as a loss of quality (eg due to pollution or climate change's effect on soil) affects them all[23]. 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.

7.5 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 – eg 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).

[23] 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 assumptions (and why they were necessary) have been described in the earlier chapters and annex, and some key elements are noted below. A phase 2 of the Economics of Ecosystems and Biodiversity will usefully address a range of these assumptions and look for measures to improve upon them (eg using risk assessment tools to complement a valuation based approach).

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 landuse 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:

- 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. For values to be useable 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, land cover type and geographic region. These essential 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 (eg 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 – eg scrublands, grasslands and tundra.

There is also more information on certain ecosystem services than others in the valuation work. There tends to be more information available on climate regulation service (on carbon storage elements), and on provisioning services for market goods (eg 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 ESSs 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 landuse and quality for the period 2000 to 2050, for the different landuses, 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[24] (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 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.

[24] 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.

7.6 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. policies.

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 a 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.

7.7 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 in 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 (eg bioprospecting 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.