

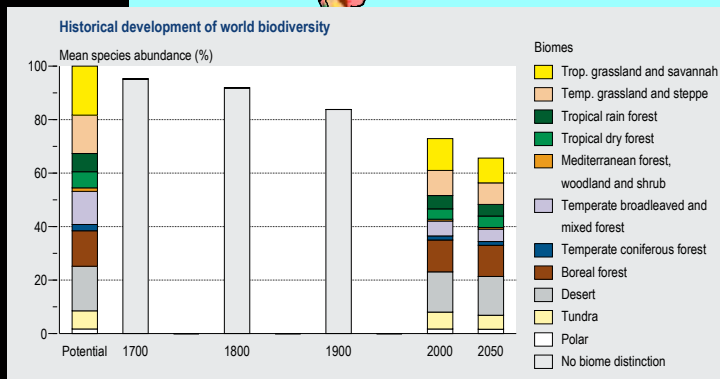
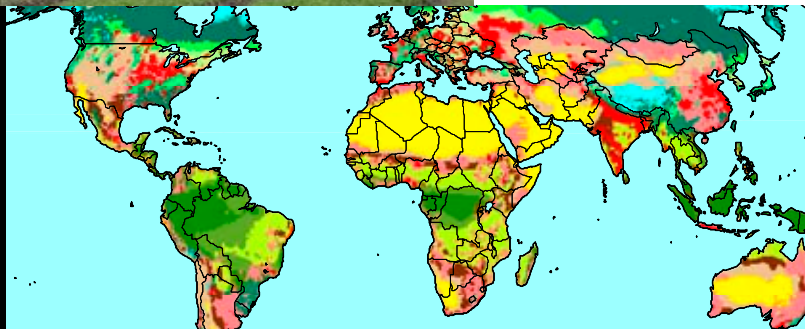


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CROSS-ROADS OF LIFE ON EARTH Exploring means to meet the 2010 Biodiversity Target



Solution-oriented scenarios for Global Biodiversity Outlook 2



CBD Technical Series No. 31

CROSS-ROADS OF LIFE ON EARTH

Exploring means to meet the 2010 Biodiversity Target

**Solution-oriented scenarios for
Global Biodiversity Outlook 2**



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FOREWORD

Travellers need to make a decision when they reach a junction. They can proceed in the same direction, turn, or even go back to where they came from. The situation is much more complicated when it comes to making policy decisions that aim at maximizing benefits for all aspects of sustainable development—including safeguarding the biodiversity that surrounds us. There is no way to turn around and go back to an earlier development stage, and no possibility to undo irreparable damage we have done to our natural environment. More importantly, there is no established road ahead of us and no map we can consult. Each step—planned or unplanned—has implications and repercussions—immediate and long-term—on our economic and social wellbeing and on the wellbeing of our living environment. Moreover, the steps we collectively make as a world community are not well coordinated. Even where as a global community we have a clear vision and common understanding of the goal we want to reach together, we need to carefully analyse and agree on the best way to get there.

Over the past years, important common goals have indeed been set—most importantly the Millennium Development Goals and, as part of these and focusing on biodiversity, the target of a significant reduction of the rate of biodiversity loss by 2010. This target needs to be achieved at all levels, from local to global, with national governments through their biodiversity strategies providing essential frameworks for action. But how do we decide on the “best actions” to take? What tools do we have to forecast the consequences of what we believe to be the “best actions” on biodiversity?

This document analyses six plausible “best actions” and forecasts their impact on biodiversity. It was originally prepared for Global Biodiversity Outlook 2, published in 2006, and the main findings are summarized there. The original version was then peer-reviewed by scientists and Parties to the Convention on Biological Diversity and has been revised on the basis of the comments received. Some valid comments could not be taken on board because they would have either implied a different scope for the study or required methodologies and analyses that we are only beginning to develop.

Beyond the interesting and sometimes surprising results, the document shows the potential and limitations of biodiversity scenarios. This will assist Parties in the development of appropriate regionally-based response scenarios within the framework of the Convention’s programmes of work—as requested by the Conference of the Parties to the Convention at its eighth meeting. I believe that it will also encourage the development of tailor-made national, sub-regional and regional scenarios on specific issues of interest at relevant scales. And it is my hope that an improved capacity will emerge to develop and calculate such response scenarios and will enable us to conserve and sustainably use the biodiversity we all depend on. Increasingly, meaningful response scenarios will enhance our ability to weigh options and decide on the path we wish to take towards a sustainable future.



Dr. Ahmed Djoghla
Executive Secretary
Convention on Biological Diversity



Prof. ir. N.D. van Egmond
Director
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ABSTRACT

The aim of this study is to explore policy options that could have major *positive* or *negative* impacts on biodiversity. The main question is whether the 2010 Biodiversity Target can be met at global and regional levels. Effects up to 2050 are taken into account.

According to a business as usual scenario (baseline), and six individual options, it is unlikely that the 2010 target will be met at either global level or regional level. The loss of biodiversity is expected to continue at an unchanged pace in the coming decades. Key drivers, global population and economic activity are expected to keep on growing. Between 2000 and 2050, the global population is projected to grow by 50% and the global economy to quadruple. The need for food, fodder, energy and wood will unavoidably lead to a decrease in the global natural stocks. The negative impact of climate change, nitrogen deposition, fragmentation, infrastructure and unchecked human settlement on biodiversity will further expand. As a result, global biodiversity² is projected to decrease from about 70% in 2000 to about 63% by 2050. According to this baseline scenario, the rate of biodiversity loss over the coming decades will increase instead of decrease. Some options for reducing the rate of loss in the longer term may lead to an increase in the rate of loss in the short term.

Increase of protected areas to 20% of all ecological regions and *sustainable meat production* contribute to bringing the 2010 target closer, and may potentially reduce the rate of loss before 2050. Measures for *limiting climate change* by, amongst others, large-scale production of bioenergy seem to inevitably lead to additional loss of biodiversity in the medium term (2010-2050). By 2050 the biodiversity gain from avoided climate change does not compensate for the biodiversity loss due to additional land use, although this may be reversed in the long term (>2100). Large-scale *plantation forestry* also leads initially to additional biodiversity loss through increased land use. However, when plantations gradually take over global production (> 2040 in this option) the total biodiversity loss becomes less than that from ongoing exploitation of mostly (semi-)natural forests. *Full trade liberalization in agriculture* (WTO) will lead to further loss of biodiversity through ongoing agricultural expansion and large-scale land conversion in low-cost areas, where agricultural productivity is less efficient. Major loss results from a production shift by abandoning agricultural areas in developed regions and converting large natural areas in developing regions, concentrated in Latin America and Southern Africa. The shift results in higher net land requirements at the global level, since current crop yields are higher in the developed regions. Full trade liberalization in agriculture in combination with *poverty alleviation in Sub-Saharan Africa* leads to additional loss of biodiversity through agricultural expansion. Over the next 50 years much of the world's remaining natural capital will consist of mountainous, boreal, tundra, ice and (semi-) arid ecosystems, generally considered less suitable for human settlement.

The reader should be aware that this study is not meant to predict the future but to explore the major contributions of various currently debated policy options. Not all the possible measures or their combinations were assessed, and inland waters and marine ecosystems have not been considered. In all calculations agricultural productivity has been optimistically estimated. Less optimistic trends would correspond to an additional biodiversity loss of several percent⁶. Increase in agricultural productivity will therefore be a key factor in reducing biodiversity loss in the future. We stress that option effects in terms of direction and relative magnitude are more robust than the absolute baseline trend.

This study was commissioned by the Secretariat of the Convention on Biological Diversity (SCBD) and carried out by the Netherlands Environmental Assessment Agency (MNP) in cooperation with the World Conservation Monitoring Centre of the United Nations Environment Programme (UNEP-WCMC), UNEP/GRID-Arendal and the Agricultural Economics Research Institute (LEI, part of Wageningen University and Research Centre). The results were used as input for the second edition of the Global Biodiversity Outlook (GBO-2).

SUMMARY

Introduction

The aim of this assessment study was to explore policy options under current discussion in the global political arena that could have major *positive* or *negative* impacts on biodiversity. The central concern of the assessment is the achievement of the 2010 Biodiversity Target at global and regional levels, as agreed upon under the Convention on Biological Diversity (CBD). However, because of the time lag of several measures, the long-term effects with a time horizon of 2050 are also taken into account. The assessment was carried out using models allowing a quantitative approach. Results have been expressed –where possible –in terms of the 2010 indicators according to the CBD Conference of the Parties (COP) decisions VII/30 and VIII/15. These results were used as input for the second edition of the Global Biodiversity Outlook (GBO-2) to support policy-makers in determining cost-effective ways to achieve the 2010 target. The study was carried out by the Netherlands Environmental Assessment Agency (MNP) in cooperation with UNEP-WCMC (UK), UNEP-GRID Arendal (Norway) and the Agricultural Economics Research Institute (WUR-LEI, the Netherlands).

Key findings: general

1. According to the baseline scenario and options examined in this study, it is unlikely that the 2010 biodiversity target of ‘*a significant reduction in the current rate of loss of biological diversity*’ will be met for terrestrial biomes¹ at global and regional levels. The loss of biodiversity² is expected to continue at an unchanged pace in the coming decades as a consequence of economic and demographic trends.
2. Six policy options, some targeted at reducing biodiversity, and others representing cross-cutting issues, have been analysed *separately*³ for their impact on biodiversity. *Protection of areas* and *sustainable meat production* contribute to bringing the 2010 target closer, and may potentially reduce the rate of loss before 2050. Measures for *limiting climate change* (including large-scale production of bioenergy) and *increasing the area of plantation forestry* seem inevitably to lead to loss of biodiversity in the medium term (2010 - 2050).
3. Global cross-cutting policies that are relevant for trade and development, i.e. *full trade liberalization in agriculture* and *poverty alleviation in Sub-Saharan Africa* (by increasing GDP) will lead to further loss of biodiversity through ongoing agricultural expansion and land conversion in low-cost areas, where agricultural productivity is less efficient.

Key findings: biodiversity change in the baseline scenario

4. A moderate socio-economic baseline scenario has been used as a reference frame to evaluate the effectiveness of policies. Key indirect drivers, global population and economic activity are expected to keep on growing. Between 2000 and 2050, the global population is projected to grow by 50% and the global economy to quadruple⁴.
5. The need for food, fodder, energy, wood and infrastructure will unavoidably lead to a decrease in the global natural stocks in all ecosystems. The negative impact of climate change, nitrogen deposition, fragmentation and unchecked human settlement on biodiversity will further expand. As a result, global biodiversity is projected to decrease from about 70% in 2000 to about 63% by 2050².
6. The baseline scenario assumes that a considerable increase in agricultural productivity can be attained. The required agricultural area is up to 20% lower than in the often used IPCC scenarios, and up to 28% lower than the MA scenarios. In the MA scenarios, global biodiversity will decrease several percentage

1 In this study marine and freshwater ecosystems are not included, and neither are Antarctica and Greenland.

2 Biodiversity is expressed in terms of the mean species abundance of the original species (MSA). This indicator of biodiversity is used throughout the report, unless stated explicitly different, for example the extent of ecosystems or the number of threatened species. See also section 2.3.

3 All options have been super-imposed individually on the baseline scenario. No option combinations have been analysed.

4 It should be stressed that the purpose of the baseline is to serve as a reference for evaluating policy options, not as a precise prediction of the future.

points more than used in the baseline. Increase in agricultural productivity will therefore be a key factor in reducing the rate of land use change and therefore biodiversity loss in the future.

7. Changes in biodiversity are not equally distributed across the globe and for the earth's biomes. Dryland ecosystems –grasslands and savannah –will be particularly vulnerable to conversion over the next 50 years. Much of the world's remaining natural capital will consist of mountainous, boreal, tundra, and ice and (semi-)arid ecosystems, generally considered less suitable for human settlement. It should be noted that inland waters and marine ecosystems have not been considered, as well as Antarctica and Greenland.

Key findings: do options reduce the rate of loss?

8. Six policy options have been evaluated with respect to their impact on biodiversity loss. The options (listed below in arbitrary order) were selected from current negotiations and discussions in various political arenas. It should be noted that these options are feasible but not 'easy' to implement. Implementation will require strong international commitment and coordination. Due to several uncertainties, the option effects should be regarded as robust in their direction and relative magnitude, and much less robust in their absolute values. It should be stressed that these options do not try to predict the future, but just explore opportunities and risks for achieving the 2010 biodiversity target. Options are:

- Effective implementation of **full trade liberalization in agriculture from 2015 onward**, driven by free-trade and development considerations following the current WTO Doha Round. Implementation leads to an additional biodiversity loss of 1.3%⁵ up to 2050 due to a 6.5% global increase in land used for agriculture, concentrated in Latin America and Southern Africa⁶. The production shift and expansion in some regions is driven by cost-efficiency considerations, since labour and land costs are particularly low. On the other hand, agricultural productivity is less efficient in low-cost regions. This shift of production is at the expense of production in the USA, Europe and Japan. The shift results in higher net land requirements at the global level, since current crop yields are much higher in these developed regions. The increase in agricultural land is at the expense of natural forest and grassland areas. About 1.3 million km² or 20% of the baseline agricultural area will no longer be required for intensive agricultural production in the USA, Canada, OECD Europe and Japan. This area potentially enables restoration of biodiversity, but only in the long term, as these disturbed lands will, initially, show a low biodiversity.
- In order to **alleviate extreme poverty**, as targeted in the Millennium Development Goals, additional investments from developed countries are focused on Sub-Saharan Africa in **combination with trade liberalization of agriculture under option 1**. This is in line with proposals in the Millennium Project (UN Millennium Project, 2005a, b). The option views economic growth as a condition for poverty alleviation. Assuming effective implementation of these investments, including a higher productivity of 10%, this option leads to a 25% GDP increase in Sub-Saharan Africa on top of the baseline in 2030. This increase in GDP has a direct effect on food consumption in Africa, food being mainly produced in the region itself, implying a 10% increase in agricultural land and an additional biodiversity loss of about 5.7% in the region⁷. Not all possible effects are taken into account. A hunger and poverty strategy will require heavy investments in infrastructure, leading to further biodiversity losses not taken into account here.
- The implementation of **sustainable meat production** takes animal and human health into account, increases animal welfare and limits loss of nutrients. These changes are translated into a 20% increase in the cost of meat production. This is estimated to result in a 10% increase in consumer prices of meat products and a decrease in the global meat consumption of about 5%. This lower consumption

5 'Additional increase' means an increase compared to the baseline. This applies for all options.

6 In this report all changes in biodiversity (MSA) are expressed in percentage points; so a decrease of 7% means for example a change in MSA from 70% towards 63%.

7 This is 2% additional loss in the region compared to the option of trade liberalisation of agriculture only.

leads to a smaller number of animals needed for food consumption and therefore to less agricultural area and nitrogen deposition. Consequently, biodiversity is expected to increase by around 0.3% compared to the baseline.

- Implementation of an ambitious and **bioenergy-intensive climate-change-mitigation policy** option, stabilizing CO₂-equivalent concentrations at a level of 450 ppmv in line with the goal of keeping the global temperature increase below 2 °C, will require substantial changes in the world energy system. One of the more promising options for reducing emissions (in particular, in transport and electric power) is the use of bioenergy. A scenario has been explored in which bioenergy plays an important role in reducing emissions. In this scenario major energy consumption savings are achieved, and 23% of the remaining global energy supply in 2050 is produced from bioenergy. By 2050 the biodiversity gain (+1%) from avoided climate change and reduced nitrogen deposition due to less fossil-fuel burning does not compensate for the biodiversity loss (-2%) due to additional land use. About 10% of the global agricultural area will be used for biofuel production. This leads to a net additional biodiversity loss of around 1%. Bioenergy is assumed to arise from products mostly grown on abandoned agricultural land and natural grasslands. This leads to a net decrease of biodiversity, since the baseline assumes that natural ecosystems will be restored in abandoned areas. This is probably an overestimation of biodiversity loss, as restoration will probably not be complete, and part of the biofuel production might be allocated on degraded lands with a low potential for restoration.
- The continuing demand for wood (30% increase up to 2050) leads to increasing forest exploitation, affecting increasing areas of (semi-)natural forests. This forest use leads to about 2.5% of the global biodiversity loss. Implementing an option increasing the area of **plantation forestry** in which almost all wood produced in 2050 comes from intensively managed plantations, leads initially to additional biodiversity loss through increased land use. When plantations gradually take over global production, the previously exploited semi-natural forests are left to recover. By 2050 the total biodiversity loss in the forestry option is slightly less (0.1%) than the loss resulting from ongoing exploitation of mostly (semi-)natural forests in the baseline. As semi-natural forests are left for further recovery after 2050, the option will show better performance. The loss due to deforestation from fires and transmigration is not taken into account. Deforestation is attributed to agriculture if conversion takes place primarily to create room for agricultural uses.
- **At least 10% of each of the world's ecological regions effectively conserved**, a provisional target agreed upon by the Conference of the Parties (COP) to the CBD, has almost already been achieved in the baseline. As this option will have a limited effect on slowing the loss of biodiversity, the 10% option has not been further analysed. **Effective conservation of 20% of the area in all the ecological regions** will reduce the total loss of 7% by about 1%, yielding the best result of the six options considered. Effective conservation reduces land conversion, and extensive use and human settlement in still intact areas, and also enables restoration of partly degraded protected areas in the period up to 2050. However, the gains from effective conservation and restoration are partly lost due to the shift of agricultural activities to adjacent areas to fulfill human needs. Or simply stated, gains within the protected areas are partly offset by losses outside the protected areas, which, in terms of area, is many times larger. Furthermore, the effects of pressures such as N deposition, fragmentation, existing roads and climate change will continue to affect protected areas. The use of a red list index or indicator that is sensitive to uniqueness will probably show stronger positive effects. By setting up a well-chosen network of protected areas, relatively large and intact ecosystems containing the majority of the species will be conserved, including large-bodied, often slow reproductive and space-demanding, species such as large carnivores and herbivores, primates and migratory animals ('wilderness area'). This will obviously have an effect on the number of threatened and extinct species or the Terrestrial Trophic Index. However, the models used in this study were not able to quantify these gains. Neither could the potentially positive effects of ecological networks as an adaptation strategy for climate change be calculated within the time frame of this study.

9. All options have an economic impact or 'cost'. In most cases there is a trade-off between biodiversity and economic growth. In the case of trade liberalization and poverty reduction, higher economic growth takes place at the expense of global biodiversity. Economic costs and biodiversity gains may be spread over time. Climate change policy will result in decreased economic growth, while beneficial effects on biodiversity and the economy (or avoided cost) can only be expected in the long term. Options more directly targeted at restoring biodiversity (protection of areas, sustainable meat production and increasing plantations) have a negligible effect on a macro-economic scale. However, these options might involve huge structural changes and large shifts in government spending and other spending in the sectors involved.

Options in perspective

10. Promising policy options that progress towards the 2010 Biodiversity Target have emerged from this preliminary assessment:
- Protected areas and sustainable meat production have immediate positive effects. Climate change mitigation and increased plantation forestry can only show beneficial effects after several decades. In the short term, these options will exert increasing pressure on biodiversity.
 - Find ways to keep the long-term benefits of some options, whilst reducing their short-term pressures. For example, the climate change mitigation option considered in this study relies strongly on substitution of fossil fuels for renewable bioenergy. Other mitigation options that may have less negative impact, or actually provide benefits for biodiversity conservation could be explored, which might undermine achievement of the climate target or, at least, lead to higher costs.
 - Options with an immediate effect should be made more efficient. For example, a substantial increase in effectively managed protected areas will provide a quick and positive outcome for the 2010 Biodiversity Target, with emphasis on the most vulnerable regions. Such efforts could also have beneficial effects by increasing revenues from tourism, protecting water resources and many other key ecosystem functions.
 - Limit the trade-off between economic growth and biodiversity.
 - More focus on agricultural productivity and stimulation of efficient land use. Further enhancement of agricultural productivity ('closing the yield gap') is the key factor in reducing the need for land and, consequently, the rate of biodiversity loss. Technology transfer and capacity building are pre-conditional to this. The feasibility of this option is one of the key focal points of the International Assessment of Agricultural Science and Technology for Development (IAASTD or Ag-assessment) in progress. This option should be implemented carefully in order not to cause new undesired negative effects, such as emissions of nutrients and pesticides, as well as risks of land degradation.
 - Controlled liberalization of the agricultural market. This contributes to poverty alleviation, although unbalanced and direct liberalization may hinder poverty alleviation in the regions where sufficient institutions and government control are not available. In order to achieve complete poverty alleviation and avoid unnecessary and persistent loss of biodiversity through land conversion in low-cost areas, trade liberalization needs to be combined with controlled policy interventions.
 - Targeting the distribution of economic growth and investments at poor people. In the long term economic growth and poverty reduction may help biodiversity, as it is assumed to accelerate the demographic transition and adoption of more productive and sustainable land-management practices. It is evident that economic growth is taking place at the expense of further decline in biodiversity. The challenge to find realistic policy options that conserve biodiversity *and* help the extreme poor remains⁸.

⁸ For example, through local-specific integration of relevant poverty reduction strategies such as production intensification, product diversification, increased farm size, increased off-farm income and exit from agriculture (Dixon *et al.*, 2001).

- Solving the value problem. Conserving biodiversity depends crucially on what societies are willing to pay for conservation of ecosystem services. More emphasis could go into demonstrating and designing markets to capture the value of these services.
11. A concerted effort is essential if the rate of loss is to be reduced. Optimal results can be obtained through a combination of options including: maximum enhancement of agriculture productivity, reducing climate mitigation with little or smart implementation of bioenergy, establishing plantation forestry and sustainable meat production, and realizing a major increase in effective protected areas. This combination of options could not be assessed due to the time limits on this study. Regional, tailor-made measures could provide additional opportunities.
 12. The decline of global biodiversity is probably underestimated, as the scenario explored is optimistic about agricultural productivity increases. Other biodiversity indicators will show similar general patterns of overall biodiversity decline, with the same main drivers in this decline; however, the exact number will vary among indicators. Obviously, not all pressures could be taken into account. Regional declines in biodiversity and land-cover shifts will show considerable variation, depending on the assumed effects of changing agricultural, protection and trade policies (with trade-offs between regions where production is moved to other areas).

1. AIMS AND LIMITATIONS OF THE REPORT

1.1. Aim

The Secretariat of the Convention on Biological Diversity (CBD) commissioned the Netherlands Environmental Assessment Agency (MNP) to explore candidate policy options that are expected to have a major impact on biodiversity. Some of the explored options might contribute towards the achievement of the 2010 Biodiversity Target at global and regional levels. Other explored options concern cross-cutting issues like trade liberalization and poverty alleviation that are expected to influence biodiversity in a significant way. We assumed that the six policy options would have a considerable impact—positive or negative. The analyses were carried out to determine the approximate size, location and time span of their effects. In view of the short time span between now and 2010, and the time lag in realizing several measures, long-term effects have been taken into account by extending the calculations up to 2050.

The assessment was carried out using the IMAGE-GLOBIO model, allowing a quantitative approach. Within the limits of the model, the results were expressed in terms of the 2010 indicators according to CBD Conference of the Parties (COP) decision VII/30. The results have served as input for the Global Biodiversity Outlook 2 to support policy makers in determining cost-effective ways for achieving the 2010 target⁹. The study was executed in cooperation with UNEP-WCMC, UNEP-GRID Arendal and Agricultural Economics Research Institute (WUR-LEI). The assessment took place from 1 October to 15 December 2005.

1.2. Limitations

The reader should be aware that this study is not meant to predict the future but to explore the major contributions of various currently debated policy options. Some of these are targeted at achieving the 2010 target on global and regional scales, while others have their origin in important global policy issues on trade and development. The exploration of options documented in this report is not exhaustive for obvious reasons: the models and means are limited. Significant limitations to the study are included below:

- Restricting the aim to increasing general quantitative insights on the efficacy of a limited number of major policy options.
- Not taking several pressures such as pollution, extensive grazing, fire, erosion, transmigration and water extraction into account in the calculations of the rate of loss of biodiversity, or possible extreme events resulting from climate change. The currently applied models do not yet include these factors. Possible policy options to reduce these pressures were therefore not considered.
- Neither taking aquatic ecosystems (freshwater and marine) into account, nor the effects on these systems.
- Not being able to investigate optimal combinations of policy options and quantify their potential to reduce the rate of loss of biodiversity within the time constraints. Only poverty reduction has been calculated in combination with liberalization of the agricultural market.
- Not being able to investigate region-specific options, and data-sources on finer scales.
- Focusing the analysis on two CBD indicators, i.e. trends in species abundance and ecosystem extent. We are not able to model the status of threatened species (red list index), being the third CBD indicator on biodiversity status.
- The baseline scenario chosen assumes high food production rates compared to rates in the four scenarios of the Millennium Ecosystem Assessment.
- The results for 2010 were interpolated from 2000 and 2030, since actual model outputs hardly differentiate between global and regional scales.
- The longer term benefits for biodiversity of reducing climate change and poverty reduction will probably occur beyond the time horizon of this study (2050), and should be taken into account in the interpretation of the results.
- Assuming less optimistic agricultural productivity figures from the MEA will lead to 20 to 30% more crop area, and several percent additional biodiversity loss. We emphasize that option effects in terms of

9 The GLOBIO model was developed in cooperation with UNEP-WCMC and UNEP-GRID Arendal.

direction and relative magnitude are more robust than the absolute baseline trend. The consequences of several other assumptions are elaborated in Chapter 6, where uncertainties and model sensitivity are dealt with.

A glossary of the most commonly used terms is included in Annex 2.

2. METHODOLOGY: FRAMEWORK, MODELS, INDICATORS AND SCALES

The model framework will be elaborated in sections 3.1 and 3.2, while the context of indicator choice is found in section 3.3; the importance of scale is given in section 3.4.

2.1. Framework

The approach is based on the conceptual framework used in the Millennium Ecosystem Assessment (MEA, 2003, 2005), where indirect drivers like population, economy, technology and lifestyle are used to determine direct drivers of change, such as land use change (agriculture and forestry), climate change, energy use, the application of bioenergy, infrastructure, nitrogen deposition and fertilizer use. These direct drivers affect ecosystems and biodiversity. Indirect and direct drivers, as well as changes in ecosystem services, affect human well-being parameters such as health and security (Figure 1). These analyses also enable the future assessments of trade-offs and synergies between biodiversity and human well-being (including poverty).

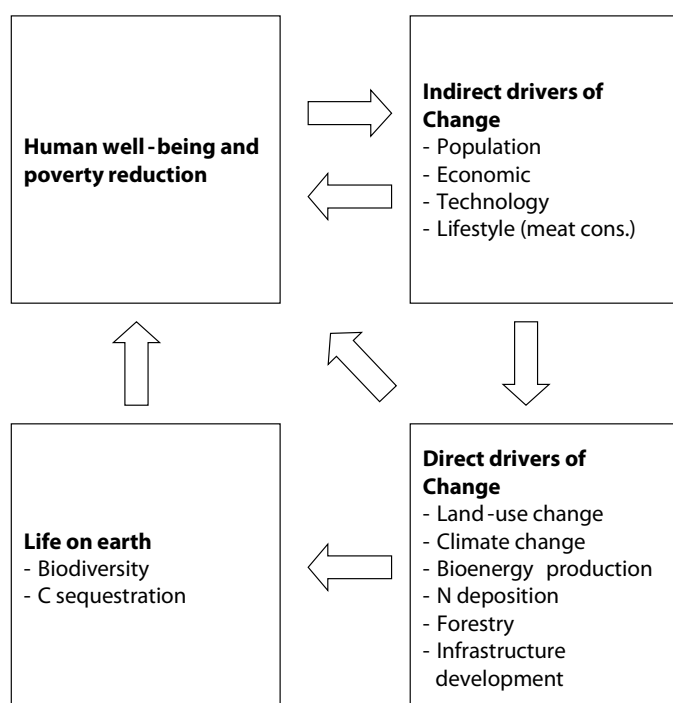


FIGURE 1: Framework for analysis of solution-oriented policy options using the GTAP-IMAGE-GLOBIO model (adapted from MEA, 2005). Not all factors are reported in this study.

The framework used to assess the environmental and economic consequences of different policy options combine: i) macro-economic projections, with ii) an agricultural trade model (extended version of GTAP: Global Trade Analysis Project) and iii) a global integrated environmental assessment model (IMAGE: Integrated Model to Assess the Global Environment) and iv) a global biodiversity assessment model (GLOBIO3). The macro-economic and demographic projections form the input of the combined modelling framework. The results of GTAP-IMAGE are fed to the biodiversity model GLOBIO3.

2.2. The GTAP-IMAGE-GLOBIO model

To analyse the economic and environmental consequences of changes in global drivers and policies, we developed a global economic-biophysical framework by combining the extended GTAP model (Van Meijl *et al.*, 2005) with the IMAGE model (Alcamo *et al.*, 1998; IMAGE Team, 2001). The details of the combined modelling framework and implementation of GTAP and IMAGE are documented in Van Meijl *et al.* (2005), Eickhout *et al.* (2006) and MNP (2006). The standard GTAP model (Hertel, 1997) is characterized by an input-

output structure, based on regional and national input-output tables. The model explicitly links industries in a value-added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption (Hertel, 1997). An extended version of the standard GTAP model that improved the treatment of agricultural production and land use was developed for this study (Van Meijl *et al.*, 2005). Since it was assumed that the various types of land use are imperfectly substitutable, the land-use allocation structure was extended by taking into account the degree of substitutability between agricultural types (Huang *et al.*, 2004). For this reason, OECD's more detailed Policy Evaluation Model (OECD, 2003) structure was used. Moreover, in this extended version of the GTAP model, the total agricultural land supply was modelled using a land-supply curve, specifying the relation between land supply and rental rate (Van Meijl *et al.*, 2005). Through this land-supply curve, an increase in demand for agricultural products will lead to land conversion to agricultural land and a modest increase in rental rates when enough land is available. If almost all agricultural land is in use, increase in demand will lead to increase in rental rates.

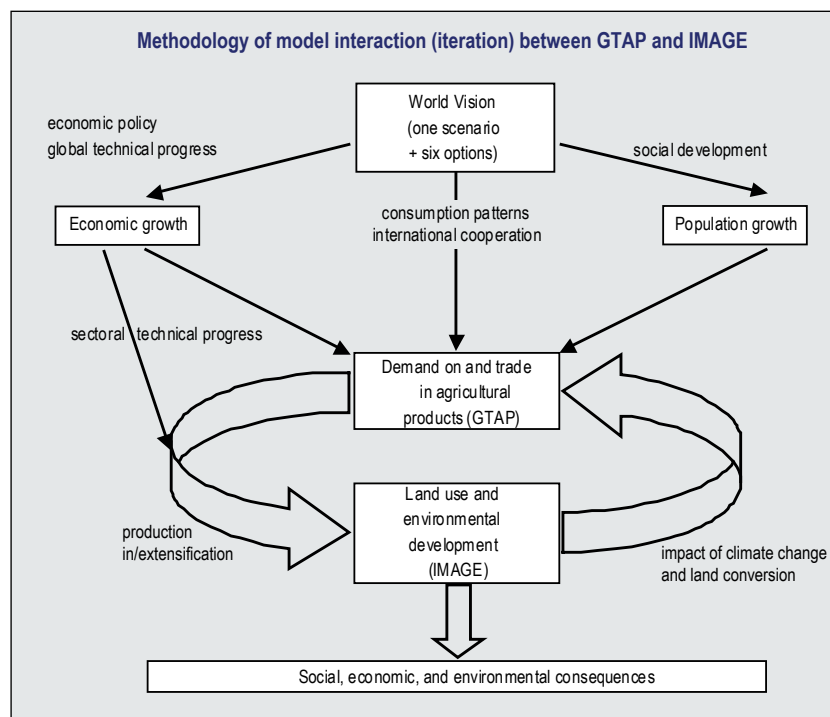


FIGURE 2: The GTAP-IMAGE modelling framework (Van Meijl *et al.*, 2005).

Figure 2 shows the methodology of iterating the extended version of GTAP with IMAGE. Macro-economic drivers like population and economic growth are used as input in both the GTAP and IMAGE models. In the extended GTAP, model yield depends on an exogenous (autonomous) trend factor (technology, science, knowledge transfer) and also on land prices. This implies the presence of substitution possibilities among production factors. If land gets more expensive, the producer uses less land and more other production factors such as capital. The impact of a higher land price is that land productivity or yields will increase. The exogenous trend of the yield was taken from the FAO study 'Agriculture towards 2030' (Bruinsma, 2003), where macro-economic prospects were combined with local expert knowledge. However, many studies indicate that change in productivity is enhanced or reduced by other external factors, of which climate change is mentioned most often (Rosenzweig *et al.*, 1995; Parry *et al.*, 2001; Fischer *et al.*, 2002). These studies indicate increasing adverse global impacts on crop yields because of temperature increases above 3–4°C compared to pre-industrial levels. These productivity changes need to be included in a global study. Moreover, the amount of land expansion or land abandonment will have an additional impact on productivity changes, since land productivity is not homogeneously distributed. Climate change feedback is in the model, including adoption of different cultivars or even different crops to avoid productivity losses expected from continued use of current cultivars.

The economic consequences for the agricultural system are calculated by GTAP. The outputs of GTAP include sectoral production growth rates, land use and an adjusted management factor describing the degree of land intensification. This information is used as input for the IMAGE simulations, together with the same global drivers as used by GTAP.

Since the IMAGE model performs its calculations on a grid scale (of 0.5 by 0.5 degrees) the heterogeneity of the land is taken into consideration on a grid level (Leemans *et al.*, 2002). Protected areas cannot be used for agricultural production in the IMAGE land-use model. Therefore, a fixed map of protected areas (taken from UNEP-WCMC) is also used as IMAGE model input. IMAGE simulations deliver an amount of land needed per world region and the coinciding changes in yields resulting from changes in the extent of land used and from climate change. Land-use changes are spatially allocated to the uniform grid cells following a simple rule-based algorithm to select cells for agricultural expansion. This implies that the natural biome occupying the grid cell will be lost to agriculture. In GLOBIO, the pattern is further refined on the basis of GLC2000 maps (1 by 1 km grid scale).

These additional changes in crop productivity are subsequently given back to GTAP, thereby correcting the exogenous (technology, science, knowledge transfer) trend component of the crop yield. A general feature is that yields decline if large land expansion occurs, since marginal lands are taken into production. In the short term, these factors are more important than the effects of climate change. Through this iteration, GTAP simulates crop yields and production levels on the basis of economic drivers and changes in environmental conditions. This combined result is once more used as input in IMAGE to consistently calculate the environmental consequences in terms of land use.

IMAGE provides dynamic and long-term perspective modelling on the consequences of global change up to 2100. The emission from the IMAGE energy model, and land-use change estimates after the iteration with GTAP, are used to calculate changes in atmospheric composition and climatic conditions by resolving the changes in radiative forcing; these are caused by greenhouse gases, aerosols and oceanic heat transport (Eickhout *et al.*, 2004). Nitrogen emissions from fuel combustion, biomass burning and agriculture are used to assess the consequences of exceeding critical loads for natural vegetation. The critical load approach describes the vulnerability of ecosystems to deposition of N. A critical load is defined as 'a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge' (Nilsson and Grennfelt, 1988). The critical load approach assumes steady state: i.e. equilibrium conditions have been reached with the deposition flux. Processes acting on a *finite* time scale (e.g. sulphate adsorption) are not considered here. Hence, this approach aims at providing long-term protection of ecosystems. Further information on treating the nitrogen impacts is given in Bouwman *et al.* (2002).

Climate change is modelled in IMAGE 2.2 using an upwelling diffusion model. This model converts concentrations of different greenhouse gases and sulphur dioxide emissions into radiative forcing and subsequent temperature changes of the global mean surface and the oceans. This is based on the MAGICC model of the Climate Research Unit (CRU) (Hulme *et al.*, 2000), the most widely used simple climate model within the IPCC (IPCC, 2001a). More details on MAGICC can be found in Raper *et al.* (1996) and Hulme *et al.* (2000). The implementation of MAGICC in IMAGE 2.2 and the calculation of the radiative forcing is described by Eickhout *et al.* (2004). Climate-change patterns are not simulated explicitly in IMAGE. Instead, the global mean temperature increase, as calculated by IMAGE, is subsequently linked to the climate patterns generated by a general circulation model (GCM) for the atmosphere and oceans, and combined with observed climate means over the 1961-1990 period (New *et al.*, 1999). Linking takes place using the standardized IPCC pattern-scaling approach (Carter *et al.*, 1994) and additional pattern-scaling for the climate response to sulphate aerosols forcing (Schlesinger *et al.*, 2000). The IMAGE environmental impact models involve specific models for sea-level rise and land-degradation risk, and make use of specific features of the ecosystem and crop models to depict impacts on vegetation and crop growth (Bakkenes *et al.*, 2006; Leemans and Eickhout, 2004).

The GLOBIO3 model (Alkemade *et al.*, 2006) is used in conjunction with the Natural Capital Index module of IMAGE (ten Brink, 2000; ten Brink *et al.*, 2000) and the GLOBIO2 model (UNEP, 2001). The NCI module was applied in UNEP's Global Environment Outlook 1 and 3 (UNEP, 1997 and 2002) and GLOBIO2 in Global

Environment Outlook 3 and various regional UNEP reports. The results of the modelling framework are used as proxies for the indicators agreed upon by the Conference of the Parties to the CBD (UNEP, 2004). The GLOBIO3 biodiversity model was conceived as a model measuring habitat integrity through remaining species-level diversity, i.e. in terms of the mean abundance of the original species (MSA). At the heart of GLOBIO3 is a set of regression equations relating degree of pressure to degree of impact (dose-response relationships). The dose-response relationships are derived from the database of biodiversity response to change. Where possible, relationships for each pressure are derived for biome and region—depending on the amount of available data. A meta-analysis is currently underway to examine which areas of the database are most urgently in need of expansion.

The *database* includes two different measures: i) *mean species abundance* of the original wild species (MSA) and ii) *species richness* of the original wild species (MSR), each in relation to different degrees of pressure. The entries in this database are all derived from peer-reviewed studies, either of change through time in a single plot, or of response in parallel plots undergoing different pressures. An individual study may have reported species richness, mean species abundance, or both. Rows are classified by pressure type, the taxon under study, biome and region. The model is static rather than dynamic, and deterministic rather than stochastic. A map of each of the pressures in 2020 is required to estimate the impact on biodiversity of pressures under a given scenario in, for example, 2020. This also includes the impact of any policy option reducing (or increasing) the pressure (for example, farming type or protected area designation). The driving forces (pressures) incorporated in the model are: i) land-use change such as agriculture, forestry and built up area (taken from IMAGE), ii) land-use intensity (partly taken from IMAGE), iii) nitrogen deposition (taken from IMAGE), iv) infrastructure development (as applied in GLOBIO2), v) fragmentation (derived from infrastructure) and vi) climate change (taken from IMAGE).

We found about 120 published data sets comparing the species diversity of different land-use types. Some of these studies include a pristine, undisturbed location (e.g. primary forest). The different land-use types mentioned in these studies were categorized into six globally consistent groups: i) primary vegetation, ii) lightly used primary vegetation, iii) secondary vegetation, iv) pasture, v) plantation forestry and vi) agricultural land, including cropland and agroforestry systems. Most of the studies describe plant or animal species in the tropical forest biome; however, the sparse studies from other biomes confirm the general picture. Different agricultural land-use intensity classes are distinguished. A gradual increase in external inputs in agricultural systems forms the basis for different intensity classes. We distinguish agroforestry, low-input (or traditional) farming, intensive (or conventional) farming and irrigated farming. Each intensity class carries a specific biodiversity value. Table 1 summarizes and describes the different categories. These figures correspond with the results of Scholes and Biggs (2005), who estimated fractions of original populations under a range of land-use types based on expert knowledge.

The data for natural land cover, land use and land-use changes come from the IMAGE model with a 0.5 by 0.5 degree resolution. To increase spatial detail, we combine the land-use data with the Global Land Cover 2000 (GLC 2000) map (Bartholomé *et al.*, 2004; Bartholomé and Belward, 2005). This map has a ~0.5 minute resolution from the VEGA2000 data set with a daily global image from the Vegetation sensor on board the SPOT4 satellite representing the year 2000. We calculated the proportion within each IMAGE grid cell of each land cover / land-use type from GLC 2000. The GLC 2000 map has 10 forest classes, 5 classes of low vegetation (grasslands and shrublands), 3 cultivated land classes, ice and snow, bare areas and artificial surfaces. These classes are based on the Land Cover Classification System developed by FAO and the United Nations Environment Programme (UNEP) (Di Gregorio and Jansen, 2000).

To calculate the impact of the intensity of agricultural production we needed to assign the categories 'intensive agriculture' and 'low-input agriculture' to the GLC class of 'cultivated and managed areas'. We used estimates of the distribution of intensive and low-input agriculture in different regions of the world from Dixon *et al.* (2001). For all other regions we assumed 100% intensive agriculture. For the future, the change in agricultural land calculated by IMAGE for each world region is distributed proportionally to current land use over all grid cells. The GLC 2000 class, containing a mosaic of cropland and forest, is assigned to the land-use category 'agroforestry'.

Grazing areas are estimated by IMAGE for current and future years and distributed proportionally among all GLC 2000 classes containing low vegetation. We assigned this area to the category of 'livestock grazing'. The GLC 2000 class of 'herbaceous cover', found in areas with forests as potential vegetation, are assigned as artificial pastures, using the potential vegetation map generated by IMAGE based on the BIOME model (Prentice *et al.*, 1992).

To calculate the impact of forestry we needed to assign the land-use categories 'lightly used forest', 'secondary forest' and 'plantation forest' to the GLC 2000 classes. We used data on forest use from FAO (2001) and assigned the derived fractions for each region. These fractions were distributed proportionally among all grid cells representing one or more GLC 2000 forest classes. For future calculations we used calculated timber demands to derive the areas needed to produce timber, and distributed the new fraction among the individual grid cells.

TABLE 1 : GLOBIO3 categories of land cover / land use and the relative mean abundance of species, on the basis of about 120 published data sets, with corresponding GLC 2000 classes listed below

MAIN LAND- COVER/ USE	SUB LAND COVER / USE CATEGORY	DESCRIPTION	MSA
Ice and snow (I)	Undisturbed Primary vegetation	Areas permanently covered with snow or ice. Considered as undisturbed areas	1.0
Bare land (D)	Undisturbed Primary vegetation	Areas permanently without vegetation due to originally occurring natural processes (e.g. deserts, high alpine areas)	1.0
Forests (F)	Undisturbed Primary vegetation	Minimum recent human impact, where flora and fauna species abundance are near pristine	1.0
	Lightly used Natural forest (u)	Forests with extractive use and associated disturbance (e.g. hunting and selective logging) where timber extraction is followed by a long period of re-growth with naturally existing tree species	0.7
	Secondary forests (S)	Areas originally covered with forest or woodlands where vegetation has been removed; areas now show forest re-growth, different cover or are no longer in use	0.5
	Plantation forest	Planted forest, often with exotic species	0.4
Shrubs and grasslands (G)	Undisturbed Primary vegetation	Grassland or shrub-dominated vegetation (e.g. steppe, tundra or savannah)	1.0
	Livestock grazing	Grasslands where naturally occurring grazing is replaced by livestock	0.7
	Man made pastures (p)	Forests and woodlands that are converted to grasslands for livestock grazing.	0.1
Mosaic (M) cropland/forest	Agroforestry	Agricultural production intercropped with (native) trees. Trees are kept for shade or as wind shelter	0.5
Cultivated land (C)	Extensive agriculture	Low-external input and sustainable agriculture (LEISA); Subsistence and traditional farming; Extensive farming and Low-External-Input Agriculture (LEIA)	0.3
	Intensive agriculture	High external input agriculture (HEIA); Conventional agriculture; Integrated agriculture, mostly with a degree of regional specialization.	0.1
	Irrigated or drained land	Irrigation based agriculture; drainage-based agriculture and greenhouse production, often accompanied by soil levelling practices and a high degree of regional specialization	0.05
Built up areas (B)		Areas built up more than 80%	0.05

Corresponding GLC2000-classes: (I) Snow and Ice, (D) Bare areas (sand, gravel and rock); (F) Broadleaved evergreen forest, closed broadleaved deciduous forest, deciduous needle-leaved forest, mixed forest, swamp forest, mangrove and other saline swamps, mosaic: forest/other vegetation, burnt forest; (G) Evergreen shrub, deciduous shrub, grassland, sparse shrub and grassland, flooded grassland and shrub, (M) Mosaic: cropland/forest, (C): Cultivated and managed areas and (B): Artificial surfaces.

Further to this, water bodies are excluded from the analysis and artificial surfaces are all considered to be built-up areas. Bare areas are considered to be primary vegetation if the potential vegetation is ice and snow, tundra or desert, where bare rocks or sand are abundant. Shrub classes are considered as secondary vegetation if the potential vegetation is forest (except for boreal forests).

The mean species abundance (MSA) is calculated in steps. First the MSA is calculated on the basis of the land-use intensity classes as described above. Subsequently, different pressures on these 'starting' values from Table 1 are superimposed, resulting in decreasing MSA values. Pressures considered are: i) climate change, ii) nitrogen deposition, iii) infrastructure and iv) fragmentation.

Climate change is treated differently from other pressures, as the empirical evidence so far is limited to areas that are already experiencing significant impacts of change (such as the Arctic and mountain forests). The current implementation in the model is based on estimates from EUROMOVE (Bakkenes *et al.*, 2002, 2006), in which the proportion of species lost per biome for climate change corresponds with increasing levels of global temperature. Regional deviations from the mean global mean temperature were taken into account when relationships per biome were established. This European bias is the most obvious area for model improvement. The model outputs are compared with the predicted biome shifts in the IMAGE model (Leemans and Eickhout, 2004). Table 2 shows the slopes of the linear regression lines that describe the global relationships between increase in temperature and stable area for each biome (IMAGE) or group of plant species occurring within a biome (EUROMOVE). We used the regression lines with the lowest regression slope (i.e. have less effect), which yielded conservative estimates.

Another way in which climate change effects are taken into account is in the treatment of land-use change, described above. Within that procedure, present or projected land use is compared with the natural occurring biomes to assign the correct MSA values from Table 1. As IMAGE predicts shifts in biomes, the impact of land-use and land-use intensity changes synchronously with these projected shifts. This implicit effect is not reported in the climate change effects, but is incorporated in land-use changes.

TABLE 2: Slopes of the regression equations between 'mean stable area relative to original area' and ΔT (relative to pre-industrial) for each biome ($MSA = 100 - \text{slope} * \Delta \text{Temperature} / 100$)

BIOMES	SLOPE	
	IMAGE	EUROMOVE
Ice	2.3*	5.0
Tundra	15.4	7.1*
Wooded tundra	28.4	5.1*
Boreal forest	4.3*	7.9
Cool conifer forest	16.8	8.0*
Temperate mixed forest	4.5*	10.1
Temperate deciduous forest	10.0*	10.9
Warm mixed forest	5.2*	13.9
Grassland and steppe	9.8*	19.3
Hot desert	3.6*	–
Scrubland	12.9*	17.4
Savannah	9.3*	–
Tropical woodland	3.9*	–
Tropical forest	3.4*	–

* Slopes used in the GLOBIO 3 model.

We reviewed some 50 studies on experimental addition of *nitrogen* in natural systems and the effects on species richness and species diversity. Based on this review, dose-response relationships were established between the amount of nitrogen deposition that exceeds the empirical critical load level and MSA. We assumed the addition of nitrogen in those studies to be equivalent to N deposition occurring in the field. The N deposition impact factor applies only to natural land and cropland, because the addition of nitrogen in agricultural systems is assumed to be much higher than the additional N deposition. Table 3 shows the regression equations for the biomes that were covered in the study by Bobbink (2004). In the GLOBIO 3 model the regression equation for boreal forests is applied to all forest GLC classes (Bartholomé *et al.*, 2004; Bartholomé and Belward, 2005), the grassland ecosystem equation is applied to all low vegetation (grassland and shrubs) ecosystems. The arctic alpine ecosystem equation is applied to the ice and snow land cover.

TABLE 3: Regression equations for the relationship between nitrogen deposition exceedances above critical loads and MSA for three ecosystems

ECOSYSTEM	EQUATION*	LAND-COVER CLASSES
Arctic-Alpine ecosystem	$N = 0.9 - 0.05 \times \text{Nitrogen exc.}$	Ice
Boreal coniferous forest	$N = 0.8 - 0.14 \log_e (\text{Nitrogen exc.})$	Forest
Grassland ecosystems	$N = 0.8 - 0.08 \times \log_e (\text{Nitrogen exc.})$	Forest

* N = MSA; Nitrogen exc. = Nitrogen exceedance defined as 'N deposition minus mean critical load'

The impact of *infrastructural development* is based on the GLOBIO 2 model, where relationships were constructed between the distance to roads and mean species abundance for different biomes. Relationships are based on 300 reviewed articles, comprising information on 200 different species (UNEP, 2001). The impact of infrastructural development includes: i) the direct effects on wildlife by disturbance and avoidance; ii) fragmentation effect due to barrier effects; iii) increased hunting activities, and iv) small-scale settlements along roads. The dose-response relationships were used to construct impact zones along linear infrastructure (roads, railroads, power lines, pipelines), based on data from the Digital Chart of the World (DMA, 1992). Buffers of different width around infrastructure elements were calculated, and assigned to impact zones with different MSA values. Table 4 shows the biodiversity MSA for the different impact zones for different biomes. The fraction of species loss was calculated for each impact zone (depending on local occurring natural land cover), and aggregated to 0.5 by 0.5 degree grid cells.

TABLE 4: Zones (in km) along linear infrastructural objects, showing impacts from infrastructure on mean species abundance (MSA) in different biomes (derived from UNEP/RIVM 2004)

VEGETATION COVER	HIGH IMPACT (MSA=50%)	MEDIUM IMPACT (MSA=75%)	LOW IMPACT (MSA=90%)	NO IMPACT (MSA=100%)
Croplands	0.0-0.5	0.5-1.5	1.5-5.0	>5.0
Grasslands	0.0-0.5	0.5-1.5	1.5-5.0	>5.0
Boreal forests	0.0-0.3	0.3-0.9	0.9-3.0	>3.0
Temperate deciduous forests	0.0-0.3	0.3-0.9	0.9-3.0	>3.0
Tropical forests	0.0-1.0	1.0-3.0	3.0-10.0	>10.0
(semi-)deserts	0.0-0.5	0.5-1.5	1.5-5.0	>5.0
Wetlands	0.0-0.5	0.5-1.5	1.5-5.0	>5.0
Arctic tundra	0.0-1.0	1.0-3.0	3.0-10.0	>10.0
Ice and snow	0.0-0.5	0.5-1.5	1.5-5.0	>5.0

Fragmentation is included by means of a relationship between habitat area and the percentage of species that have stable populations (Table 5). In large areas all original species can find sufficient resources to support at

least a minimum viable population, whereas a small area may only support a few species. Data on the minimum area requirements of 156 mammal and 76 bird species were used to construct a general relationship between patch size and the percentage of species with at least one viable population. This biodiversity indicator is assumed to represent the relative MSA. Data were derived from Allen *et al.* (2001), Bouwma *et al.* (2002), Verboom *et al.* (2001) and Woodroffe & Ginsberg (1998). We assumed a much smaller area requirement (1 km²) for plant species than for animals. Plant and animal groups were equally weighted. For plant species we assume a much smaller area requirement (1 km²) than for animals.

TABLE 5: The relationship between patch sizes (area) and the corresponding fraction of species (MSAF) assumed to meet the minimal area requirement

AREA (KM ²)	MSAF
1	55
10	75
100	85
1000	95
>10000	100

Calculation of biodiversity loss and relative contributions of each driver

There is little quantitative information about the interaction between pressures. The model can therefore make a range of assumptions, from ‘all interact completely’ (only the maximum response is delivered) or ‘no interaction’ (the responses to each pressure being cumulative). For the analyses in this report, we used results assuming no interaction.

The GLOBIO 3 model calculates the overall MSA value by multiplying the MSA values for each driver for each IMAGE 0.5 by 0.5 degree grid cell according to:

$$MSA_i = MSA_{LU_i} MSA_{N_i} MSA_{I_i} MSA_{F_i} MSA_{CC_i} \quad (1)$$

where *i* is the index for the grid-cell, MSA_{X_i} relative mean species abundance corresponding to the drivers LU (land cover/use), N (atmospheric N deposition), I (infrastructural development), F (fragmentation) and CC (climate change). MSA_{LU_i} is the area-weighted mean over all land-use categories within a grid cell.

2.3. Indicators

The Conference of the Parties to the CBD has agreed on a set of headline indicators for assessing progress towards the 2010 Biodiversity Target, as shown in Table 6 (UNEP, 2004b). The bold indicators in this table have been dealt with in this study, focusing on terrestrial ecosystems and corresponding threats. The GLOBIO3 model calculates biodiversity status at the species and ecosystem level: i) mean species abundance (MSA) of the original species, and ii) trends in extent of biomes. The former indicator is a composite indicator, drawing on the CBD indicator ‘trends in abundance and distribution of selected species’ (see Box 1 for a more detailed description). The latter indicator draws on the ‘trends in extent of selected biomes, ecosystems and habitat’ indicator to show the trend in all major biomes, covering all terrestrial areas without mutual overlap. We did not focus on specific small-scale ecosystems or habitats.

TABLE 6: Set of headline indicators agreed on by the Conference of the Parties to the CBD through decision VII/30 and VIII/15

FOCAL AREA	INDICATOR
Status and trends of the components of biological diversity	<ul style="list-style-type: none"> • 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
Sustainable use	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Nitrogen deposition • Trends in invasive alien species
Ecosystem integrity and ecosystem goods and services	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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 benefit-sharing	<ul style="list-style-type: none"> • <i>Indicator of access and benefit-sharing</i>
Status of resource transfers	<ul style="list-style-type: none"> • Official development assistance provided in support of the Convention • Indicator of technology transfer

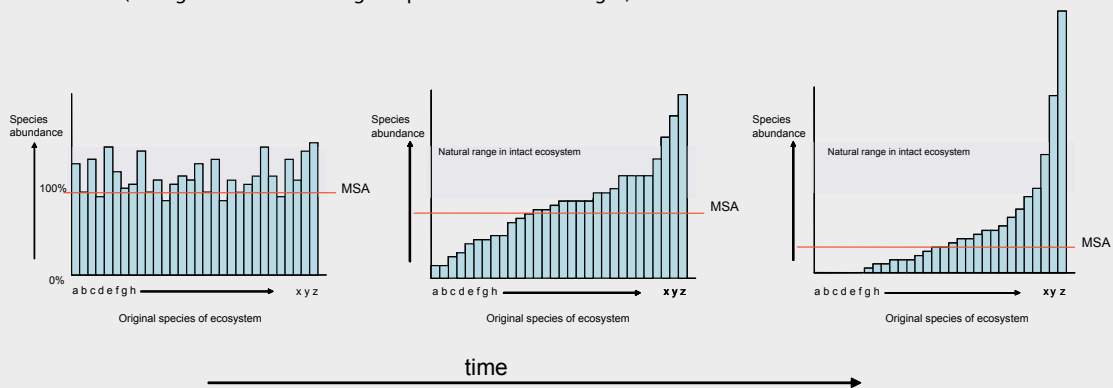
* Indicators shown in bold typeface have been assessed in this study. Indicators in italics are still in development.

The coverage of protected areas is included in the analyses as one of the options. Threats to biodiversity, such as nitrogen deposition, climate change and habitat fragmentation are included in the modelling exercise (see section 3.2). The figures shown represent the change in the effect of nitrogen deposition on the mean species abundance (MSA) compared to the baseline scenario. The issue of official development assistance is taken into account in the baseline scenario and all options as a result of the significant technology transfer on food production technology. Additional economic and technology support to alleviate poverty in Sub-Saharan Africa is worked out for one option and calculated for its effects.

Finally, we also dealt with costs of the different measures as a means of broadening the scope of our analysis, and acknowledging that economic development is needed for alleviation poverty; To assess the economic consequences or 'costs' of selected policy options, we used GDP as a crude measure, showing the cumulative effect of a policy on GDP relative to the baseline: for example, an effect of 1% means that GDP is 1% above the baseline level. The estimates are based on GTAP (see section 3.1). It should be noted that this approach does have some serious drawbacks. Using a macroeconomic measure like GDP ignores distributional effects. The results refer to structural effects as well, while adjustment costs are not taken into account. Hence, estimates are provisional, but do provide what we believe are the correct orders of magnitude.

BOX 1: How biodiversity loss was measured and modelled?

Biodiversity is a broad and complex concept that often leads to misunderstandings. According to the CBD, biological diversity means the variability among living organisms from all sources... and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. In this document we will focus on species, considering the variety of plant and animal species in a certain area and their population sizes. Population size is the number of individuals per species, generally expressed as the abundance of a species or, briefly, 'species abundance'. The various nature types or 'biomes' in the world vary greatly in the number of species, their species composition and species abundance. Obviously a tropical rain forest is entirely different from tundra or tidal mudflats. The loss of biodiversity we are facing in modern times is the — unintentional — result of increasing human activities all over the world. The process of biodiversity loss is generally characterized by the decrease in abundance of many original species and the increase in abundance of a few other — human-favoured — species, as a result of human activities. Extinction is just the last step in a long degradation process. Countless local extinction ('extirpation') precedes the potentially final global extinction. As a result, many different ecosystem types are becoming more and more alike, the so-called homogenization process (Pauly *et al.*, 1998; Ten Brink, 2000; Lockwood and McKinney, 2001; Meyers and Worm, 2003; Scholes and Biggs, 2005; MEA, 2005c). Decreasing populations are as much a signal of biodiversity loss as highly increasing species, which can sometimes even become plagues in terms of invasions and infestations (see figures below showing this process from left to right).



Until recently, it has been difficult to measure the process of biodiversity loss. 'Species richness' appears to be an insufficient indicator. First, it is hard to monitor the number of species in an area, but more important, species richness often increases as original species are gradually replaced by new human-favoured species (the 'intermediate disturbance diversity peak'). Consequently, the Conference of the Parties to the CBD (decisions VII/30 and VIII/15) has chosen a limited set of indicators for immediate use, including the 'change in abundance of selected species', to track this degradation process. This indicator has the advantage that it measures this key process and can be measured and modelled with relative ease.

In this study biodiversity loss was calculated in terms of the *mean species abundance of the original species* or briefly *mean species abundance* (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. To avoid masking, significant increased populations of original species are truncated at 100%, although they should actually have a negative score. Exotic or invasive species are not part of the indicator, but their impact is represented by the decrease in the abundance of the original species they replace. The *mean species abundance* (MSA) at global and regional levels is the sum of the underlying biome values, in which each square kilometre of every biome is equally weighted (ten Brink, 2000; UNEP, 2003b and 2004c). Paragraph 5.4 elaborates on sensitivity and uncertainties concerning the indicator choice.

The indicator applied in this study (MSA) is similar to the Natural Capital Index framework (NCI) and the Living Planet Index (LPI), both of which are proposed as candidate composite indicators under the CBD (UNEP, 2003b, 2004c). MSA differs from the LPI in that it applies a low-impact baseline as common denominator, which enables a fair comparison between regions which are in different stages of socio-economic development. MSA differs from the NCI framework in that MSA makes no difference between the assessment of agricultural and natural areas. Both are compared to the low-impacted natural state. NCI assesses agricultural ecosystems separately by using traditional agricultural ecosystems as baseline.

2.4. Temporal and spatial scales

The effects of the options were explored at global and regional levels for 2000, 2030 and 2050, and compared with the trends in a moderate growth, business-as-usual scenario (baseline). The following geo-political

regions and biomes were distinguished (Figures 3 and 4), the latter covering the thematic areas and their sub-divisions of the CBD as much as possible. The status and trends of biomes will be presented by region.

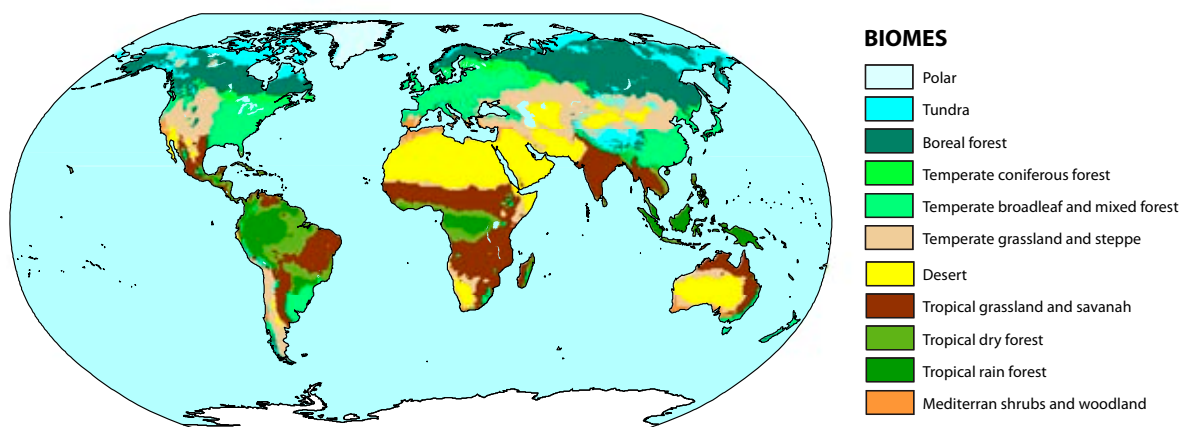


FIGURE 3: The biomes distinguished in the present IMAGE-GLOBIO model analysis.

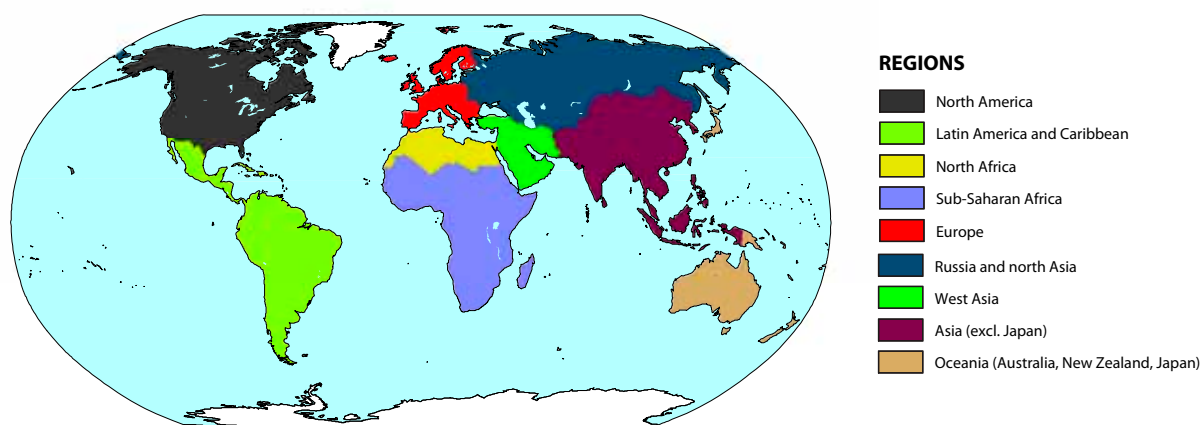


FIGURE 4: The regions considered: Greenland and Antarctica are excluded from the analysis.

The thematic areas; marine and coastal, inland waters, mountains and islands could not be assessed because of model limitations. The biomes considered (figure 3) are modelled on a grid level of 0.5 by 0.5 degrees in the IMAGE model. Within GLOBIO3, the IMAGE maps are downscaled to approximately a 1-km scale, following some simple decision rules and using Global Land Cover 2000 as a base map. These maps are used to estimate the response to changes in the land cover and land-use intensity. They may also be used to estimate the indicators ‘trends in extent of biomes’ and ‘trends in fragmentation of biomes’.

These and the maps representing other pressures are used to generate maps showing percentage of remaining biodiversity, which may be derived either in terms of remaining percentage of original species richness or remaining percentage of mean original species abundance. More data is being collated for abundance than for richness.

3. BASELINE SCENARIO AND POLICY OPTIONS

A 'baseline scenario' is used to explore candidate policy options on their effects on and contributions to the CBD 2010 biodiversity target. The baseline scenario is defined here as an autonomous process of socio-economic developments on which policy makers have no influence. A number of separate 'policy options' are superimposed on this baseline. Policy options are defined here as real possibilities to intervene in socio-economic developments. The policy options are derived from proposals and studies from international bodies, such as WTO, CBD, IPCC, UNFCCC and FAO. These will affect one or more of the indirect or direct drivers. Implementation of options is feasible in principle, but demands strong international commitment and cooperation.

The baseline is based on a 'business as usual scenario' for land-use changes developed by FAO (FAO, 2003) and for a world energy and climate change outlook by IEA (IEA, 2004). The scenario includes autonomous developments in demography, the economy and technology, and current policies agreed upon in international treaties. The scenario is based on moderate assumptions on population growth and economic development. The global population grows from 6.1 billion in 2000 to 9 billion in 2050, but at a declining growth rate. Over the same period, the global average income increases from \$5,300 to \$ 16,000 per capita. The compounded effect of population and economic growth represents more than a fourfold increase in global GDP in the next half century. Due to structural shifts of economies to less energy-intensive sectors and technological improvements leading to energy savings, total primary energy consumption increases by just over a factor of 2: from 400 to 900 EJ in 2050. In the baseline, energy supply continues to rely on fossil resources (coal, oil and gas) and thus emissions of greenhouse gases from combustion also keep rising. Together with emissions from land use and other sources, this leads to an ongoing rise in global temperature to 1.8 K compared to pre-industrial levels in 2050. This means that the rise in the next half century will exceed the observed increase in the last 130 years. After implementation of the Kyoto Protocol for 2008-2012, no further climate mitigation measures are to be taken at the baseline.

Consumption of agricultural products lags behind overall economic growth. However, the combined effect of more people taking in more calories, especially in currently undernourished regions, and the shift towards more animal products in the diet at higher income levels, imply a sharp increase in agricultural output. If we follow and extend the assumptions on agricultural productivity according to the FAO projection towards 2030, the total area required for food crops, grass and fodder remains fairly stable over the entire period. This illustrates that productivity assumptions here are relatively optimistic compared to other recent studies. For example, in the scenarios of the Millennium Ecosystem Assessment (MEA) the total crop area increases by 8% to 23% over the same period. It is worth noting that the bleak prospects emerging from the MEA in this respect have inspired the FAO, World Bank and other organizations to launch an assessment process (IAASTD). This will be aimed at a more in-depth investigation, with (regional) detail on the opportunities of higher agricultural productivity. The outcome of the IAASTD process may produce insights which will lead to an update of this crucial factor.

As far as nature conservation policies are concerned, the current protected areas are not expanding in the baseline scenario, being close to 10%. Rising timber demand is met by production from use of (semi-) natural forests. Forest conversion for agricultural expansion (slash and burn) does not contribute to the wood demand, and there is no wood production from (current or future) plantations.

Policy options that strive to reach the 2010 target calling for a significant reduction in the rate of loss of biodiversity can be numerous. Effective measures aim preferably at the reduction of pressure factors that affect biodiversity, i.e. land-use change and intensification, land degradation, climate change, economic and population growth, and corresponding infrastructural development as well as pollution. Policy measures in these fields often have multiple goals. We selected a number of policy options initiated, proposed and discussed in international fora, some of which aim at reducing the rate of biodiversity loss or present policies that can be expected to have a large impact on biodiversity. The selected policy options influence several of the major pressures on biodiversity loss. The options partly relate to the CBD framework of targets on promoting sustainable use, addressing threats to biodiversity, providing adequate resources and protecting components of biodiversity.

The policy options selected are (from indirect to direct drivers, see further Annex 1):

- 1. Liberalization of the agricultural market:** this has an effect on economic drivers and leads to regional shifts in food production, land use, agricultural intensification, habitat loss and nitrogen deposition, and is accompanied by high rates of technology transfer. All areas of negotiations are targeted: market access, domestic support and export competition.
- 2. Alleviation of extreme poverty and hunger in Sub-Saharan Africa:** additional economic and technology support to the poor and hungry in Sub-Saharan Africa will change the lifestyle, technology, demographics and finally land use in the poorest regions. This option is calculated in combination with liberalization of global agricultural markets.
- 3. Limiting climate change:** this includes more stringent application of measures aiming to comply with the ultimate UNFCCC goal, including a major increase in bioenergy production on marginal and abandoned agricultural lands and converted natural areas in order to mitigate climate change¹⁰.
- 4. Sustainable meat production:** reducing the land requirements for meat production, by implementing standards on meat production that will reduce health effects and nitrogen deposition, increase meat production costs, and reduce meat consumption.
- 5. Increasing the area of plantation forestry:** this will affect the efficiency of producing wood products, offering the opportunity to take pressure off (semi-)natural forests.
- 6. Protected areas: extending** the protected areas network to cover at least 20% of each biome. The newly protected areas were allocated to cover a representative selection of the earth's ecosystems, and are located in areas with concentrations of threatened and endemic species.

Many other policy options are conceivable, making a selection indispensable. Examples are: reduced population growth, abatement measures on pollution, invasive alien species, overgrazing, over-exploitation of natural resources, forest fire, habitat destruction, illegal logging, deforestation and trade. The options were selected on the basis of: i) the possibilities of the IMAGE/GLOBIO model, ii) this model's potential to significantly reduce the rate of loss of biodiversity, iii) the coverage of the major causes of biodiversity loss according to the CBD, iv) current political discussion or targets in the international fora, v) the option's link to real political means to intervene and vi) the availability of an operational indicator. The present selection is not an exhaustive list. If more time and means are available, more options can be assessed.

10 Bioenergy is assumed to be produced on the basis of both bioenergy crops and agricultural residues. In this study we assumed that around 50-100 EJ bioenergy can be produced from agricultural residues. The remainder is produced from bioenergy crops. Only bioenergy crops lead to additional use of land, as discussed in this report.

4. FUTURE BIODIVERSITY

4.1. Planet Earth

4.1.1. Results for planet Earth

Baseline development

- The last 300 years has seen a drop in the planet's biodiversity to 70%¹¹. Initially, extensive land use such as hunting and gathering, and land conversion into extensive agriculture were the main contributing factors. In the last century, infrastructure, human settlement, intensification of agriculture and forestry, pollution and fragmentation added to the decline¹².
- A further decline in biodiversity from about 70% to 63% is projected up to 2050. It should be noted that the purpose of the baseline was to serve as a reference for evaluating policy options, not as a precise prediction of the future.
- The most affected regions are drylands—grasslands and savannah—which show the largest deterioration, followed by tropical forests and tundra.
- Infrastructure (plus related settlement) and climate change are the dominant causes of the further loss in the baseline development.
- The share in biodiversity loss due to agricultural land use remains constant, provided that agricultural productivity shows a considerable rise. Increasingly, agricultural products are traded between world regions, implying that food consumption in densely populated regions will affect land-use change in production regions more than in one's own region (see also van Vuuren en Bouwman, 2005).
- The linearity of the biodiversity loss in the 2000-2050 period is remarkable. This is caused by the decreasing rates of population growth, and the simultaneous increase in economic growth rates. Taken together, this results in a roughly linear effect.

Effects of options

- Option effects in terms of direction and relative magnitude are more robust than the baseline trend. Only one scenario was used as a reference with an optimistic trend for land productivity. When a less optimistic trend is used—such as those applied in the Millennium Ecosystem Assessment—20 to 30% more crop area is necessary, which corresponds to several percent points additional biodiversity loss. It should therefore be noted that, in drawing conclusions from the study, the absolute level of the biodiversity and its decline are less relevant than the relative effect of the options.
- Effectively protected areas and sustainable meat production have an immediate effect on reducing the rates of biodiversity loss. These effects are not sufficient to compensate for the loss caused by the primary driving factors.
- In the case of climate change mitigation, increased plantation forestry and poverty alleviation initial losses in the short and medium term (2010 - 2030) can be followed by improvements in the much longer term. Eventually, the long-term benefits can offset the medium-term losses. This is not yet the case for the climate change option and poverty alleviation within the time frame up to 2050 .
- Further enhancement of agricultural productivity is the key factor in reducing the need for land and consequently the rate of biodiversity loss. This is not shown directly in the options, since the baseline scenario contains a considerable productivity increase. If productivity assumptions from the Millennium Ecosystem Assessment scenarios were applied, this would lead to an additional loss in the range of 1%-4% (from about 70% to 62%-59%), due to higher land-use changes (see Figure 18).
- It is unlikely that the CBD 2010 Biodiversity Target will be met at the global level. The loss of biodiversity is expected to continue at an unchanged pace as a consequence of persistent economic and

11 'Biodiversity' in this report is expressed in terms of means species abundance (MSA)

12 The so-called 'first, second and third strike'

demographic development trends. Delays in institutional and ecosystem changes can be expected to play a role as well¹³, as they will delay the necessary changes until after 2010.

Costs

To assess the policy options, it is not enough to look at their impact on biodiversity. It is also important to evaluate the economic impact or 'costs' of the various options. In most cases there is a trade-off between biodiversity and economic growth. It is not easy to assess these costs. Information is scattered and the right economic tools for valuation are incomplete or missing,

Trade liberalization is beneficial for economic growth. Especially developing regions will experience economic benefits from free agricultural trade. According to our evaluation, the world economy will experience a growth of 1% in 2030. GDP effects in developing countries are greater.

Addressing extreme poverty and hunger in Sub-Saharan Africa not only involves trade liberalization, but also an increase in aid from industrialized countries. This increase in official development assistance will slightly mitigate the positive effects of liberalization in industrialized countries. However, this shift in investment will boost economic growth in Sub-Saharan Africa. GDP per capita is projected to be 25% above baseline levels in 2030.

The ambition of international climate policy is at the moment far from clear. According to the IPCC, any form of climate policy is likely to require substantial changes in the energy system (IPCC, 2001b). Abatement costs for the world as a whole are in the order of a few percentages of global GDP. Economic research indicates that the costs of climate policies is lower when effective international emission trading schemes can be implemented (IPCC, 2001c). The distribution of costs across regions is very uncertain, as it crucially depends on the distribution of emission reduction targets (burden-sharing). In a multi-stage approach, developing countries might benefit from the surplus of emission rights and gain from the export of emission permits (den Elzen *et al.*, 2005).

Sustainable meat production, increased plantation forestry and protection of areas are options that hardly influence the economy on a macroeconomic scale. After all, the meat and forestry sectors form only small components of the national economies (in the order of 1%; FAO, 2004). Globally, spending on protected areas amounts to approximately 0.2% of national budgets. However, implementing these options might involve considerable structural shifts or require huge increases in government spending. Current global expenditure on nature reserves comes to—very roughly—\$6.5 billion per year (US \$ in 2000). It is estimated that establishing and running a global reserve system (covering ~15% of land and ~30% of the sea) would cost very roughly \$30 billion per year (Balmford *et al.*, 2003; Balmford. and Whitten, 2003; James *et al.*, 1999a). Establishing plantations would involve government subsidies or tax exemptions in the order of \$10 billion (Enters and Durst, 2004).

13 These are not part of this study.

TABLE 7: Summary of indicators for global baseline development up to 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	POVERTY REDUCTION	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	PROTECTED AREAS 20%
Biodiversity*	62.5%	-1.3%	-1.7%	-1.0%	0.3%	0.1%	1.1%
Cost**		+	+	-	0	0	0
Climate	1.8 °C	1.8 °C	1.8 °C	1.5 °C	1.8 °C	1.8 °C	1.8 °C
Poverty			+				
N deposition	1.00	1.02	1.04	0.53	0.99	1.00	1.00

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), - (less than -0.2%), -- (less than -1.5%).

** Biodiversity in this and similar tables is measured per region in terms of mean abundance of the original species.

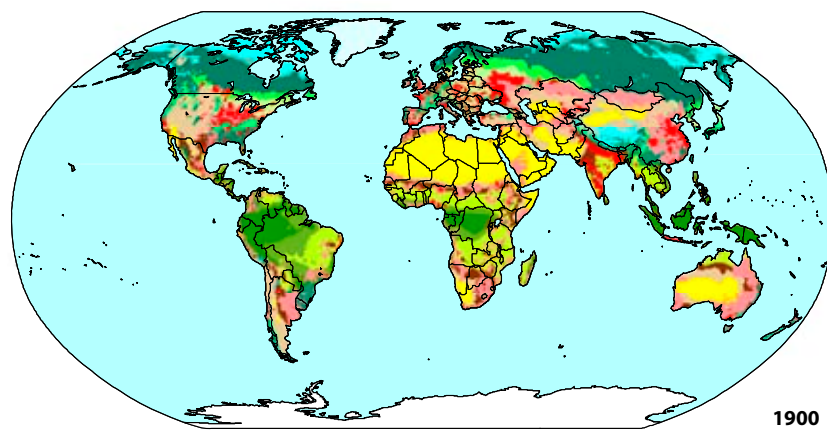
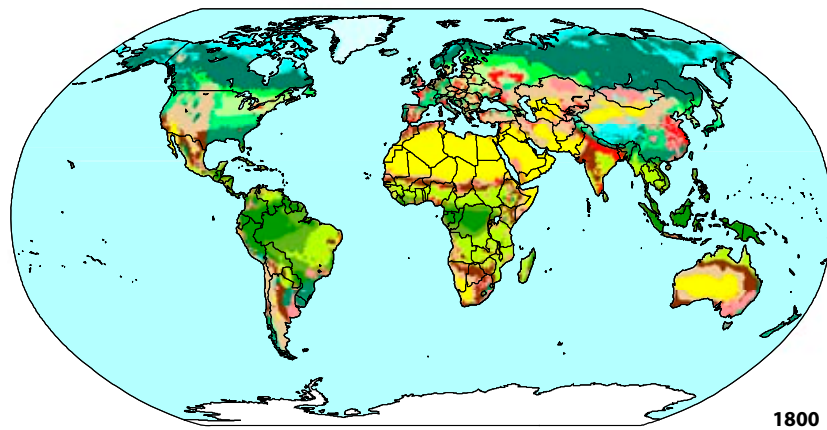
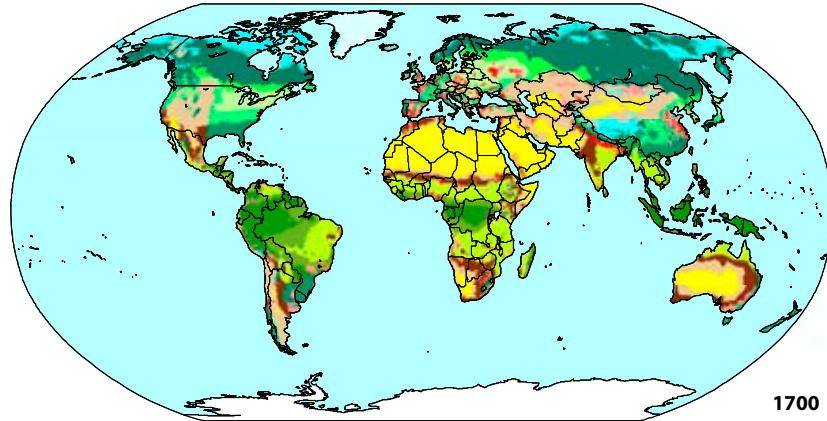
TABLE 8: Overview of baseline trends in biodiversity and additional (-) or avoided (+) loss per option

REGION	BIODIVER- SITY 2000	BASELINE 2050	BASELINE LOSS	LIBERAL- IZATION	POVERTY REDUCTION	CLIMATE CHANGE	SUSTAINABLE MEAT PROD.	PLANTA- TION FORESTRY	PROTECT- ED AREAS OF 20%
North America	75%	65%	-9.2%	1.4%		-1.5%	0.7%	-0.3%	1.0%
Latin America	66%	59%	-6.2%	-5.4%		-1.6%	0.7%	0.0%	0.5%
North Africa	87%	84%	-2.2%	-0.2%		0.6%	0.1%	0.0%	0.2%
Sub-Saharan Africa	73%	61%	-11.7%	-3.7%	-5.7%	-1.7%	-0.2%	0.4%	0.8%
Europe*	45%	33%	-11.4%	4.2%		-0.2%	0.6%	-0.6%	1.1%
Russia and north Asia	76%	71%	-5.1%	-0.1%		-2.0%	0.6%	-0.4%	1.2%
West Asia	76%	72%	-4.0%	-0.7%		0.2%	0.1%	0.0%	1.6%
South and East Asia	55%	46%	-9.0%	-0.3%		0.4%	0.3%	0.8%	1.3%
Oceania and Japan	78%	74%	-4.3%	-0.1%		-0.6%	0.1%	0.0%	2.9%
World	70%	63%	-7.6%	-1.3%	-1.7%	-1.0%	0.3%	0.1%	1.1%
MEA best result		62%							

* The calculated loss of biodiversity in Europe in the baseline is due to modeled conversion of forest to agricultural land. This conversion is in reality questionable. If this expansion of agriculture would take place in other regions than Europe, the loss of biodiversity in Europe would be less, but the loss in other regions would be higher.

4.1.2. Figures for earth

- Agricultural land
- Extensive grassland
- Regrowth after abandonment
- Regrowth after timber
- Bio energy
- Ice
- Tundra
- Wooded tundra
- Boreal forest
- Cool coniferous forest
- Temperate mixed forest
- Temperate deciduous forest
- Warm mixed forest
- Grassland and steppe
- Hot desert
- Scrubland
- Savannah
- Tropical woodland
- Tropical forest
- Mediterranean shrub



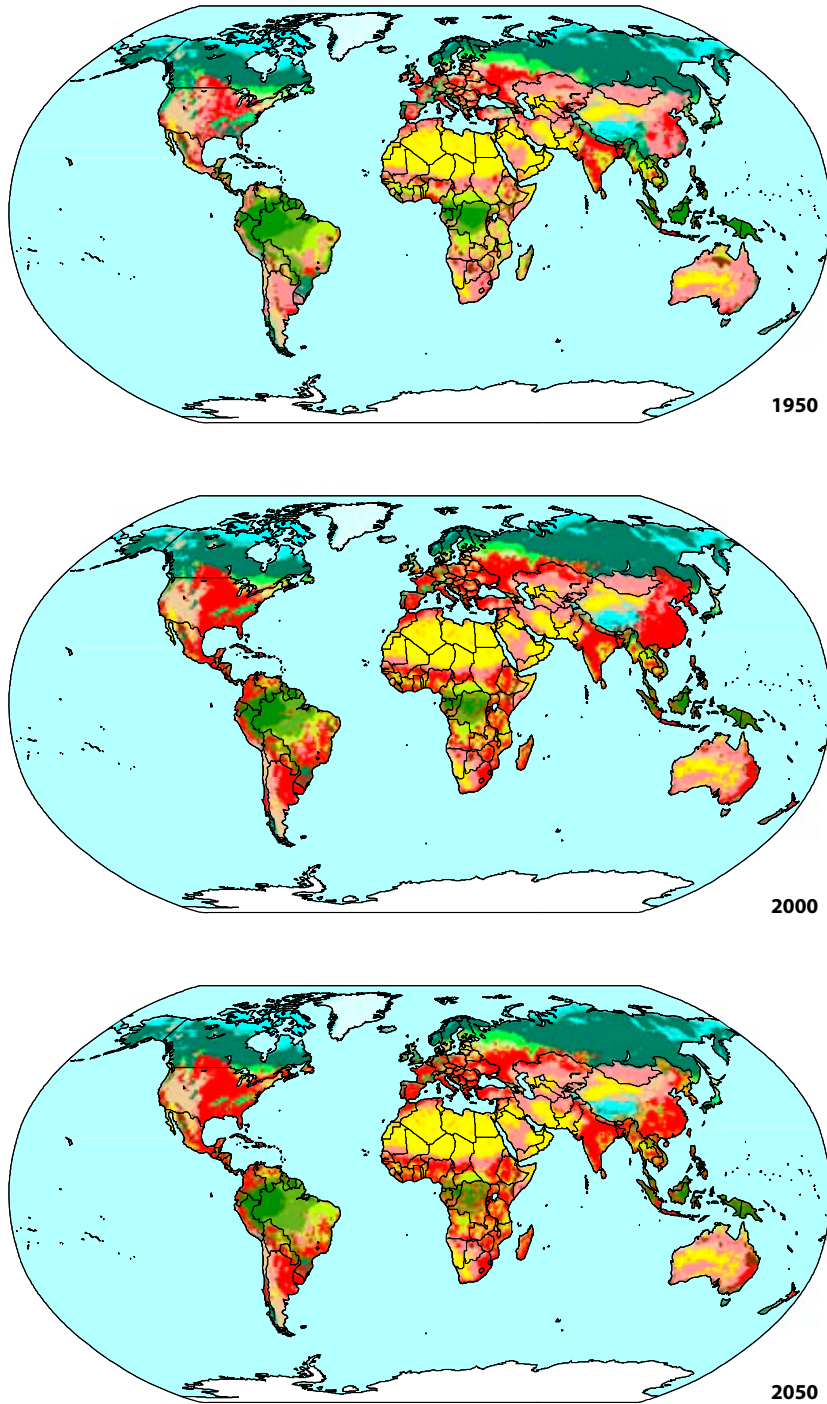
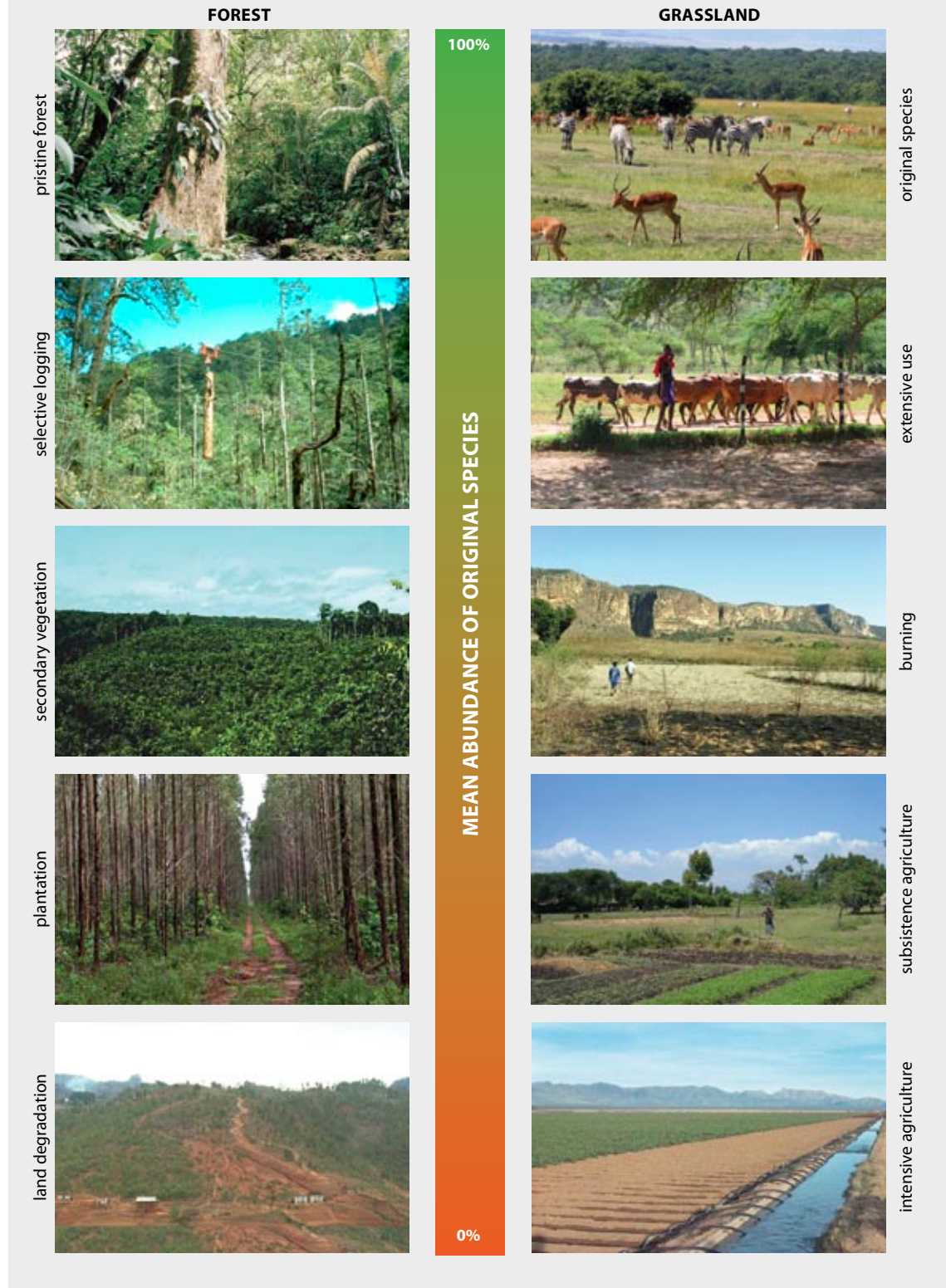


FIGURE 5: Land-use changes since 1700 and up to 2050 (Klein Goldewijk, 2001; IMAGE-team, 2001).

BOX 2: Visual impressions of the mean species abundance scale for forest and grassland as in Figure 6

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). Locally, this indicator can be perceived as a measure of naturalness, or conversely, of human-impact (see also Box 1).



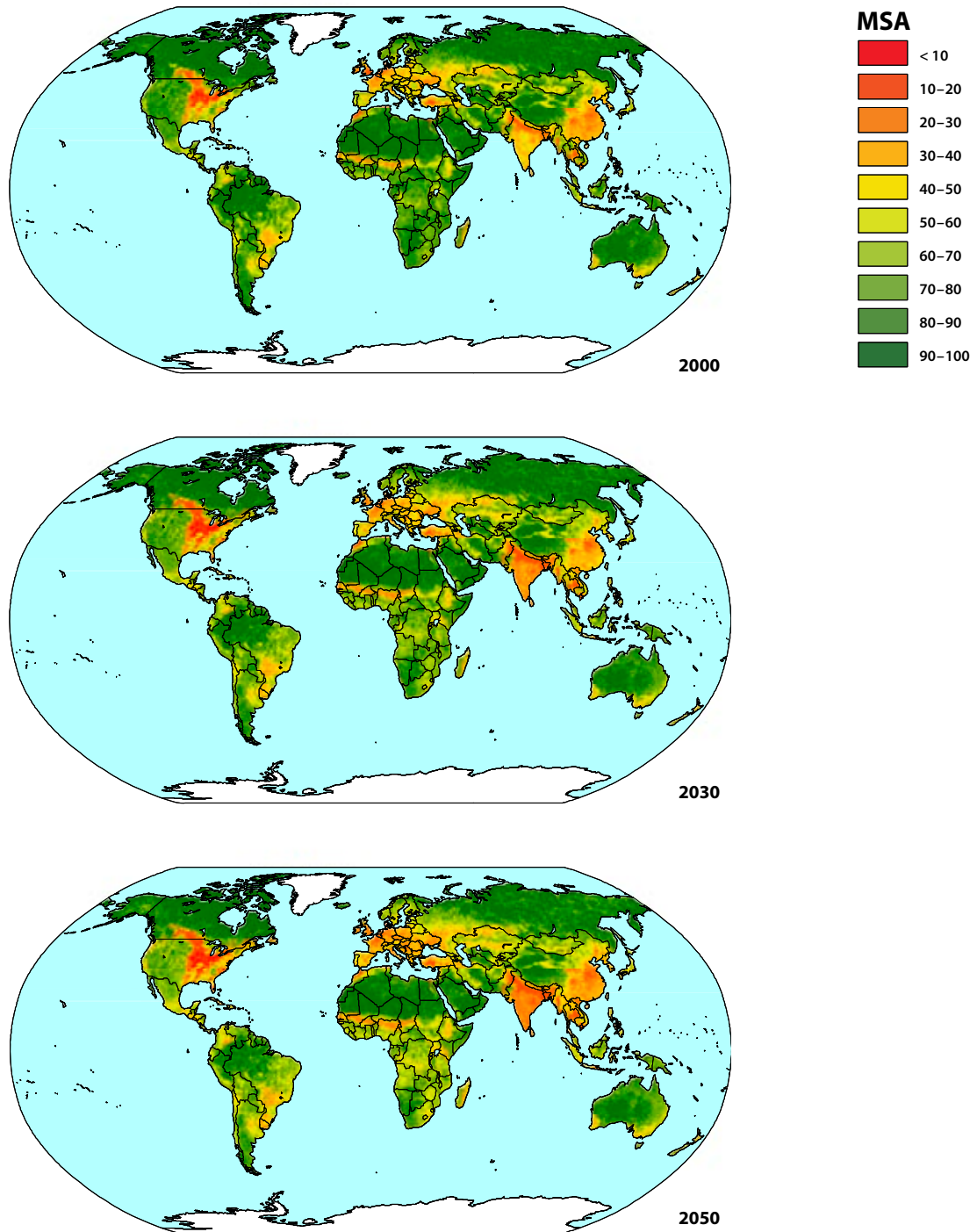


FIGURE 6: Global maps on remaining mean species abundance (MSA) in the scenario period 2000-2050 (see Boxes 1 and 2 for further explanation of methodology and indicator scales).

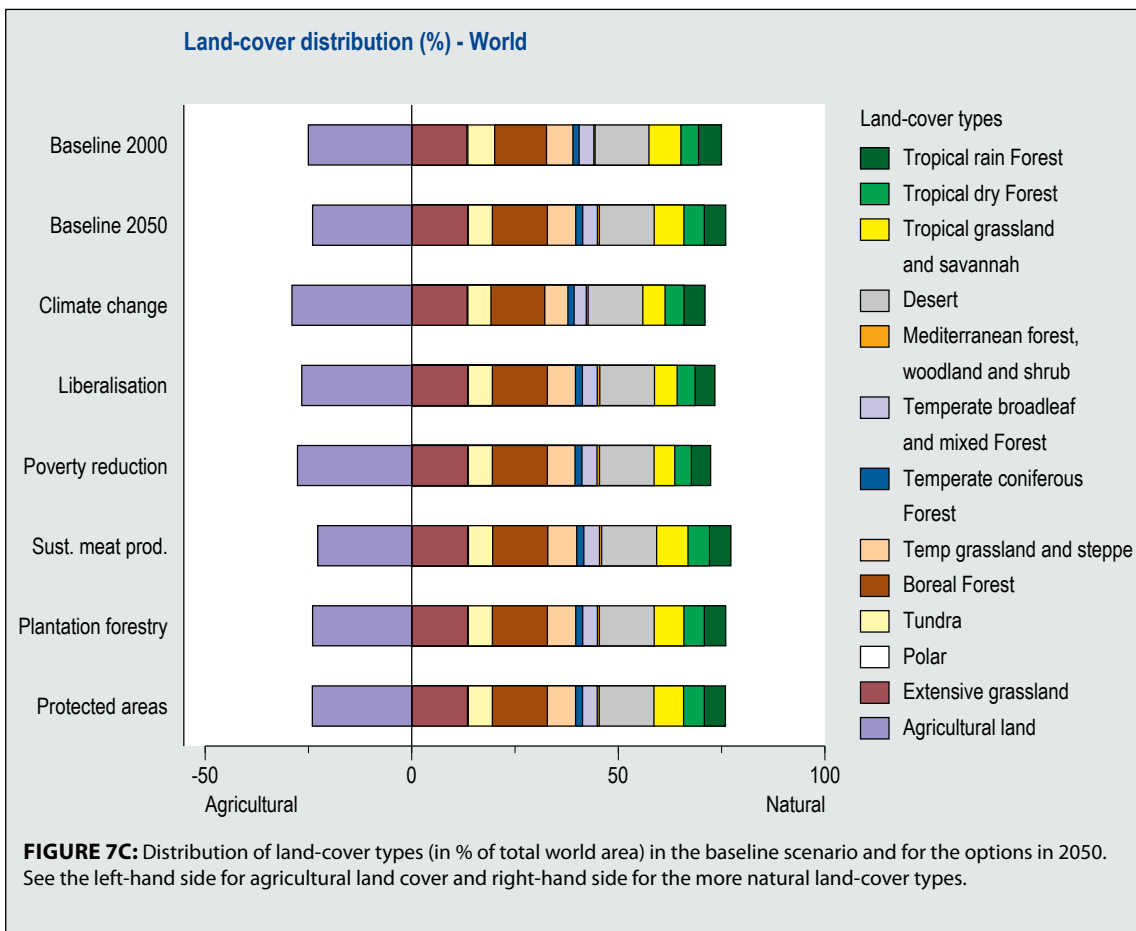
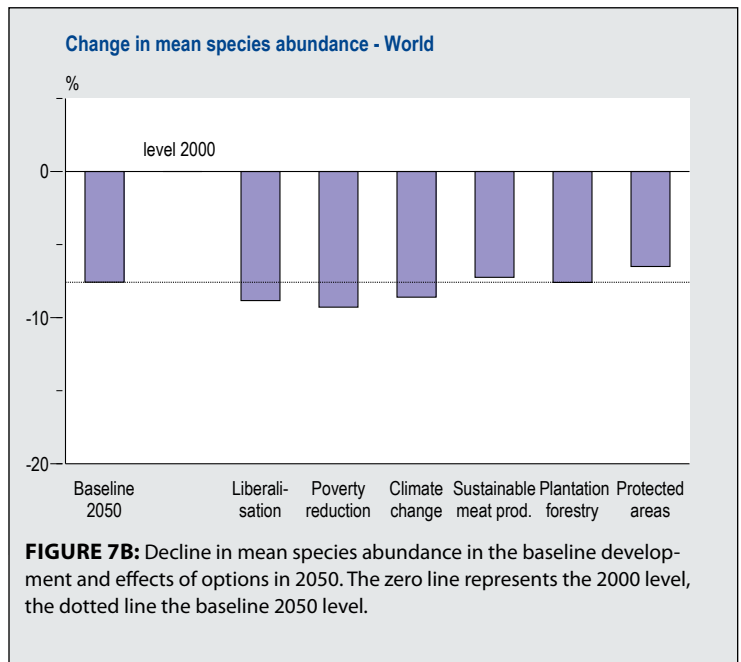
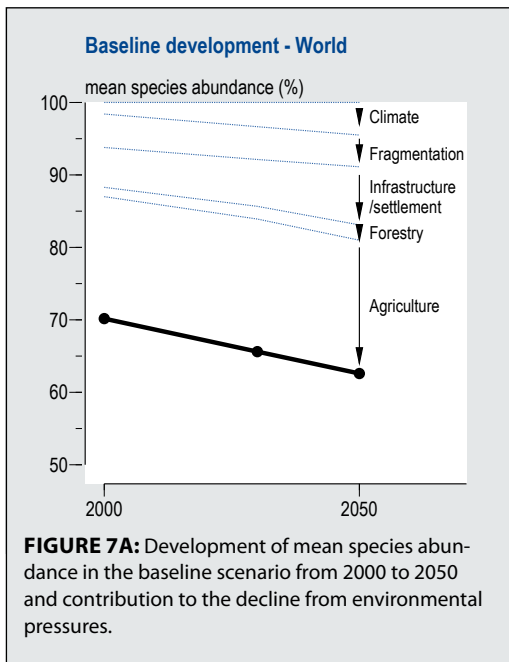


FIGURE 7: Results for the World: baseline development (a); option effects on MSA (b) and land-cover (c).

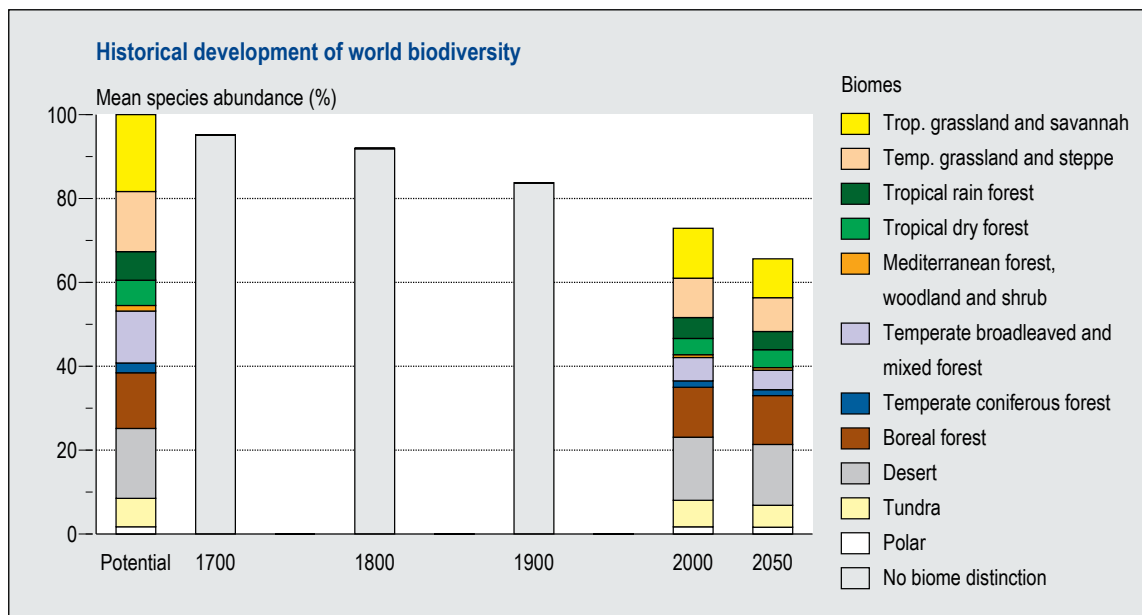


FIGURE 8: Trends in biodiversity from 1700–2050. Biodiversity is given in terms of mean abundance of the original species (MSA) per natural biome. Remaining biodiversity in man-made land-cover types (i.e. arable land and extensively used grassland) are included in the naturally occurring biome. Annexes 3 and 4 contain the regional historical biodiversity development (1700-2050) and the regional spatial biodiversity distribution (2000 and 2050).

4.2. Sub-Saharan Africa

4.2.1. Figures for Africa

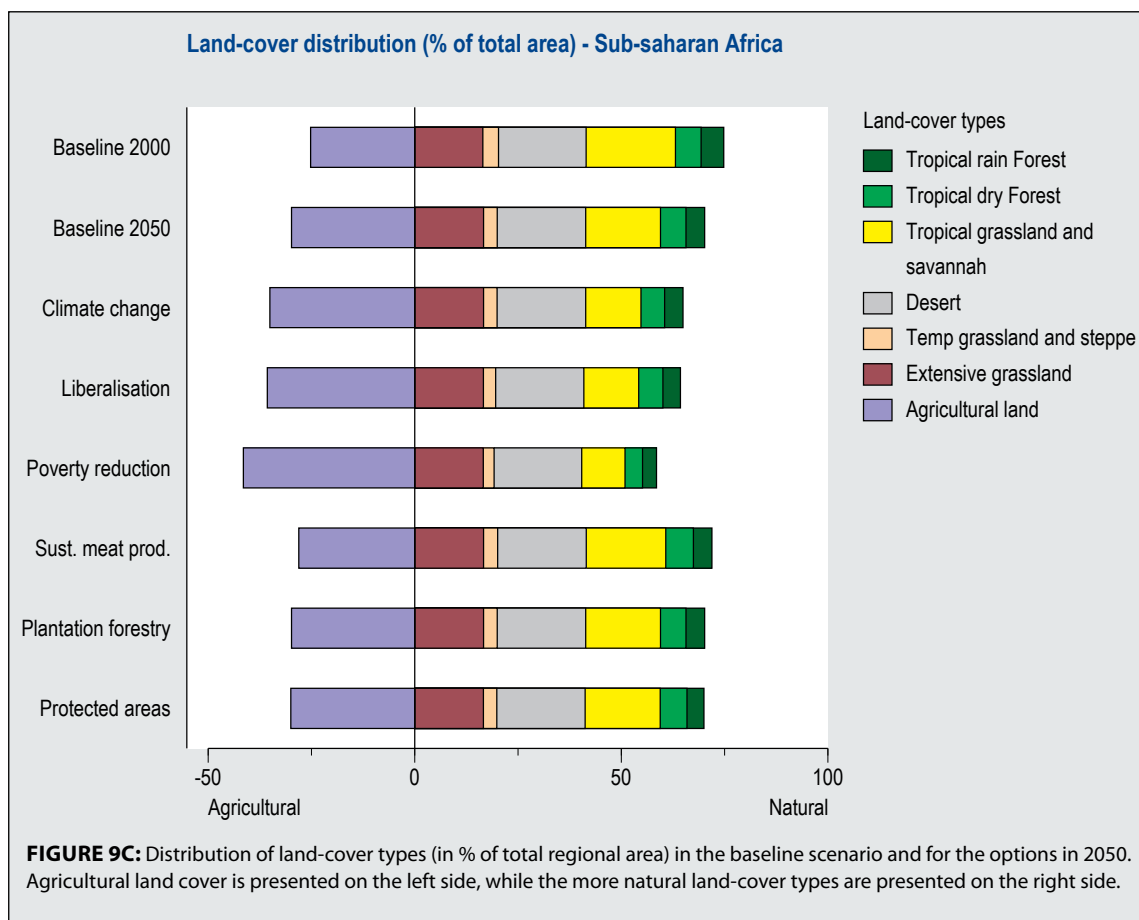
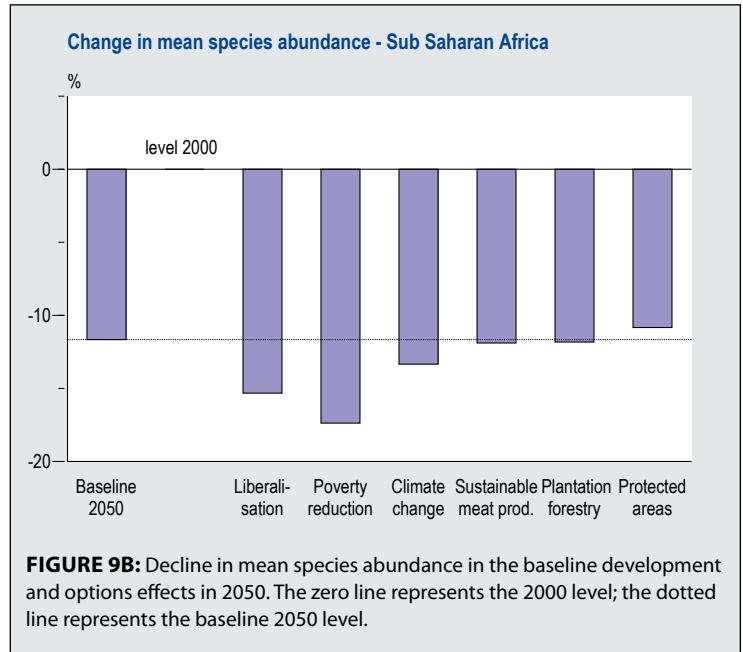
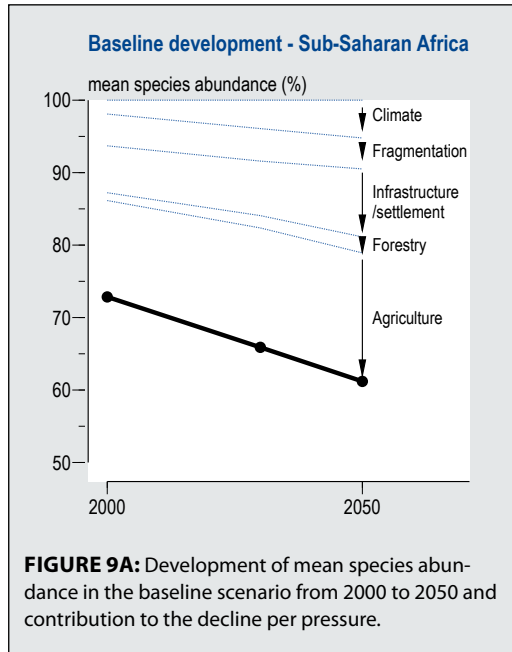


FIGURE 9: Results for Sub-Saharan Africa: baseline development (a); option effects on MSA (b) and land-cover (c).

4.2.2. Results for Sub-Saharan Africa

Baseline development

- In Sub-Saharan Africa, the biodiversity decreases from 73% in 2000 to 61% in 2050.
- This region is the only one where agricultural development plays a significant role in further biodiversity loss. The doubling of the population in this region, and the absence of substantial improvements in agricultural productivity drive the agricultural expansion.
- Conversion of mainly tropical grasslands and savannah takes place to accommodate the agricultural expansion. Further, tropical forest is converted (deforestation).
- Other factors adding to further biodiversity decline are climate change, infrastructural development and forestry.

Effects of options

- Both liberalization and poverty reduction lead to a significant further reduction of the remaining biodiversity (-3.7% and -5.7%, respectively). Expansion of the agricultural productive area is the main driving force for both. Not surprisingly, tropical forest, grassland and savannah bear the burden, especially in the case of poverty reduction.
- The negative effect of liberalization is smaller than in Latin-America. In absolute terms, shifts in global agricultural production are small, given the modest role Africa plays in world trade. In relative terms the region highly benefits from trade liberalization. GDP increases by 5% above baseline values in 2030.
- To meet the Millennium Development Goals, poverty is removed in all its dimensions in the poverty reduction option, while economic growth is assumed to experience strong growth. In 2030, GDP per capita in Sub-Saharan Africa is projected to be 25% above baseline level. The higher demand for agricultural production and the improved infrastructure will exert a downward pressure on biodiversity. The negative impact of higher economic growth is partly offset by higher productivity in agriculture with a net effect on biodiversity of -5.7%.
- Limiting the effects of climate change leads to biodiversity decreases (-1.7%). The Sub-Saharan region becomes an important area for biofuel production at the expense of tropical grasslands and savannah.
- In a climate regime with a global system of emissions trading, Sub-Saharan Africa can become a region with a surplus of emission rights. This system is economically beneficial for the region. Revenues from the export of emission permits to industrialized regions might improve income levels in the order of 1%.
- Increasing the extent of protected areas is beneficial for biodiversity values (+0.8%).

TABLE 9: Summary of indicators for Sub-Saharan African regional baseline development up to 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	POVERTY REDUCTION	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS BY 20%
Biodiversity	60.6%	-3.7%	-5.7%	-1.7%	-0.2%	0.4%	0.8%
Cost*		++	+++	+	0	0	0
Poverty			+				
N deposition	1.00	1.04	1.17	0.99	0.70	1.00	1.00

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), - (less than -0.2%), -- (less than -1.5%).

4.3. North Africa

4.3.1. Figures for North Africa

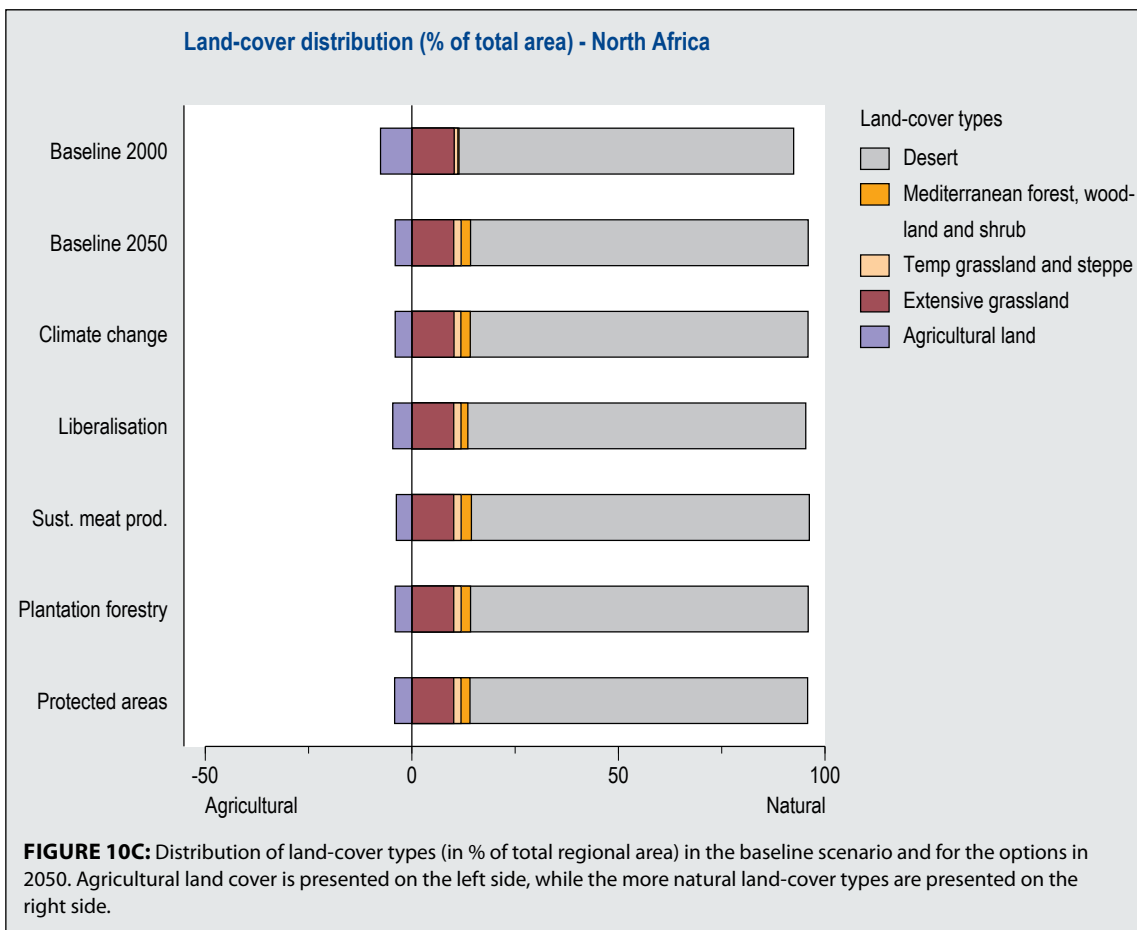
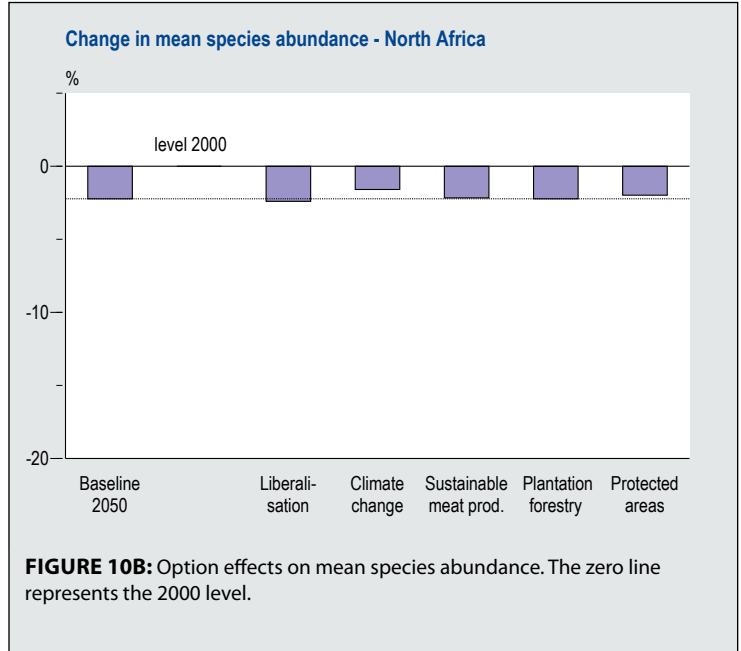
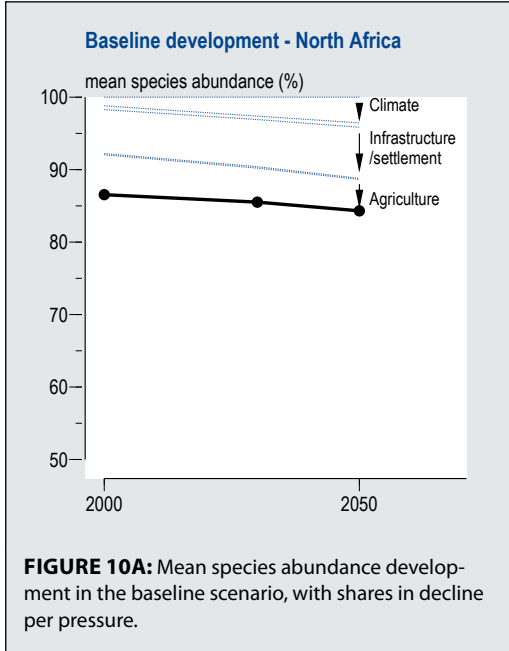


FIGURE 10: Results for North Africa: baseline development (a); option effects on MSA (b) and on land-cover (c).

4.3.2. Results for North Africa

Baseline development

- In the North African region, the biodiversity is reduced from 87% to 84% between 2000 and 2050.
- The most important cause of this further loss is the effect of climate change on the natural biomes. Through temperature increase and increased drought, arable land is lost and replaced by other biomes (desert and grassland and Mediterranean biomes). At the same time, the climate change effect reduces the quality of the predominant natural desert biome and the other biomes (Mediterranean shrub and temperate grassland steppe).
- The relatively slow biodiversity decline, in comparison with other regions, is caused by the dominance of the desert biome that cannot be easily exploited and developed for human use. Therefore, the indirect drivers that operate globally (population growth and economic development) have a smaller effect here.

Biodiversity effects of options

- Most options have very small effects. The region is characterized by a dominance of the desert biome that is either inaccessible or unsuitable for human exploitation. The area is therefore not very susceptible to options that affect land-use changes, such as biofuel production or increased agricultural activities through market liberalization.
- Reduction of climate change is the only option with a noticeable and positive effect (+0.6%). This is not surprising, as climate change is the main factor contributing to further biodiversity loss in the baseline.
- Developments that do take place (plantation establishment and increased agricultural production) might be small, but can be crucial for the small amount of remaining species rich biomes, such as the Mediterranean ecosystems.

TABLE 10: Summary of indicators for North African regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	84.2%	-0.2%	0.6%	0.1%	0.0%	0.2%
Cost*		++	--	0	0	0
N deposition	0.00	0.00	0.00	0.00	0.00	0.00

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), – (less than -0.2%), -- (less than -1.5%).

4.4. South and East Asia

4.4.1. Figures for South and East Asia

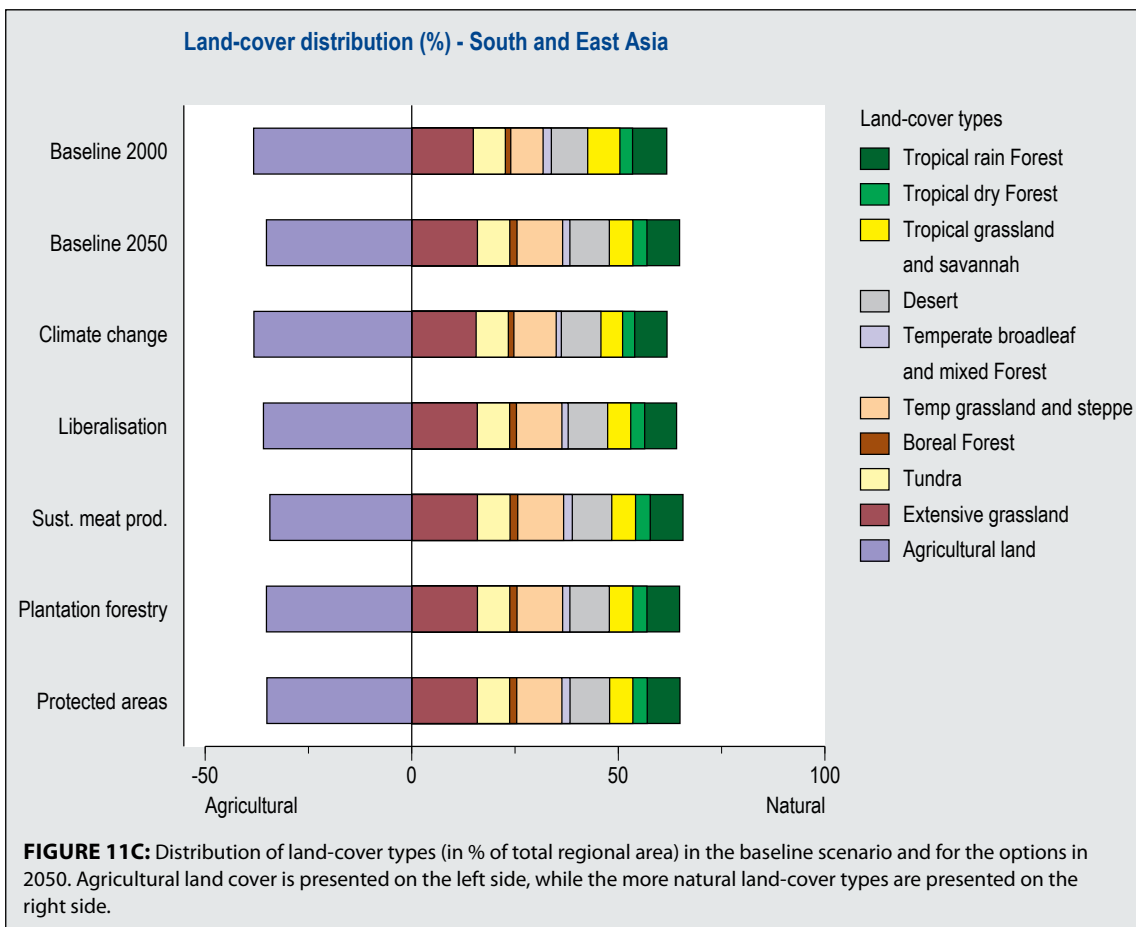
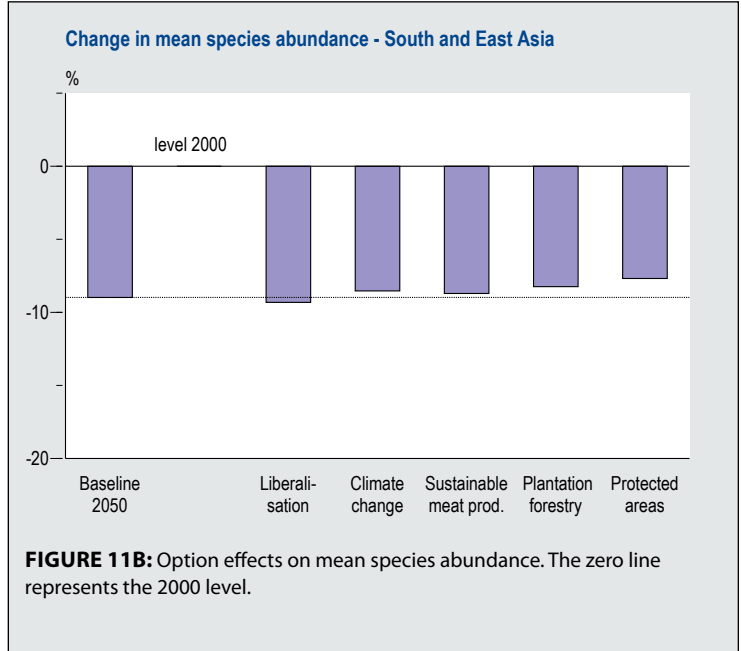
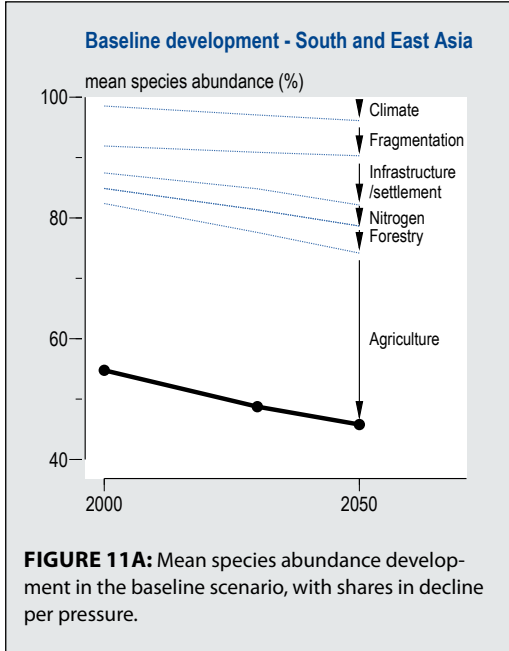


FIGURE 11: Results for South-East Asia: baseline development (a), option effects on MSA (b) and land-cover (c).

4.4.2. Results for South and East Asia

Baseline development

- In South and East Asia, the biodiversity decreases from 55% in 2000 to 46% in 2050.
- This region is by far the largest under consideration. The economic developments in the past and the pressure from the large population have had strong effects in the past. This has resulted in a relatively low regional biodiversity value in 2000 (only Europe has lower values). The size of the region and the dominance of China and India may blur the view on specific countries and sub-regions with higher biodiversity levels (see Figure 13).
- The relatively moderate decrease in biodiversity is partly caused by the already high use intensity. The region shows a dominance of arable land, with little room for further development and exploitation.
- An important contribution to the biodiversity decrease comes from infrastructural development and settlement. This development is driven by the strong economic growth.
- Asia has the highest demand for wood of all the regions, with a steady increase after 2000. The required production area rises sharply near 2050 because of over-exploitation. This is reflected in an increasing share of forestry in the biodiversity decline.
- The last factor contributing to biodiversity decline is the climate change effect that negatively affects a wide variety of natural biomes (temperate to tropical grassland and forest biomes, deserts, tundra and boreal forest).
- The area of arable land is decreasing, through productivity increases mainly in China where population growth is comparatively modest. The abandoned land develops to natural biomes (temperate grasslands), leading to biodiversity gains.

Biodiversity effects of options

- In the forestry option, Asia is able to effectively produce wood from large areas of plantations, thereby substantially reducing the yearly cut forest area. Exploitation of semi-natural forests is gradually declining, and forests can recover and the original biodiversity levels will return. The biodiversity increase is +0.8% by 2050. The effect will become stronger after 2050 as forests take a long time to recover.
- In the climate mitigation option, China becomes an area for biofuel production, taking advantage of available agricultural land (through productivity increases). This partly counteracts the biodiversity gain from climate change mitigation (total effect +0.4%).
- Increasing the area of protected areas leads to higher biodiversity (+1.3%).
- Liberalization has negative effects on Asian biodiversity (-0.4%), just like for Latin America and Sub-Saharan Africa. This is mainly because of China, where room for expansion is available through productivity increases (baseline). Nature restoration in abandoned agricultural areas will be therefore much less.

TABLE 11: Summary of indicators for South and East Asian regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	45.8%	-0.3%	0.4%	0,3%	0.8%	1.3%
Cost*		+	0	0	0	0
N deposition	1.00	1.01	0.55	1.00	1.01	0.99

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), – (less than -0.2%), – – (less than -1.5%).

4.5. West Asia

4.5.1. Figures for West Asia

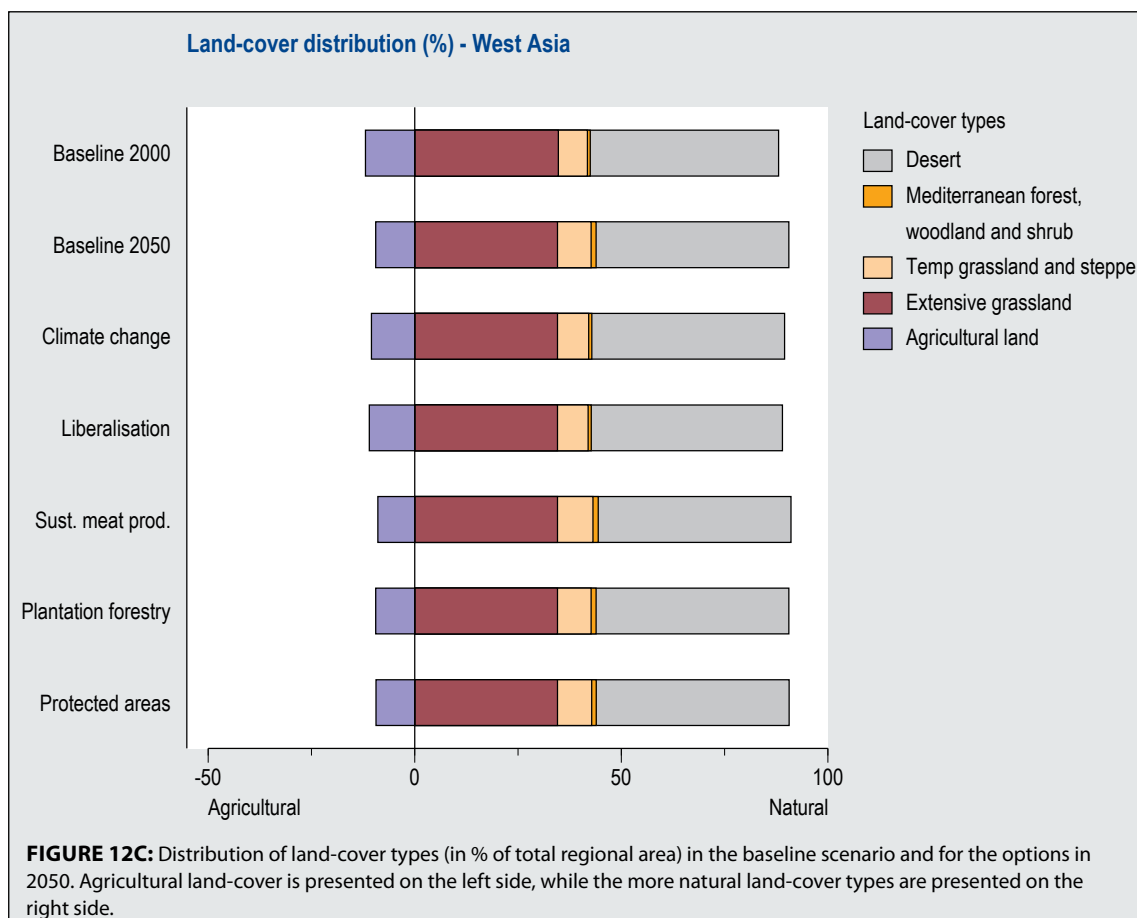
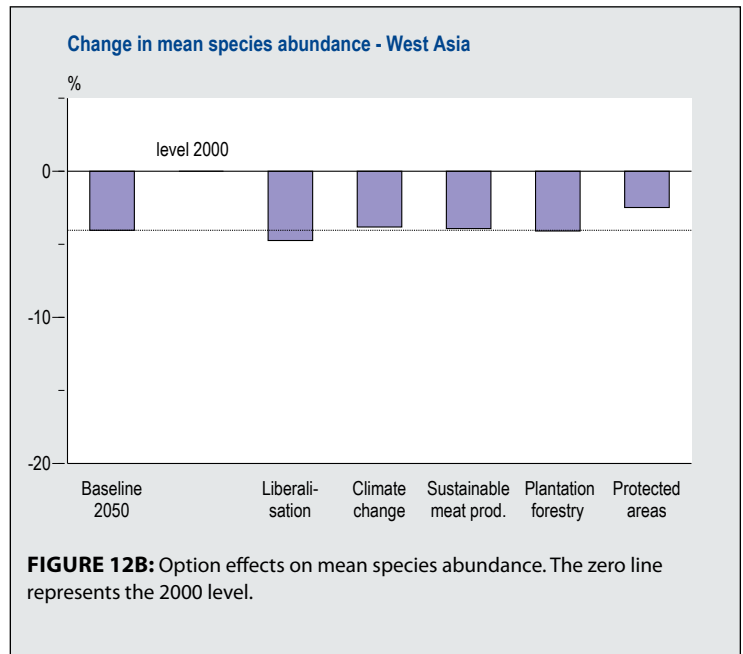
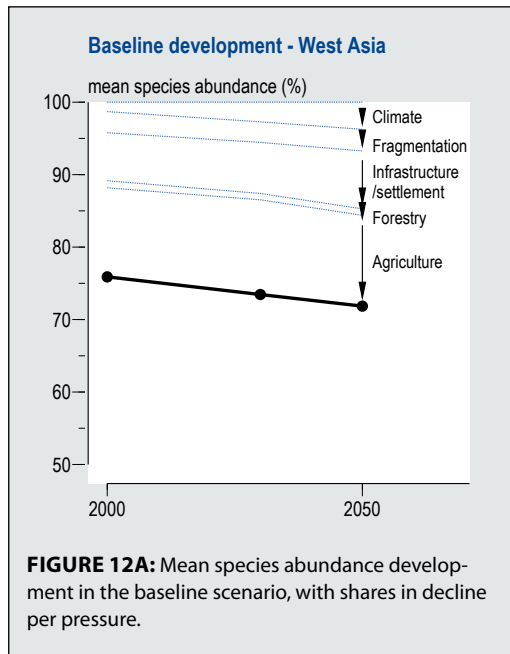


FIGURE 12: Results for West Asia: baseline development (a), option effects on MSA (b) and land-cover (c).

4.5.2. Results for West Asia

Baseline development:

- In the West Asian region, biodiversity declines from 76% in 2000 to 72% in 2050.
- The relatively slow biodiversity decline, in comparison with other regions, is caused by the dominance of the desert biome that cannot be easily exploited and developed for human use. As a result, the indirect drivers that operate globally, population growth and economic development, have a smaller effect here.
- The most important cause of the further loss is the effect of climate change, which affects both arable land and natural biomes. Through temperature increase and increased drought, arable land is lost to desertification.
- The most important cause of this further loss is the effect of climate change, which affects the natural biomes. Through temperature increase and increased drought, arable land is lost and replaced by other biomes (desert, grassland and Mediterranean biomes). The climate change effect further reduces the quality of the dominant desert biome and the temperate grassland steppe.
- Infrastructural developments and settlement further factor responsible for increased biodiversity loss. The main driver for this is the strong economic development.

Effects of options

- Liberalization of the agricultural market has a further biodiversity reducing effect (-0.7%). Arable land is expanded at the expense of temperate grassland and species rich Mediterranean shrub and woodland.
- Increasing the area of protected areas leads to higher biodiversity (+1.6%).
- Reduction of climate change has a small positive effect (+0.2%). This is not surprising, as climate change is the main factor contributing to biodiversity loss in the baseline. This effect is not very large as the northern part of the region (Turkey) is also used for biofuel production at the expense of natural biomes (grassland, steppe and Mediterranean biomes).
- The other options have negligible effects.

TABLE 12: Summary of indicators for West Asian regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	71.7%	-0.7%	0.2%	0.1%	0.0%	1.6%
Cost*		0	--	0	0	0
Climate		0	--	0	0	0
N-deposition	1.00	1.10	0.16	0.93	1.00	0.93

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), – (less than -0.2%), -- (less than -1.5%).

4.6. Russia and North Asia

4.6.1. Figures for Russia and North Asia

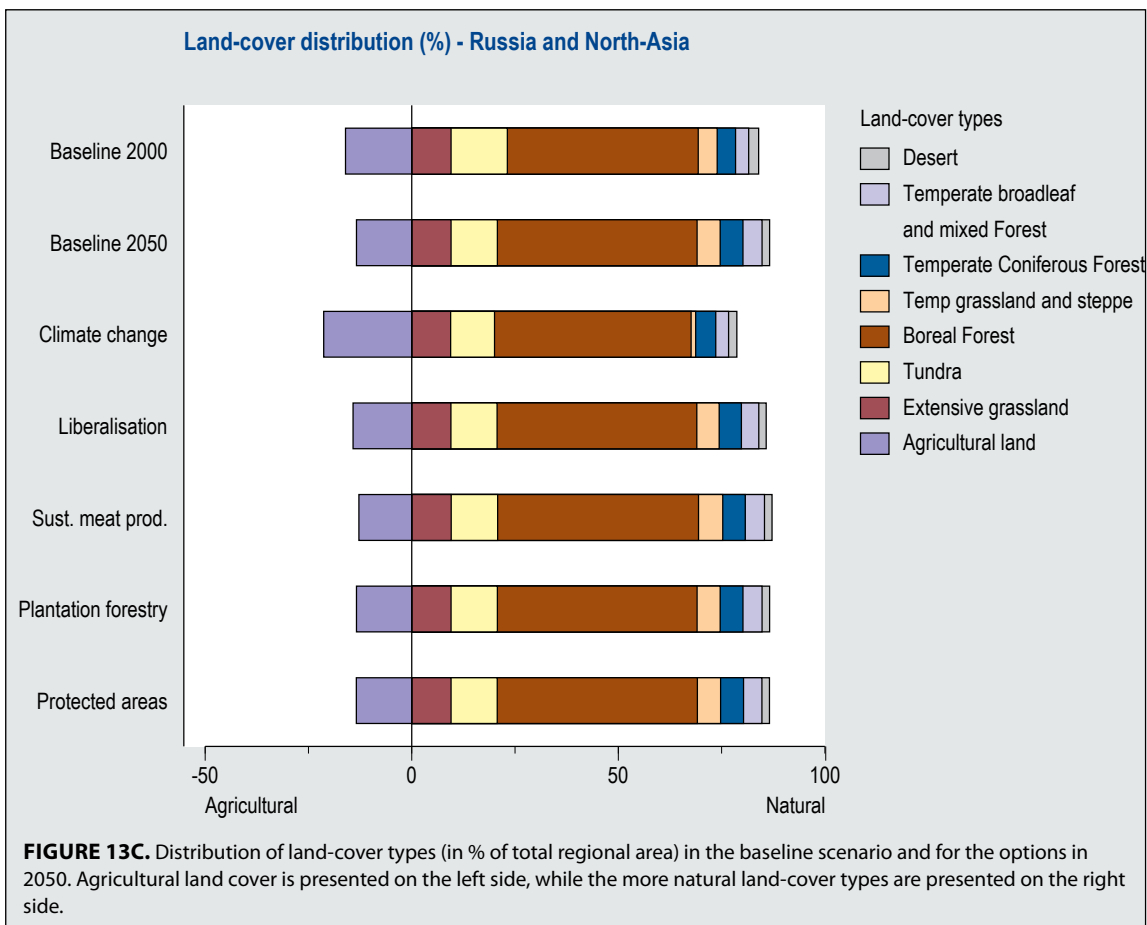
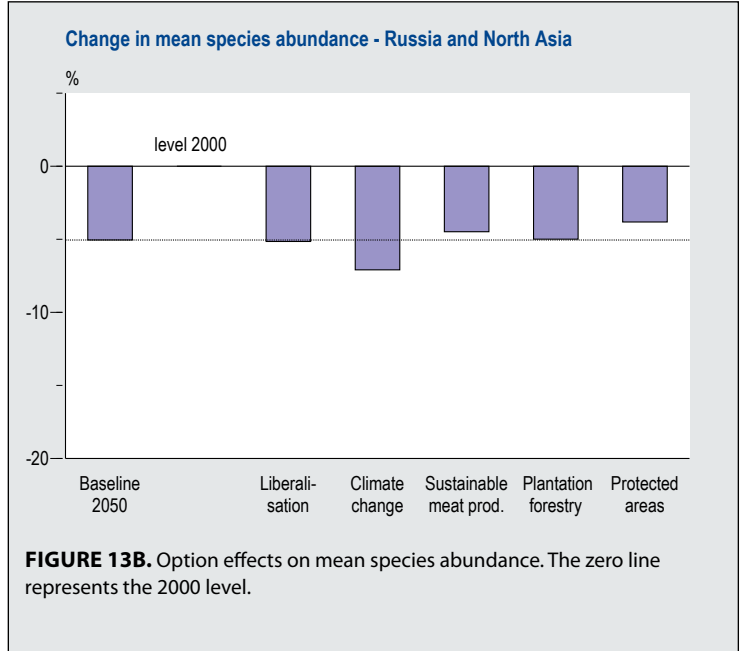
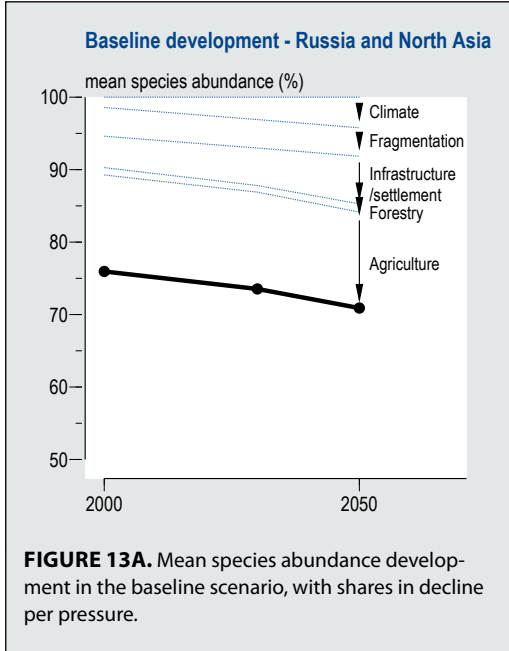


FIGURE 13: Results for Russia and North Asia: baseline development (a), option effects on MSA (b) and land-cover (c).

4.6.2. Results for Russia and North Asia

Baseline development

- In Russia and North Asia, the biodiversity declines from 76% in 2000 to 71% in 2050.
- The most important cause of the further loss is the climate change effect, affecting the vast areas of boreal forests and tundra.
- The infrastructural development is a further factor contributing to the biodiversity loss, especially after 2030. This is driven by economic development.
- The total population, an important driver for development in most regions, shows a declining trend from 2000 and onwards. The amount of arable land is decreasing, as land is taken out of production. This land is available for restoration of natural biomes, mainly boreal and temperate forests, steppe and grasslands. This effect explains the relatively low biodiversity decline for this region.
- The wood production in this region has dropped sharply between 1990 and 2000, and only recovers at the former production levels after 2040. Not much additional semi-natural forest area is therefore lost to forest exploitation in the baseline. Nevertheless, model calculations underestimate the total demand for this region, as Russia also produces for Europe and China. This increased trading will put additional pressure on the remaining vast boreal forest biome.

Biodiversity effects of options

- The option with the largest effect for Russia and North Asia is reduction of climate change, leading to a further biodiversity loss of -2%. The region becomes an important area for biofuel production. Developments in the baseline have led to large areas of abandoned agricultural land that can be exploited. The increased land use more than counteracts the positive effect of climate measures.
- Increasing the area of protected areas leads to higher biodiversity (+1.2%).
- Liberalization of agricultural markets leads to a small increase in the area of arable land, at the expense of natural biomes (forest, grassland and steppe). This results in a further decline of the remaining biodiversity (-0.4%).
- The other options all have a very small effect. The effect of the forestry option is underestimated if the region will become an important production area for other regions.

TABLE 13: Summary of indicators for Russian and North Asian regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline summary of indicators (2050)

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	71.2%	-0.1%	-2.0%	0.6%	-0.4%	1.2%
Cost*		+	-	0	0	0
N deposition	1.00	1.08	0.20	0.95	1.00	1.02

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), - (less than -0.2%), -- (less than -1.5%).

4.7. Latin America & Caribbean

4.7.1. Figures for Latin America & Caribbean

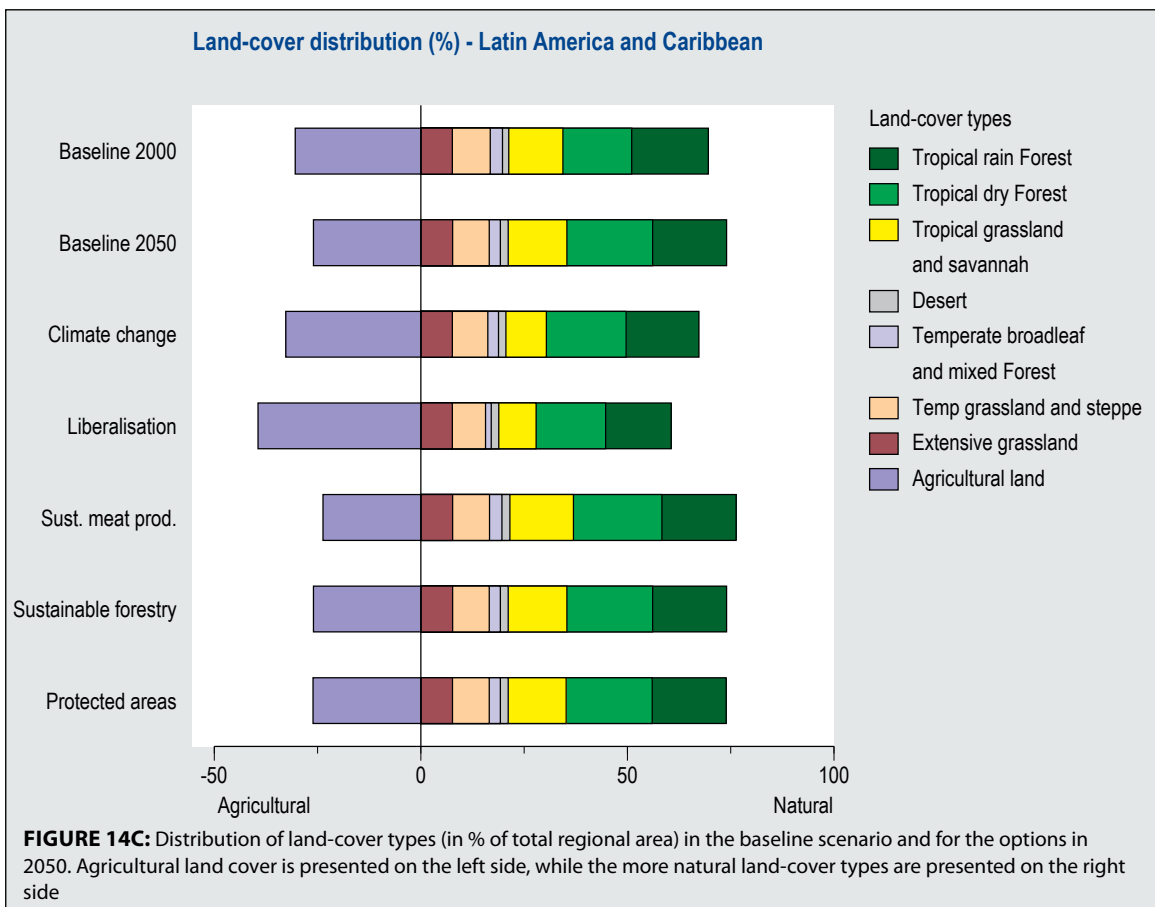
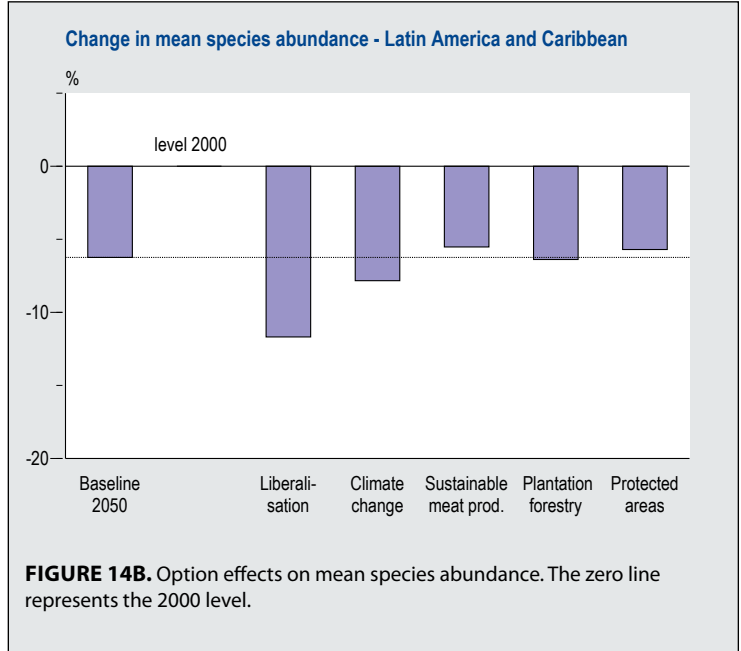
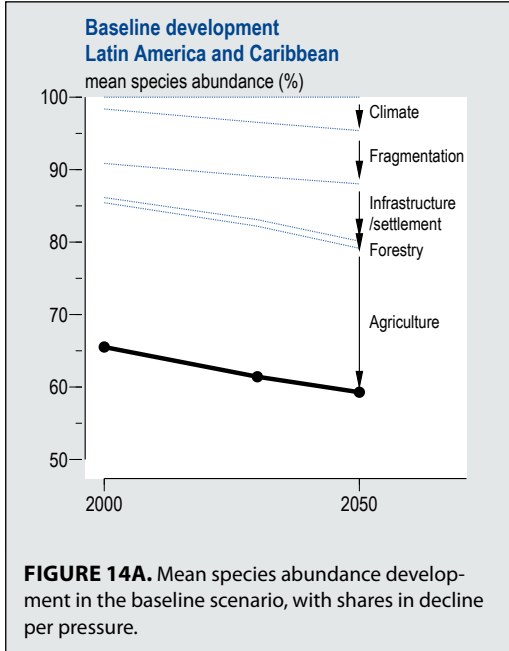


FIGURE 14: Results for Latin America and Caribbean: baseline development (a), option effects on MSA (b) and land-cover (c).

4.7.2. Results for Latin America & the Caribbean

Baseline development

- In Latin America, the biodiversity declines from 66% in 2000 to 59% in 2050.
- The significant loss observed until 2000 was mainly due to habitat loss (land conversion for agriculture and forestry).
- The main factors contributing to the further biodiversity loss are infrastructural development, fragmentation and the effects of climate change (total loss 7%).
- Continued population growth and economic development drive up food consumption, and the region maintains its strong position in international agricultural markets. Nevertheless, the agricultural occupied area makes a slight fall due to productivity increases. Abandoned agricultural land gradually reverts to tropical dry forest, but recovery is slow. Hence, the future net effect of agriculture on biodiversity is negligible.
- The role of forestry is surprisingly small. The IMAGE model uses relatively high forest yields, which leads to an underestimation of the actually required forest area for selective logging. Further, the production function for other regions through increased trade is neglected. Increased trading in pulp and wood will put an additional pressure on the remaining vast tropical forest biome.

Effects of options

- Liberalization of the agricultural market has by far the strongest effect in Latin America, reducing the biodiversity by -5.4%. Liberalization induces a boost in 'south-south-trade' in agricultural products, driven by low production costs and an ample supply of cheap, productive land. As a result, there is a strong expansion of agricultural production in Latin America. The increase in productivity is not enough to enable this production increase on a limited amount of land. The area for food crops, grass and fodder grows by 40% in 2050 compared to the baseline. The main habitats affected by land conversion are tropical dry and rain forest (inducing deforestation), and grassland and savannah areas.
- The climate mitigation option shows a net negative effect on biodiversity (-1.6%), as this region becomes an important producer of bioenergy. This leads to further land-use change, mostly in tropical grasslands and savannah, the preferred location for bioenergy production. In the short term, the effect of additional land use is larger than the positive effect from reduced climate change. This can change as time proceeds.
- There is a small effect of producing more sustainable meat (+0.7%), as meat production is an important activity here. Tropical dry forests, dry lands and savannah gain the most. The biodiversity improvements will become more significant in the longer term.
- The effect of the forestry option is hardly noticeable in 2050. The present model calculations underestimate actual forest use in the baseline (see above), which explains the relatively small effect of the plantation option.

TABLE 14: Summary of indicators for Latin American and Caribbean regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	59.0%	-5.4%	-1.6%	0.7%	0.0%	0.5%
Cost*		+	-	0	0	0
N deposition	1.00	1.15	0.78	0.99	1.00	0.99

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), - (less than -0.2%), -- (less than -1.5%).

4.8. North America

4.8.1. Figures for North America

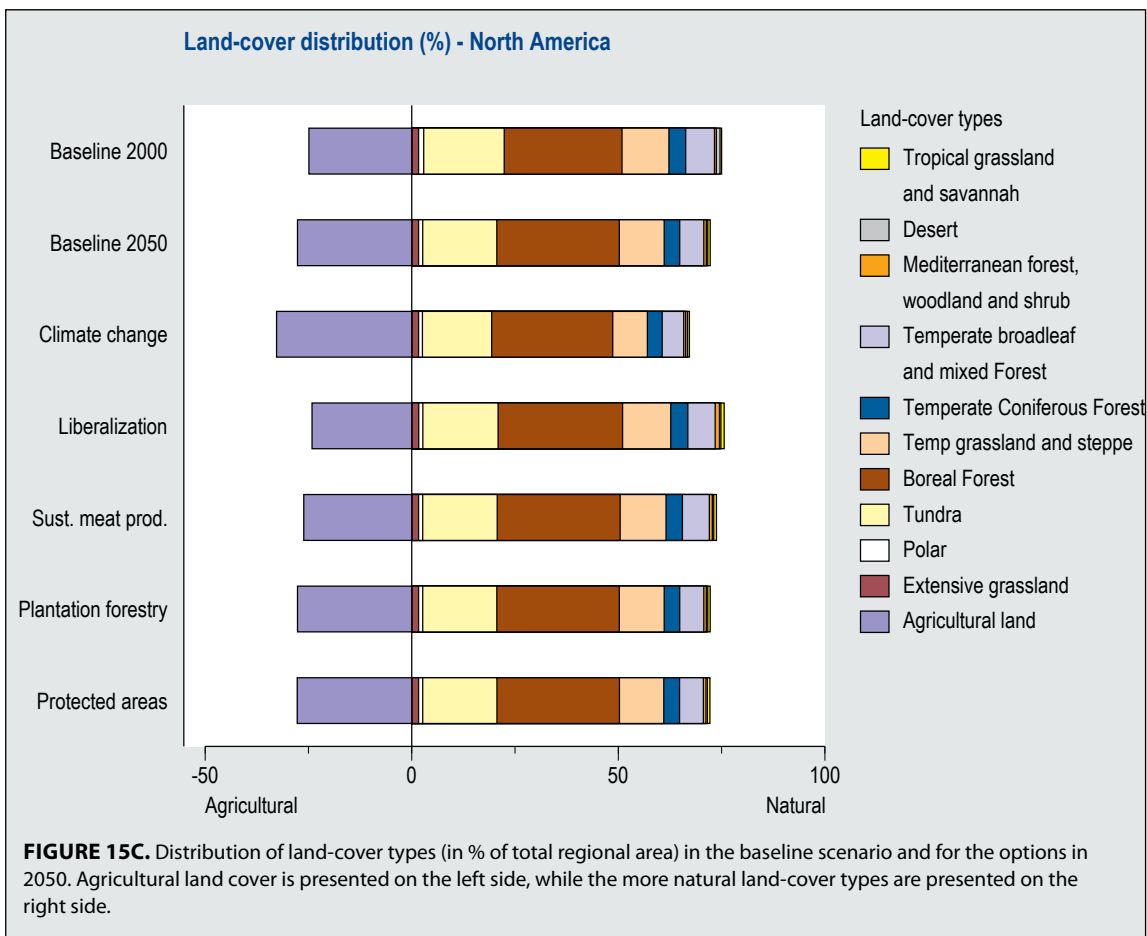
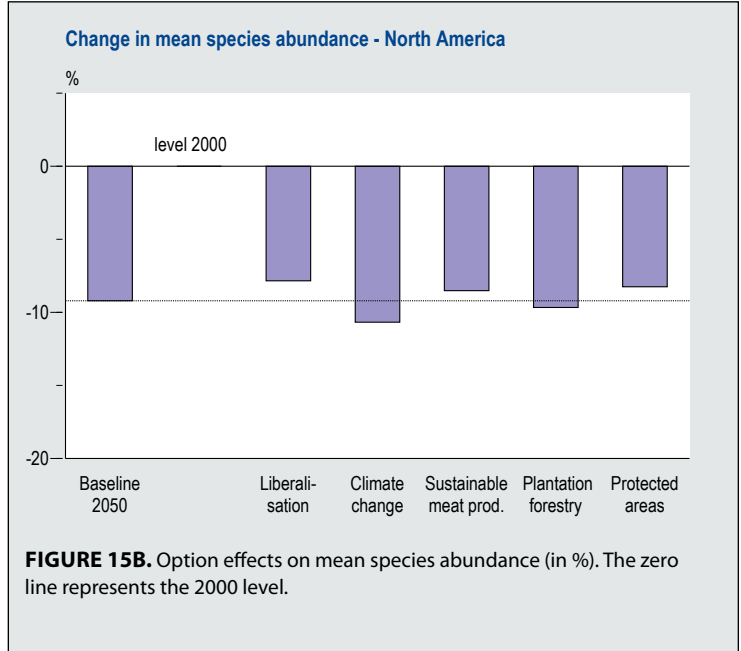
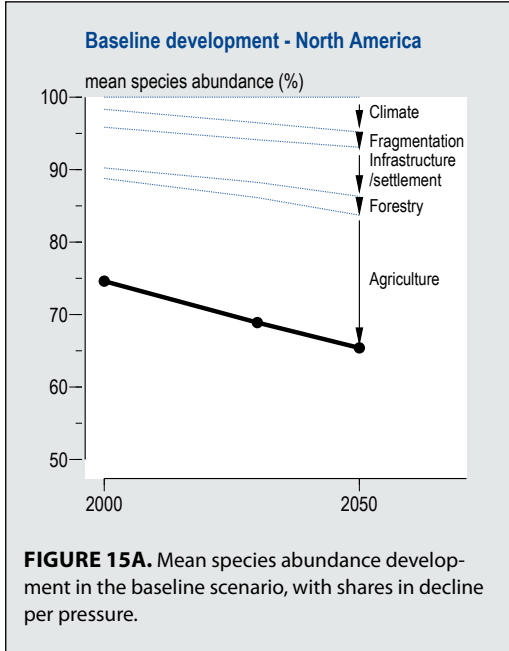


FIGURE 15: Results for North America: baseline development (a), option effects on MSA (b) and land-cover (c).

4.8.2. Results for North America

Baseline development

- In North America, biodiversity decreases from 75% in 2000 to 65% in 2050.
- This decrease is mainly due to climate change, affecting boreal to temperate biomes.
- Further, there is an increase in agricultural land. The agricultural sector remains a strong player on world markets and will expand with growing demand. As productivity in agriculture is already high today, the possibilities for further gains within the present agricultural areas are limited, compared to other regions such as Latin America and Asia. Hence the crop area increases at the expense of natural biomes, mostly at the expense of temperate grasslands and steppe.
- Biodiversity is still relatively intact in North America, taking into account the advanced stage of economic development. The vast landmass leaves ample room for relatively undisturbed land and extensively used grasslands, next to the large areas used for intensive agricultural production, such as the 'corn-belt'.
- The region is the second producer of wood, after Asia. The demand increases slightly, which puts a moderate additional pressure on semi-natural temperate and boreal forests.

Effects of options

- Liberalization has a distinct positive effect on biodiversity in North America (+1.4%). The increase in agricultural land use of the baseline is now reversed, as the opening up of global markets induces a shift of agricultural production to other regions like Latin America and Sub-Saharan Africa. Lifting trade regulations allows these regions to capture a larger share of the world market, capitalizing on lower production cost structures and availability of productive land.
- By contrast, the climate mitigation option has a negative effect (-1.5%). The large potential for bioenergy production is utilized. As a consequence, temperate grasslands and tundra are lost. This loss is only partly compensated by the reduced climate impact.
- Higher meat prices, associated with more sustainable meat production, have a noticeable positive effect on biodiversity (+0.7%). Meat production decreases, lowering the demand for grass and fodder (also in other regions). The high share of meat and dairy products in the regional diet is an important factor in this respect.
- Increasing the area of protected areas leads to higher biodiversity (+1%).
- The forestry option leads to a net biodiversity loss (-0.3%). The productivity of plantations is not very different here from production in semi-natural forests. Establishing plantations (mainly in the USA) therefore leads to additional habitat loss that is not yet counteracted in 2050 by biodiversity recovery in slowly restoring semi-natural forests.

TABLE 15: Summary of indicators for North American regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	65.6%	1.4%	-1.5%	0.7%	-0.3%	1.0%
Cost*		0	--	0	0	0
N deposition	1.00	0.88	0.01	0.95	0.99	0.99

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), – (less than -0.2%), -- (less than -1.5%).

4.9. Europe

4.9.1. Figures for Europe

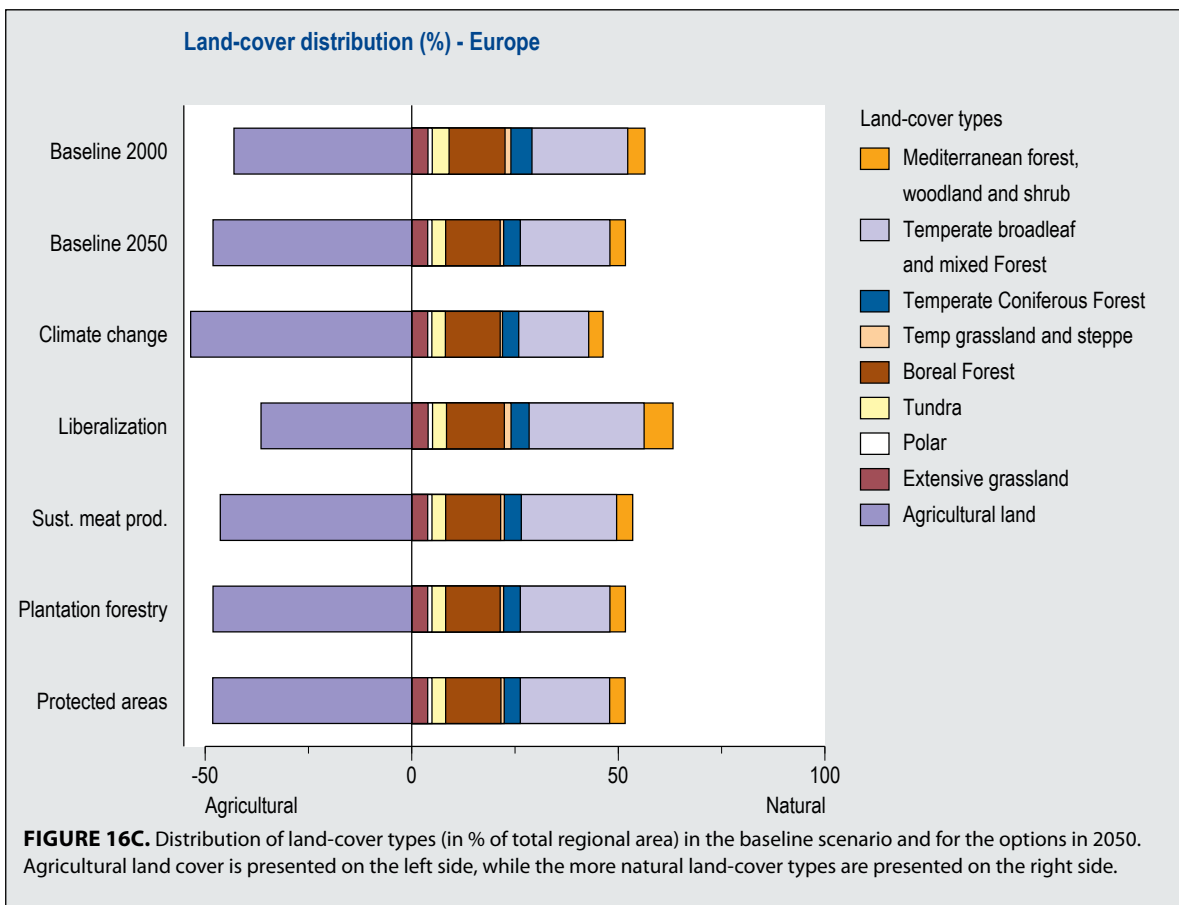
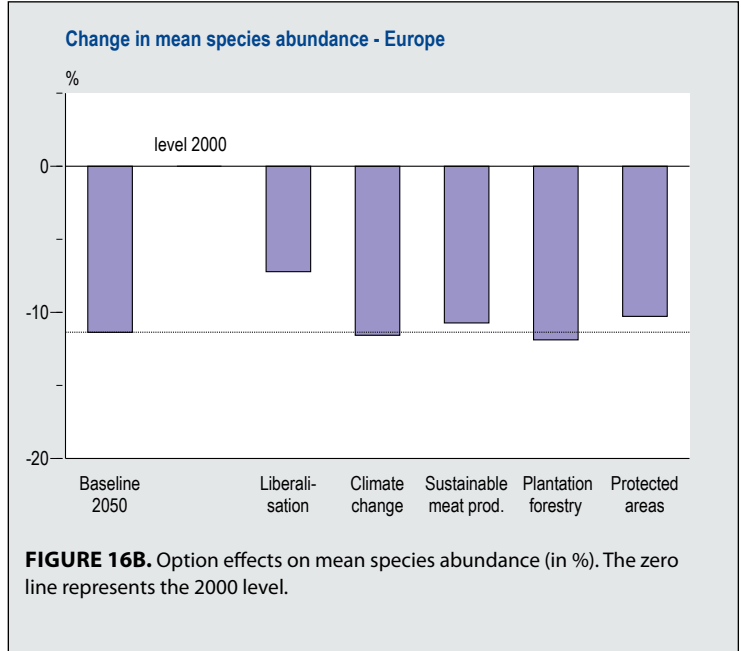
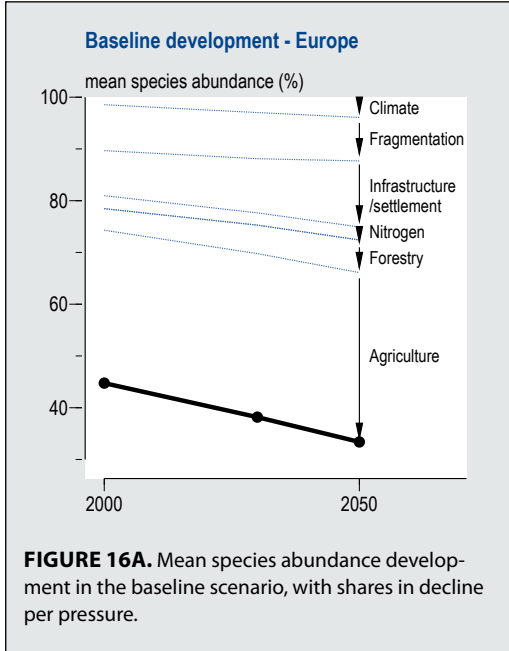


FIGURE 16: Results for Europe: baseline development (a), option effects on MSA (b) and land-cover (c).

4.9.2. Results for Europe

Baseline development

- In Europe, the remaining biodiversity is the lowest of all regions in 2000 (biodiversity level of 45%). This is due to centuries of land conversion and other pressures, such as infrastructural development and fragmentation in this densely populated region.
- A further loss of biodiversity from the 2000 level is projected in the baseline, leading to 33% of the original value in 2050. This is partly caused by the assumed conversion of forest to agricultural land. Although this conversion is not likely in current policies, it is an integral part of the scenario. If no conversion would take place in Europe, this would be compensated by agricultural expansion in other regions. Given the main goal of this study -the evaluation of policy options and not the development of a 'perfect' baseline- this is not a limitation for the use of this study. The results should however not be used isolated from the global context, as policies in one region have direct effects in others.
- Several of the pressure factors contribute to this biodiversity loss: climate change, infrastructural development, forestry and agriculture. The last cause indicates that European agriculture maintains its position in expanding world markets under continued agricultural policy and trade rules and regulations. This region already has an intensive agriculture, and increased production leads to expanding agricultural areas.

Effects of options

- Liberalization has the largest positive effect on biodiversity in Europe (+4.2%). Lifting trade regulations implies that other players on the international market can improve their position at the expense of Europe and North America. Hence, the upward trend in agricultural land use of the baseline is reversed as agricultural production declines by 24%. The abandoned land is slowly returning to a more natural state, with a higher biodiversity value; however this process is still not completed by 2050. Mediterranean forests, woodland, and shrub and temperate forest areas, show the largest improvements.
- Relatively modest volumes of biofuel production, relative to the energy consumption, emerge in the climate mitigation case. Suitable land is scarce so the net loss of habitat remains limited in size, affecting primarily temperate forest area. At the same time, the negative effect of climate change is removed and the net option effect on biodiversity is almost neutral. As climate change affects mostly boreal and temperate forests, and Mediterranean biomes, biodiversity gains in these biomes can be expected.
- The forestry option leads to a further biodiversity loss (-0.6%). The productivity of plantations in this region is not very different from production in semi-natural forests. Establishing plantations will therefore lead to additional habitat loss. Increased trade with other regions is not taken into account, which would show shifting production areas. This would give a more realistic scenario, with more forest protection in Europe.

TABLE 16: Summary of indicators for European regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	33.7%	4.2%	-0.2%	0.6%	-0.6%	1.1%
Cost*		0	--	0	0	0
N deposition	1.00	0.91	0.36	0.98	0.99	0.99

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), - (less than -0.2%), -- (less than -1.5%)

4.10. Oceania incl. Japan

4.10.1. Figures for Oceania

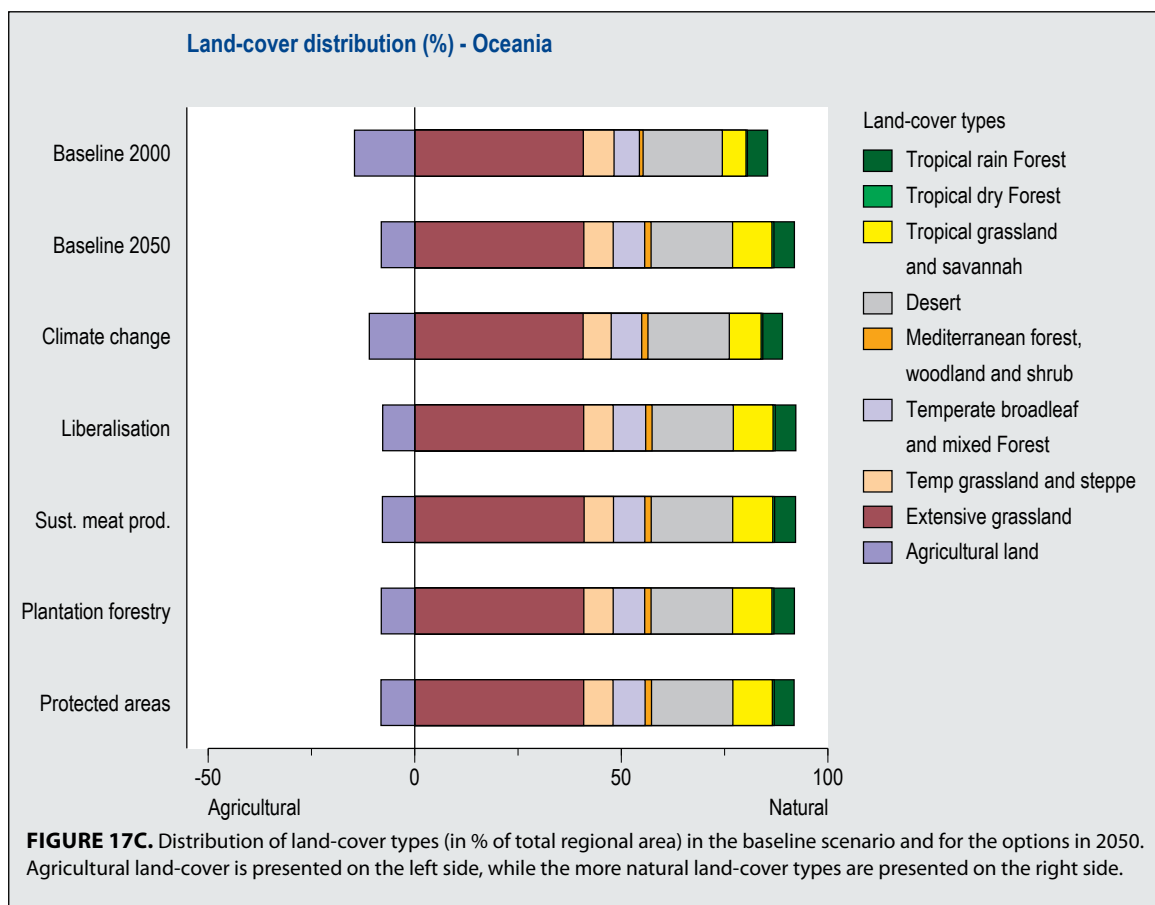
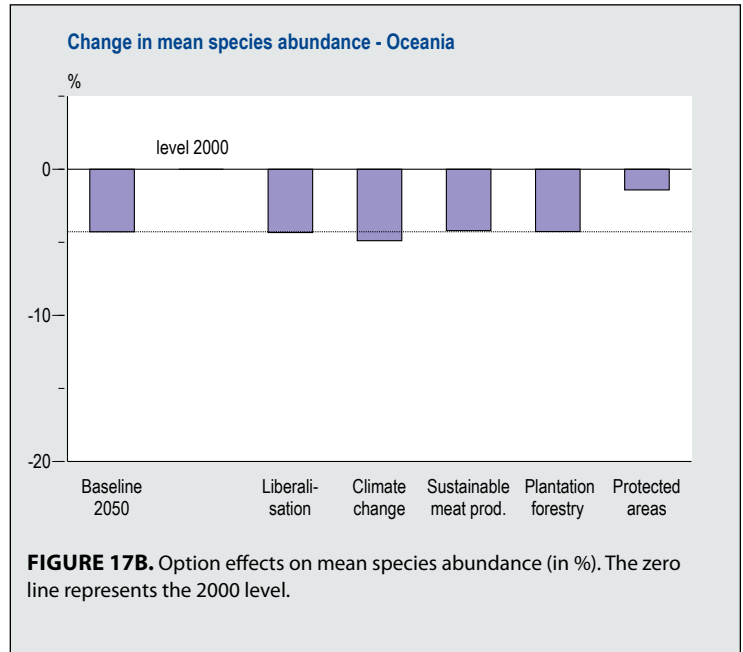
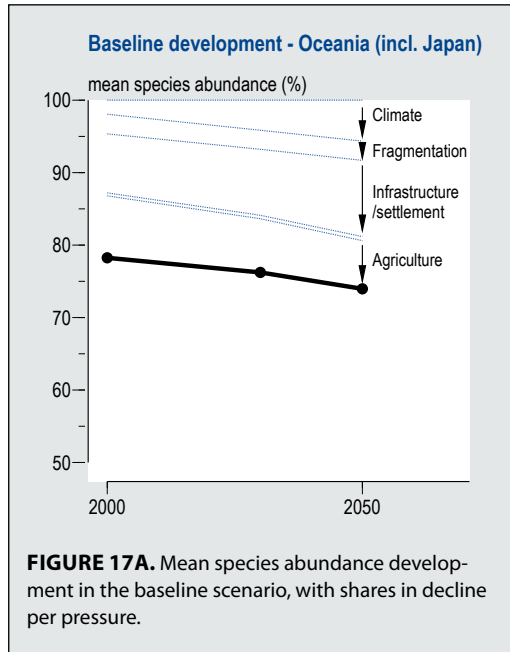


FIGURE 17: Results for Oceania: baseline development (a), option effects on MSA (b) and land-cover (c).

4.10.2. Results for Oceania and Japan

Baseline development

- In Oceania and Japan, the biodiversity decreases from 78% in 2000 to 74% in 2050. Due to its relative large area, Australia plays an important role in the overall regional behaviour.
- This decrease is mostly due to climate change effects on a broad range of natural biomes (desert, savannah, temperate and tropical forests and grasslands, and Mediterranean biomes).
- Further loss is caused by infrastructural developments and settlement, driven by economic development.
- The relatively modest decline in biodiversity is explained by the decrease in agricultural land use in the study period, as land is taken out of production through productivity increases. The area of disappearing arable land shows up as restored natural forest and savannah biomes.

Effects of options

- Increasing the size of protected areas is very effective for this region and leads to a substantially higher biodiversity (+2.9%).
- The climate mitigation option leads to a further loss of -0.6%. Australia and New Zealand will become countries for biofuel production, mainly at the expense of savannah. This increased land use counteracts the positive effect of climate measures.
- Liberalization of the agricultural market does not have a great effect on this region. The Oceanic region does not employ import barriers at the moment, such as North America and Europe. Removing these barriers can be expected to benefit the agricultural production in this region, but this effect is very small.
- The options on sustainable meat and plantation production all have a similarly small effect.

TABLE17: Summary of indicators for Oceania (including Japan) regional baseline development up to the year 2050 and effects of options in 2050 compared to the baseline

OPTIONS/ ISSUES	BASELINE	LIBERALIZATION OF AGRICULTURAL TRADE	LIMITING CLIMATE CHANGE	SUSTAINABLE MEAT PRODUCTION	PLANTATION FORESTRY	INCREASING PROTECTED AREAS
Biodiversity	73.8%	-0.1%	-0.6%	0.1%	0.0%	2.9%
Cost*		+	--	0	0	0
N deposition	1.00	1.00	0.00	0.94	1.00	1.03

* Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), – (less than -0.2%), -- (less than -1.5%).

5. UNCERTAINTIES AND SENSITIVITIES

Introduction

There are numerous sources of uncertainty that influence the outcome of this analysis (Petersen *et al.*, 2003), ranging from problem framing, indicator selection, data imprecision and variability, model uncertainties (in parameters, dose-response relationships and conceptual structure), to scenario and option assumptions (ignorance on future developments and consequences of policy interventions). These sources differ in the location of uncertainty, either in the project context, the data, the model, output indicators, and expert judgement.

All these numerous of uncertainty cannot be dealt with completely here. Only the most important uncertainties and assumptions affecting the baseline and option results are addressed in this section, and qualitative expert judgments on their biodiversity effects are given. The assessment of different options must be regarded as a way to show the consequences of policy decisions (what-if analysis), and is the main objective of this type of study. Therefore, the option assumptions form an important part of this chapter. A more formal and complete uncertainty and sensitivity analysis, based on the MNP framework and guidelines on uncertainty analysis (Petersen *et al.*, 2003), could shed more light on this subject.

5.1. Main findings

Main uncertainty message: The key finding on global biodiversity (7% decrease between 2000 and 2050) is most probably a conservative indication of the future decline, as the explored baseline scenario is optimistic on agricultural productivity increases. Taking more scenarios into account can shed light on the range of possible outcomes. Most of the options, using the baseline as reference, are –on purpose– extreme designs and consequently show exaggerated biodiversity effects, either positive or negative. Not known is what the combined effect of options will be. Such an elaborate task demands many different assumptions on combined policy effects.

The used proximate indicator for the multi-faceted concept of biodiversity combines impacts of habitat loss and quality loss (in terms of mean species abundance), which make it possible to assess land-use dynamics and impacts of pressures. The relevance of this proxy for policy support is high, as it concerns two of the focus areas listed by the CBD. For specific option effects, such as protection of rare and unique species, the MSA indicator is insensitive. Other biodiversity indicators, like ecosystem extent, red list and a species-richness weighted MSA will show similar general patterns of overall biodiversity decline, with the same main drivers for this decline, but the exact number will vary between indicators. Especially a red list indicator provides complementary information to the MSA and ecosystem extent indicators in respect to rare species.

Regional declines in biodiversity and land-use shifts will show considerable variation, depending on the assumed effects of changing agricultural and trade policies (with trade-offs between regions when production moves to other areas), and the speed of technological transfer. Changes in land-use are the result of land-allocation rules, and implementing different rules (for instance, making more use of marginal and degraded grounds) will result in different effects. Additional work on specific regional implementation and assessments of options will help this work further.

The study uses mean abundance of species relative to the ‘original’ abundance of that species as proxy for biodiversity. The main advantage of this indicator is that it is possible to link scenarios on economic developments, climate and land-use change (indirect and direct drivers) to dose-response relationships between environmental pressures and species abundance. Thus, scenarios and option effects can be assessed in an integrated way for all global terrestrial biomes. Alternative biodiversity indicators show similar general patterns of overall biodiversity decline, with the same main drivers for this decline. They can probably better distinguish between species rich and species poor biomes, putting more focus on global hot-spots, whereas the indicator used here weighs all biomes equally.

The main missing element in the present analysis is the aquatic habitat, and thus the impacts of overexploitation of fish resources, destruction of sea-fringing habitats, and pollution of inland waters as well as effects of options such as large-scale aquaculture. Preliminary analyses on this subject indicate an even stronger decline in biodiversity values for the year 2000 (40%, opposed to 30% for terrestrial).

The main ecosystem models used are IMAGE and GLOBIO3. In these models, sensitivities and uncertainty are related mainly to the underlying dose-response relationships on climate sensitivity and biodiversity response to environmental pressures and land-use dynamics. The relationships are based on the best current available and extensive literature reviews. Using the terminology from the Millennium Ecosystem Assessment (MEA 2005), the knowledge base can be characterized as ‘established incomplete knowledge’ for IMAGE, and as ‘established’ to ‘speculative knowledge’ for GLOBIO3, depending on the type of pressure.

The GTAP model captures economic and demographic developments that determine land use. The most important uncertainties in the GTAP model are related to macro-economic and demographic growth. Sensitivity analysis shows that model outcomes are mostly determined by variation in economic growth. This is caused by the relatively low demographic growth, relative to economic growth. Sensitivities are generally low, but are considerable for Africa, as developments in this region are determined by the more sensitive part of the land-supply curve.

The study presents one scenario (the ‘baseline’) that does not cover a range of uncertainties that would result from assessing alternative scenarios. Compared to the Millennium Ecosystem Assessment, the scenario analysed is located at the lower bounds of future biodiversity decline (*optimistic view*), since considerable productivity improvements restrict the additional required agricultural area for the growing world population. The areas pertaining to the required agricultural crops are up to 20% lower than in the often used IPCC scenarios, and up to 28% lower than in the MA scenarios. When lower productivity is assumed, much more land is necessary, leading to more conversion of natural biomes, and lower biodiversity values in 2050. In the presently used baseline, abandoned agricultural land (as a consequence of productivity increases) becomes available for nature restoration, which is assumed to be successful. These abandoned areas are used in several of the options for measures that need room (i.e. agricultural expansion or biofuel production). When assuming lower baseline productivities, abandoned areas will not be available and room must be made by converting natural areas. An important question is therefore whether it is likely that abandonment (and restoration) will indeed take place in different parts of the world.

Most of the options have an extreme design that clearly shows, but overestimates the effects on biodiversity and possible trade-offs. However, overestimations do not all follow a similar general direction. An analysis of option combinations would be a valuable addition to the present study.

Negative consequences for biodiversity are overestimated in the options on liberalization and poverty reduction, by assuming a fast and complete implementation instead of a smoothed introduction. The positive effects of increasing the protected areas and sustainable meat production are overestimated due to the assumption that both are effectively implemented and maintained, and that protected areas will lead to a restoration of the original biodiversity to the 90% level. The impact of climate change is probably underestimated, due to conservative estimates on climate sensitivity and therefore a limited need for mitigation measures. If alternative assumptions were to result in a higher deployment of bioenergy to compensate climate impacts, it would lead -in turn- to higher biodiversity impacts due to habitat loss. The biodiversity-saving potential of plantation forestry is probably underestimated, as the area requirement of traditional forestry is underestimated in the baseline. The effect of forestry and the forestry option as a whole is limited because deforestation is attributed to agricultural expansion.

The negative impact of energy crops and carbon plantations due to habitat loss might be overestimated. In the baseline, the model assumes entire restoration of the original biodiversity after an area has been abandoned. However, in practice not all abandoned land will restore naturally. In the climate mitigation option, energy crops were allocated as much as possible in abandoned land. If carbon plantations and energy crops are established on degraded lands, this might reduce the impact or even slightly improve biodiversity.

5.2. Problem framing

The present analysis has been commissioned by the CBD. The most important results of the study are the relative effects of the baseline development and of the options, and not so much the calculated absolute biodiversity values.

The analysis concentrates on one central scenario and individual option effects as ‘add-ons’. Other possible future storylines, options and especially option combinations can be designed, but have not been implemented

and analysed within the limited time available. Furthermore, no region specific options have been taken into account. A complete analysis of different future scenarios, including regional options specifically tailored to each scenario, will reveal the full range of possible outcomes. The scenario applied is probably located at the optimistic end of this range, as the consequences for biodiversity decline are underestimated due to the assumption of high productivity improvements (see below under scenario choice). Furthermore, not all pressures on biodiversity are taken into account, which can also result in a too optimistic view on current and future biodiversity.

An important restriction of the present set-up is the absence of the aquatic (freshwater and marine) environment. Scenarios on fish consumption, diet shifts to more healthy fish products, and increased agricultural nutrient use from productivity increases use could not be assessed. The effects of aquaculture options (including natural habitat alterations and fish fodder harvesting or production) are not calculated either.

Overexploitation of fish resources, destruction of sea-fringing biomes (mangroves and coral reefs), and pollution (nutrients and pesticides) of inland and marine aquatic biomes are not accounted for in this study. A preliminary study on this subject (Rood *et al.*, 2004) to include different pressures, ecosystems and trophic levels suggests that the present biodiversity decline in the oceans (40% loss) is even higher than for the terrestrial biomes calculated in this study (30% loss; Table 2 and see MEA 2005c).

5.3. Communication

Interactions between socio-economic developments and biodiversity are so complex that it is hard to communicate straightforward messages. Because the indicators are aggregated and simplified, complex messages including trade-offs (in space, time or in specific effects) can be avoided, but this way of presenting can't tell the whole story. In the near future significant progress is needed in communication methods. Visualization by photographs, documentaries and transforming the IMAGE-GLOBIO models into interactive models for policy makers in the form of games (with Google-Earth like images) are worth to be explored on their potential to communicate the messages. The initiative for a scientific panel (IMOSEB) could be involved for the communication to a wide audience.

5.4. Indicator choice

Obviously the indicator and model present limited possibilities for interpretation and assessment of developments and option effects. Two selected CBD biodiversity indicators are included (species abundance and ecosystem extent), but threatened species still lacks. What are the consequences of indicator selection for the results? After all, each indicator indicates a specific aspect of the multi-dimensional entity of biodiversity. Below, several notions on the applied indicators are given, and a few alternative indicators and their likely impact on the conclusions are discussed. The project limits only allowed for a few quantitative calculations.

The mean species abundance (MSA) indicator in GLOBIO3:

- applies equal weights for the different biomes (non-weighted MSA), from polar to tropical forests. So every km² of a terrestrial biome contributes equally to the regional or global MSA. If the biomes are weighted on their species richness (weighted MSA), land-use changes and other pressures in species rich biomes (tropical forests, Mediterranean grasslands, and temperate grasslands) are accentuated. Preliminary calculations based on species richness figures from Rodrigues *et al.* (2004a, b), WWF (2006) and Kier *et al.* (2005) indeed show that the impacts on biodiversity at the global level are more severe, in both the baseline and policy options. The relative effect of options stays more or less the same. The overall decreasing values indicate that human impacts are greater in species-rich tropical and temperate zones than in species-poor boreal and Polar regions, which is a confirmation of the results in Figure 8. The regional results change unexpectedly. Weighted MSA values are lower for all regions, except for South America, because the species-rich Amazonian region remains relatively unimpacted. On the basis of these preliminary results, and bearing in mind that the report focuses on the effects of options, we conclude that the main findings would not change significantly when applying weights per biome, other than the effects in the baseline scenario and options becoming somewhat larger.

- shows the value of the original species abundance relative to ‘natural’ conditions (for climate and soil). So MSA is a human-impact measure. The consequence of this design is that changes due to human interference always lead to lower indicator values, and restoration and mitigation lead to higher indicator values with a maximum of 100%. Not all possible indicators behave this way. For instance, a species assemblage-based trend index (STI) can increase above 100% if one or more species become extremely abundant due to human interference or natural fluctuations.
- is not sensitive to all option effects. This is the case for expanding protected areas, where specific hotspots are included based on species richness and uniqueness. MSA and ecosystem extent (biome level) are not sensitive to these aspects, and consequently underestimate its benefit. A Red List indicator would as well as a species richness weighted MSA (assuming that species rich biomes are favoured for selection of protected areas). It should be noticed that no indicator can cover all aspects. That is the very reason that CBD selected a set of complementary indicators, as is common practice in the socio-economic field.

Other indicators

- Another often-used biodiversity indicator is species richness. This indicator is less sensitive or even insensitive to the homogenization process. Species richness at the local to the regional levels can be expected to be stable or even to increase during the coming decades as a result of the introduction of many new species due to human disturbances. New species will become more and more abundant, partly replacing original species, without necessarily leading to the extinction of the original species (Lockwood and McKinney, 2001). However, at the global level species richness will decrease. The process of increasing species richness while at the same time the abundance of the original species declined by a factor of three has been observed between 1900 and 2000 in a period of large-scale industrialization and demographic growth in the Netherlands (Ten Brink, 2000; Ten Brink et al., 2002).
- Another often used indicator is the ‘number of threatened and extinct species’. As the status of threatened species depends on the threats to and sensitivity of species, the pattern of change cannot easily be predicted. In general, we assume that an indicator based on threatened species will show a decline when pressures on ecosystems increase, as many threatened species have restricted ranges. We expect changes similar to mean species abundance (MSA) but less profound, and lagging far behind.
- Changes in the ‘number and abundance of endemic species’ are expected to be similar to changes in threatened species. Both species groups have generally small distribution areas (by definition), making them more vulnerable to habitat loss and other causes of homogenization.

5.5. Model uncertainty and sensitivity

IMAGE

As a global Integrated Assessment Model, the focus of IMAGE is on large-scale, mostly first-order drivers of global environmental change. Most of the relations in IMAGE can be characterized as ‘established but incomplete knowledge’. This obviously introduces some important limitations, particularly on how to interpret the accuracy and uncertainty. As previously mentioned, an important method for coping with the uncertainties in socio-economic developments is the use of a scenario approach. A large number of uncertain relationships and model drivers that depend on human decisions can be varied. Uncertainties in model parameters can be assessed using sensitivity analysis.

For the energy sub-model (TIMER; de Vries *et al.*, 2001), an elaborate uncertainty assessment pointed out that assumptions for technological improvement in the energy system and translation of human activities (such as human lifestyles, economic sector change, and energy efficiency) into energy demand were highly relevant for the model outcomes.

The carbon cycle model has also been used in a sensitivity analysis (Leemans *et al.*, 2002). Central to climate change modelling are the responses to increased greenhouse gas concentrations. In the IMAGE model this concerns the responses in global temperature increase and local climate shifts. The consequences are further discussed in the climate option section.

Another model element relevant to the biodiversity issue is the implementation of specific land-use allocation rules determining conversion of natural biomes (see preference rules in Alcamo *et al.*, 1998). These rules are most relevant for the calculated biodiversity value. Only a limited set of land-use change is implemented, that is obviously a simplification of actual land-use changes. This limits the assessment of careful land-use planning, for instance, bioenergy production and plantations on available, already impacted, areas instead of natural biomes.

GLOBIO

The heart of the GLOBIO3 model is a set of dose-response relationships between the mean abundance of original species and pressure factors. The relationships are based on model exercises (climate change effects), on data from extensive literature reviews for pressure factors (for land-use change, nitrogen deposition and infrastructure), and on review studies on fragmentation. The data found in literature was interpreted and figures were recalculated to fit into comparable relationships and indicators. This procedure is sensitive to errors and, to some extent, misinterpretation, but allows comparison between effects of different pressure factors. The unavoidable differences in the quality of datasets used create uncertainty in the estimated dose response relationships. The overall result of GLOBIO3 shows similar patterns as earlier global studies (Sala *et al.*, 2000; Wackernagel *et al.*, 2002; MEA, 2005a, 2005b, 2005c). GLOBIO3 is a more quantitative and more complete approach.

We used 130, 50 and 300 studies for land use, nitrogen and infrastructure effects, respectively. The majority of the land-use studies are from tropical biomes, while the studies on nitrogen and infrastructure mostly build on temperate and boreal data. The bandwidth of literature-based relationships is considerable (5-10% on a scale between 0 and 100%). Especially low impact pressures, like grazing in grassland ecosystems, tree logging or nitrogen deposition close to critical load values have high uncertainty. For secondary vegetation we currently use a mean value, but a time-dependent component (reflecting natural recovery) needs to be incorporated. Still, we find the order of the pressure effects on biodiversity to be far more certain than the exact values.

The climate dose-response relationship cannot be based on data that measure the climate effects directly, as most effects will show up in future. Therefore, the relationships are based on model exercises that estimate climate envelopes for species (Bakkenes *et al.*, 2002) or vegetation types (Leemans & Eickhout, 2003). Meta analyses (Parmesan & Yohe, 2003; Walther *et al.* 2002) and other model studies (Thomas *et al.*, 2004) confirm the main tendencies of the IMAGE-GLOBIO3 exercises, but the modelled effects are relatively low. Thus the effect of climate change might be underestimated in this study.

For fragmentation, we used five review studies on minimum area requirement (MAR) of animal species (data on 156 mammal and 76 bird species). This study is biased towards the European region. Establishing dose-response relationship suffers from the different definitions of individual MAR, but the overall picture comparing the different studies is remarkably consistent. A similar method was used in the EURURALIS study (e.g. Verboom *et al.* in press), where a general species area relationship was used.

GTAP

The agricultural production and land-use outcomes of the Computable General Equilibrium model (GTAP) are dependent on the demographic and macro-economic growth assumptions, which are both surrounded with considerable uncertainty. Land use is dependent on the position and elasticity of the land-supply curve, and trade flows are very dependent on the values of the Armington elasticities, which are difficult to estimate.

In van Meijl *et al.* (2005) a systematic sensitivity analysis (SSA) was used to test the robustness of results with regard to these assumptions. Using the Global Economy scenario, six different SSAs were performed for the period 2001-2010, by assuming the GDP and population shocks fall within a band of $\pm 20\%$ or $\pm 40\%$ of the mean (triangular distribution for $\pm 20\%$, or uniform for both bands). Results are given for EU-15 and Africa (Table 18).

Most importantly, macro-economic growth is surrounded with more uncertainty than demographic growth. Further, standard deviations are generally low. For example, when GDP growth is varied ($\pm 20\%$, triangular distribution), an interval is obtained from -2.2 to -2.6 for the EU 15, and from 16.7 to 20.7 for

Africa. The confidence interval for Africa is much wider because Africa is on the flatter part of the land-supply curve. With a uniform distribution the size of the interval is about 50% larger, if the applied variation doubles to $\pm 40\%$ than the size of the interval doubles again. When population growth rates are varied, the obtained standard deviations are generally lower than for varying GDP. This is mainly caused by the lower demographic than macro-economic growth in the period 2001-2010.

TABLE 18: Results for a Systematic sensitivity analyses for the GTAP model, in a Global Economy (A1) scenario, period 2001-2010. The table lists the mean values for input variables (GDP and population growth) , and means and standard deviations for output variables (agricultural land use). Population and GDP growth were considered as random variables (Gaussian quadrature; Arndt, 1996)

	GDP GROWTH		POPULATION GROWTH	
	EU15	AFRICA	EU15	AFRICA
MEAN VALUES FOR INPUT VARIABLES				
GDP growth in A1 (2001-2010)	24.6	45.7		
Population growth in A1 (2001-2010)			1.2	23.1
MEAN VALUES FOR OUTPUT VARIABLE				
Agricultural land use	-2.4	18.7	-2.4	18.7
STANDARD DEVIATIONS FOR OUTPUT VARIABLE				
Varying input with 20% (triangular distribution)	0.11	1.03	0.09	0.42
Varying input with 20% (uniform distribution)	0.16	1.45	0.13	0.6
Varying input with 40% (uniform distribution)	0.34	2.9	0.25	1.2

5.6. Validation

Validation of the model and the results is an important task, but not an easy one. The GLOBIO3 model was reviewed by an international team in April 2005 (Leemans et al. 2007), but was not subjected to an independent validation. The IMAGE model framework (MNP, 2006), including its linkages with GTAP and GLOBIO3, were subject to an international scientific review in November 2006; a report on the findings is forthcoming.

The current GLOBIO cause-effect relationships are based on about 500 peer-reviewed articles on the impact of individual pressures on species abundance of the original species compared to the original state. The effects of multiple pressures are calculated by multiplying the impact factors from the separate relationships. Both the generalization of these site-based cause-effect relationships and the multiplication should be validated. The results we obtained are in line with those of Scholes & Biggs (2005), who estimated the fractions of species populations to be found in a range of land-use types based on expert knowledge.

The most promising way to validate the approach is to compare the year 2000 results with actual monitoring of the actual abundance of a representative set of species, relative to their potential abundance (baseline state). We carried out an informal test by comparing the model outcome with the species abundance monitored for many years in the Netherlands, and found a similar outcome - but the area is very small compared to the terrestrial land surface. This can be extended to a limited sample of large countries, but requires large budgets, time and good organization. Only a few countries are able to provide the necessary information. In fact, the difficulty to obtain scientific data is the very reason for the GLOBIO model and the selected indicator, to overcome this problem in the short term.

Validation is possible in the medium term if it can be done for several countries or regions. The work on species monitoring and modelling in Europe is fairly advanced and would lend itself to compare model results with actual data. Data are compiled for the bird and butterfly indicators (Streamlining European Biodiversity Indicators programme and BioScore project). Currently, the GLOBIO team is also working on species-based monitoring and modelling with various partner institutions around the world (Africa, South East Asia and Latin America), which could eventually be used for validation purposes.

5.7. Scenario selection and choices

Baseline position

The baseline scenario contains several assumptions on world and regional development that have an important influence on land use (mainly agriculture). The development of the total required crop area in the baseline is relatively low in comparison with other often used IPCC scenarios (up to 20%), and up to 28% lower than the MA scenarios (see figure 18). This is caused by the fact that implemented productivity increases are optimistically in the baseline. This is a very influential variable for agricultural land use and biodiversity, as high productivity can lead to abandonment of agricultural areas, making room for nature restoration (which is assumed to be successful). Options requiring more agricultural area can make use of the abandoned areas, limiting the possibilities of nature restoration. Thus, the baseline contains important technological improvements that will reduce the biodiversity loss rates in the future. It is important to keep this in mind when judging the potential effects of options. Implying less optimistic assumptions of agricultural improvements will lead to higher baseline losses of biodiversity, and to less abandonment. Room requiring options will then only be implemented by additional conversion of natural areas.

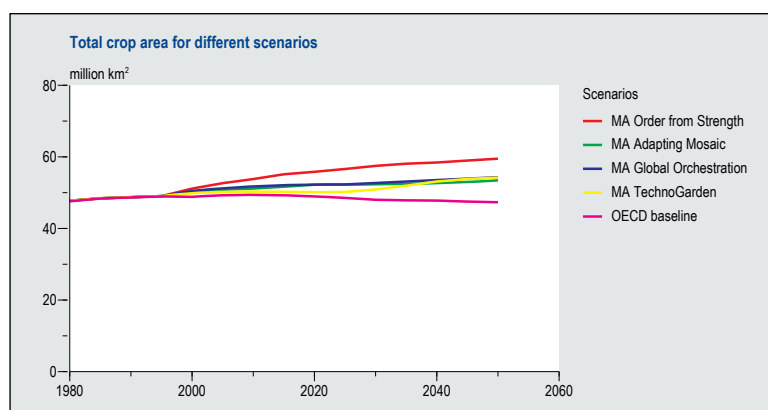


FIGURE 18: Total world crop area for the different MA scenarios, compared with the OPECD baseline used in the present analysis. The OECD baseline uses less area for food production than the MA scenarios (up to 20%).

5.8. Options and assumptions

Combination of options

No single option can reduce the rate of loss alone. Only a combination can, but as stated above, this could not be assessed within the limitations of this study. We preview that reducing meat consumption in combination with increasing agricultural productivity and protected areas will have a positive and mutually additional effect on the short term. However, combining plantation forestry, biofuels, agricultural productivity and protected areas will result in competing area claims which -on a certain level- are not compatible. Besides, their impacts on biodiversity are not linear and differ over time (short to long term) and space. These interactions are far too complex to make any guesstimate on the final outcome over time and space. This can only be tackled by a thorough design of combined options and further integrated modelling.

Liberalization option sensitivity

The liberalization option is rather extreme in assuming that all barriers of agricultural products to free trade are abolished simultaneously. In reality, such agreements are introduced with delays, exemptions and special conditions leading to more gradual and partial shifts. Differences in wages and land rents that drive the observed shift from North to South tend to decrease as time elapses. Thus the effects will never materialize to the full extent reported here. Moreover, the WTO rules allow for interventions in unfettered trade under certain conditions, including environmental impacts and regulations. Altogether, this means that the negative effects of liberalization are probably smaller as the process will take place along more smoothed trajectories. This will result in a less dramatic effect on additional land use, production shifts and biodiversity decline.

Poverty reduction sensitivity

The poverty reduction strategy is implemented in a fairly straightforward way. Trade liberalization is combined with extra income growth as a result of increased investments. Agricultural productivity and labour productivity are adjusted upwards.

A more specific targeting of investments might help the poor *and* reduce the pressure on biodiversity. These strategies could focus on increased off-farm income and exit from agriculture (Dixon *et al.* 2001). On the other hand, MDG-focused investments assume a relatively strong emphasis on infrastructure, given the extensive road system in Sub-Saharan Africa (SSA). This might increase the pressure on biodiversity.

In the long run, the negative impact of improved human development in SSA on biodiversity might be mitigated by a demographic transition. Improvements in health, education and income will have a downward pressure on fertility rates. Ultimately, population growth, one of the major drivers of biodiversity loss, will decline. Given the long lag times, the positive effect on biodiversity is, within the scenario horizon, assumed to be negligible. Altogether, the impact of implementing a more sophisticated poverty strategy remains ambiguous within the scenario period.

Climate-change mitigation sensitivity

The core uncertain factors in the climate-change mitigation option are the so-called climate sensitivity, i.e. the response of the climate to changes in the atmospheric concentration, and the role of bioenergy in mitigation strategies.

In the option analysis we adopt the central assumption that the mean global temperature will increase by 2.5 °C in response to a doubling of CO₂ equivalent atmospheric concentration. There is considerable uncertainty around this value. Current IPCC estimates range from less than 1.5 to 4.5 °C, and recent literature suggests that even much higher values cannot be ruled out. A low sensitivity implies that far less mitigation efforts are required to reach the 2 degrees target, lowering the pressure to convert land for bioenergy production. If the climate sensitivity turns out to be high, however, the beneficial effect of mitigation efforts is much lower.

Changes in local climate are subject to even larger uncertainties than global climate indicators, which implies that impacts on biomes in specific regions can differ from what is projected in the present analysis. For example, while climate models by-and-large agree on more drought risks in Southern Europe in response to global mean temperature rises, precipitation trends for North-West Europe between the various models even differ in sign (IPCC, 2001d). Hence, negative impacts on Mediterranean biomes are fairly robust, but the effects on temperate broadleaf and coniferous biomes should be treated with care.

At any mitigation effort level, the contribution of bioenergy can range from very marginal to very substantial. The contribution of technical measures to reduce GHG emissions is a function of their estimated potentials and relative costs. To meet the ambitious target, large shares of the estimated potential will be called upon, including high cost measures. Hence, reaching the same target with less bioenergy production could occur if competing options are cheaper and more abundant than assumed here.

In the option, energy crops are first located on abandoned agricultural areas, and the remaining part on natural, low productive non-forested areas. The assumption in the baseline is that abandoned areas will restore to more or less natural systems. If this was not the case, the biodiversity effect of growing bioenergy on abandoned areas will be less negative.

Finally, if the productivity of agricultural land use can be further improved, more abandoned land will become available for energy production, with an overall positive effect on biodiversity as less natural systems are converted. Baseline assumptions on productivity adopted from FAO (FAO, 2003) are already comparatively high (chapter 4). The current Agricultural Assessment (IAASTD) may potentially shed more light on the feasibility and conditions for further productivity gains.

Sustainable meat option sensitivity

Crucial in the sustainable meat option is the issue of whether (and how fast) this option is applied globally. In some regions (e.g. Europe) the public awareness of the negative side-effects of meat production is greater than in other regions. A slower and less complete implementation than is assumed is more likely.

Another uncertain aspect is the influence of improving sustainable production methods on the costs of meat, next to consumer's response to price increases. The option assumes relatively high cost increases that negatively affect consumption levels. Through further development of improved sustainable techniques and learning effects, the additional costs can be expected to be lower. The elasticity of the meat prices are also uncertain, but it is not known whether these will cause an under or overestimation of meat consumption.

The last factor worth mentioning is the environmental impacts of the sustainable production methods, i.e. nutrient and energy efficiency, and productivity (which determine land use). These factors will also improve in the future; this has been taken sufficiently into account in the baseline and option. Further improvements are not probable. Altogether, this means that the effect of the sustainable meat production option is overestimated because of less complete implementation and probably lower cost figures. Correcting for this will result in a lower biodiversity reduction in the option.

Increased plantation forestry option sensitivity

Plantations are assumed to become established on areas occupied by (semi-)natural forests (deforestation), and not on abandoned land or set-aside land from agricultural use (reforestation and afforestation). This practice does not take place according to the sustainability criterion ('FSC-principle 10'), which is also under discussion at present. Therefore, the option cannot be named 'implementing sustainable forestry'. Applying the FSC establishment criterion for reforestation and afforestation, will reduce the impact of the plantation option on the forest biome, but will shift the impact to other biomes that might otherwise be left to restore to a more or less natural situation.

Letting plantations take over almost all global production is not a very realistic scenario. The option has been implemented in this very broad way to show its potential effect and relevance for biodiversity. Analysing more scenarios can shed more light on this subject, but is not feasible within the present study.

Relatively high standing stocks are used in IMAGE for the semi-natural forests. This leads to high yields and corresponding low required areas of semi-natural forest, especially in the baseline. Using lower yields and considerable harvest damage will lead to a larger area under forestry management and a higher biodiversity loss in the baseline. In this case the plantation option will have a larger effect.

The extent to which slash and burn practices take place in conversions processes is unknown and will differ strongly between regions. The assumption in the IMAGE model is that forests are burnt in the conversion process, which indeed occurs frequently in Asia and South America. So no wood is derived from conversion, both in the baseline and option. Taking this possible wood source into account in the forestry option will decrease the area of required production forest and will also reduce the considerable CO₂-emissions from burning, thereby reducing the biodiversity loss.

Each region produces the regionally demanded wood. There are no global trade shifts. This assumption is plausible as production goods (the forest and processing industries) are not easily translocated. But, in practice, shifts will occur where regions border. For instance, harvesting in the Former USSR will take place to supply industries in OECD Europe (transport via Finland) and China. This allows regions as Europe to move away from plantation forestry and promote re-naturalization. Regional demand and biodiversity loss in the Former USSR will therefore be underestimated. Shifts within regions will also take place (Indonesia supplies many countries in Asia). The total effect is additional use of semi-natural forests in exporting countries, and maybe a less efficiency production improvement through slower investment in plantation establishment.

Altogether, we have assumed mostly conservative assumptions in the baseline and on possible plantation effects. Taking the aforementioned factors into account will result in a larger biodiversity loss in the baseline and a larger effect of the biodiversity saving potential for this option.

Protected areas sensitivity

Assumptions for the baseline are that present protected areas will be maintained, including the current land use, while no further conversion takes place. This means that enforcement of the reservation status is assumed to be complete. For the 20% protected areas option, suggested areas for expansion of the network are based on congruity of available existing maps and prioritization schemes, focused on representation of ecosystems,

target species, species richness and endemism. Key uncertainties are effectiveness of management and success of restoration (i.e. rate of species establishment).

A more elaborate analysis would distinguish between different IUCN land-use categories, with more extractive uses being allowed. Further, where protection is weak, unsustainable levels of extraction and land use will undoubtedly take place. Including these factors will lead to biodiversity losses within protected areas.

Newly protected areas are assumed to restore to a more natural state through natural succession whether or not supported by human management. This will increase the biodiversity value of expanded protection areas. In practice, many protected areas will not be effectively managed and degrade. A more detailed solution of the implemented option maps would encompass the world's 867 terrestrial eco-regions.

The used biodiversity indicator MSA is focused on naturalness, and is not sensitive to species richness and uniqueness. Using alternative indicators that are sensitive to these important selection criteria for allocating protected areas will probably show stronger positive effects of the option..

Altogether, this means that implementing protected areas in the baseline and protected areas option is generally less efficient than assumed. Where protected areas encompass former agricultural areas, future biodiversity values are overestimated. Correcting for these influences will probably result in more biodiversity loss.

TABLE 19: Most important assumptions and uncertainties for the different options and qualitative expert judgment of the consequences on biodiversity losses, where consequences are the effects of correcting for the aforementioned uncertain or ignored factors (assumptions); + means less biodiversity loss; - means more biodiversity loss

OPTIONS	ASSUMPTIONS AND UNCERTAINTIES	CONSEQUENCES FOR BASELINE BIODIVERSITY	CONSEQUENCES FOR OPTION BIODIVERSITY
Liberalization of agricultural market	Slower implementation of trade reform, leading to less dramatic shifts in land use	0	Developed - Developing ++
Poverty reduction	Investment targeting on off-farm income	No change	+
	Emphasis on extra infrastructural investment	No change	-
	Reduced population growth through removal of reduction	No change	In the long term +/++
Limiting climate change	Climate sensitivity	+ / --	+ / --
	Costs of alternative measures	+ / -	+ / -
	Biodiversity response to change	??	??
Sustainable meat production	Costs of sustainable production overestimated	No change	-
	Elasticity of meat prices and consumption	No change	-/+
	Environmental impacts of sustainable production	No change	??
Plantation forestry	Yields in baseline too high	--	++
	Conversion wood neglected	+	+
	Shifts in global trade relations to areas with more virgin forests	-- / 0	+
	Plantation establishment on available land	no effect	+ / ++
Protected areas	Land-use classes with more extraction than presumed	-	-
	Less effective protection	-	--
	Less successful restoration	No change	--

ANNEX 1: DESCRIPTION OF BASELINE AND POLICY OPTIONS

1. Liberalization of global agricultural trade

Baseline development

In the baseline, no major shifts in current agricultural protection rules are expected. For Europe, the shifts in the Common Agricultural Policies (CAP) from market price support to income support (like the McSharry and Agenda 2000 reforms) are not followed by further changes. Therefore, agricultural protection remains one of the heavily debated issues in WTO rounds, leading to the agricultural agreement on the Doha Agenda. This agreement aims at establishing a fair and market-oriented trading system in the long term (WTO, 2001).

Description of the policy option

Liberalization of trade will have environmental consequences, which might be positive or negative for a region. The impacts on biodiversity are regionally specific. Shifts in trade regimes will lead to additional arable land in major food exporting regions (and therefore habitat loss), while other regions might see a decline in their agricultural practices, leading to improved options for nature conservation, but a possible decline in agricultural biodiversity. Moreover, trade liberalization will also impact the agricultural practices through intensification of food production, leading to an increased use of fertilizer, impacting quality of nature. The combined effect of trade liberalization on biodiversity will be assessed for the main global regions.

Positive environmental effects of trade liberalization can be removal of market distortions that prevent the spread of environmentally-friendly technologies and involvement of foreign investors who bring with them environmentally-friendly management practices. However, environmental standards can also be pushed lower by allowing competition with firms with less strict production standards. International transport will increase as a result of trade liberalization, but environmental effects (greenhouse gas emissions) are small relative to baseline emissions.

The economic costs and benefits of trade liberalization can be taken from many economic studies (Van Meijl et al., 2005), although these economic consequences cannot be regarded as biodiversity driven policies.

2. Alleviation of extreme poverty and hunger in Sub-Saharan Africa

Baseline development

Sub-Saharan Africa has over 200 million hungry and is the only region of the world where hunger is increasing (Millennium Project, 2004).

Tropical Africa is stuck in a poverty gap. Africa's extreme poverty leads to low saving rates. Low domestic saving is not offset by high inflows of private foreign capital. The combination of low domestic saving rates and high population growth rate has led to stagnation in Africa's pattern of capital accumulation. To a significant extent, Africa is living off its natural capital.

Hungry people suffer severe limitations on their physical, economic social and physiological access to food. The prevalence of hunger is very high among smallholder farmers, herders, fishers and forest dependent people. Regional differences exist and for Sub-Saharan Africa the number of hungry people is projected to increase in most countries. Poor and hungry people are highly dependent for their livelihood on access to and quality of the natural resource base.

Description of the policy option

Trade liberalization is considered one of the most efficient ways to eradicate poverty. However, most of the studies recommending trade liberalization only address the economic benefits (World Bank, 2003; Hertel et al., 1999), which are also debated given the disputed positive assumptions (Francois et al., 2005).

Effects of trade liberalization are calculated at the macro economic, country level of scale. Economic growth at this level cannot directly be translated into improved socio-economic conditions of the (extreme) poor. We assume for this policy option that negative effects of trade liberalization on human wellbeing are eliminated by way of government control in the case of large-scale production investments in rich natural resource base as well as extra measures to avoid isolation from market integration of poor people dependent on a low quality natural resource base.

An increase in GDP does not automatically lead to a reduction in poverty, and it might even lead to increased disparity between the rich and poor. Ending the poverty trap in Africa and meeting the Millennium Development Goals will require a comprehensive strategy for public investment in conjunction with improved governance. In the implementation of the option we assumed economic growth as a condition for poverty alleviation, and the poverty reduction case made specific assumptions in this respect. We followed the concrete recommendations from the Millennium Project (UN Millennium Project 2005a, b) in which additional financial support is focussed on the most deprived regions (in this study represented by Sub-Saharan Africa). An intensive investment program should directly confront high transportation costs, low agricultural productivity, high disease burden, the weak infrastructure and poor educational attainment. Therefore, the assumed financial boost is not a lump-sum increase in income, but is dedicated to improve those sectors deemed crucial to break the poverty trap: infrastructure, agriculture education and health services.

Meeting the Millennium Development Goals for Sub-Saharan Africa is modeled in a stylized way in line with the recommendations of the Millennium Project.

- Liberalization agricultural trade (option 1)
- Increase in investments through domestic resource mobilization and more official development assistance. Leading to a growth in GDP per capita of 25 percent above baseline in 2030. Effect on GDP per capita of implementing MDGs in Sub-Saharan Africa is based on projections in Millennium Project (Millennium Project, 2004).
- Gradual increase in labour productivity of 3 percentage points, due to reduction of malnutrition
- Increase in agricultural productivity of 10 percent points in 2015.

The elements of this poverty option are on MDG needs assessments that the UN Millennium Project has carried out in a number of African countries. Estimates of GDP-effects and productivity changes have a provisional nature, but are believed to have the right order of magnitude.

No adjustments are made for specific MDG-investments that may disproportional influence biodiversity losses, e.g. specific investments in infrastructure. Not captured is the environmental degradation reversed, because of poor people putting a relative high pressure on ecosystems. A more developed, better educated and healthier population will have lower fertility rates, leading to lower population growth, one of the driving forces behind biodiversity losses. This demographic transition is assumed not to take place within the scenario period.

3. Limiting climate change

Baseline development

In the baseline, future emissions of greenhouse gases and other drivers of climatic change will develop in the absence of any intervention policies beyond what is firmly decided and/or implemented today. This will lead to an ongoing build-up of greenhouse gas concentrations in the atmosphere, induced climatic change and associated direct and indirect impacts on human and natural ecosystems.

Description of the policy option

As confirmed by a multitude of publications, assessed by the IPCC (EEA, 2004; IPCC, 2001d) on already observed impacts of climate change to date, projected further climate change is bound to have an increasing

effect on biodiversity. Recently, the Millennium Ecosystem Assessment (MEA, 2005; Leemans and Eickhout, 2004) assessed the impacts on ecosystems, broken down into the main constituents.

The recognized risks associated with climate change have resulted in the UN Framework Convention on Climate Change (UNFCCC), which calls for stabilization of greenhouse gas (GHG) concentrations in the atmosphere at levels that will avoid dangerous interference with the climate system. As a first step towards meeting this global goal, the Kyoto Protocol was agreed and recently entered into force and is therefore included in the baseline. Agreement on what level to pursue to meet the ultimate UNFCCC goal is hampered by uncertainties in the climate system itself, but also in the political valuation of impacts, adaptation and mitigation strategies. Here we assume the EU target to limit global warming to maximum 2 degrees from the pre-industrial level. Based on studies on the uncertainty between the greenhouse gas concentration and global mean temperature increase, achieving such a target with a certainty of (on average) 50% requires stabilization of the greenhouse gas concentration at 450 CO₂-equivalent. This requires a very substantial reduction of greenhouse gas emissions, in the order of 90% compared to a situation without climate policy. For achieving such ambitious reductions, various options exist including energy efficiency improvement, carbon capture and storage, nuclear power, renewable power, reduction of non-CO₂ emissions, carbon plantations and bioenergy (see Metz and Van Vuuren, 2006; Figure 19 and 20). The last two options require –next to other sources such as waste– the use of substantial amounts of land for biofuel crops. Nevertheless, the use of bioenergy is among the most promising options to reduce emissions. Here, we explore a scenario that uses a very substantial amount of bioenergy as part of its total portfolio of measures that has been recently developed using the IMAGE/TIMER/FAIR models. The portfolio of measures in this scenario is chosen on the basis of costs-criteria (van Vuuren *et al.*, 2006). In 2050, the total amount of modern bioenergy used is about 150 EJ—while total energy amounts to about 650 EJ. Compared to other studies, this scenario can be characterized as bioenergy intensive (see e.g. Berndes *et al.*, 2004).

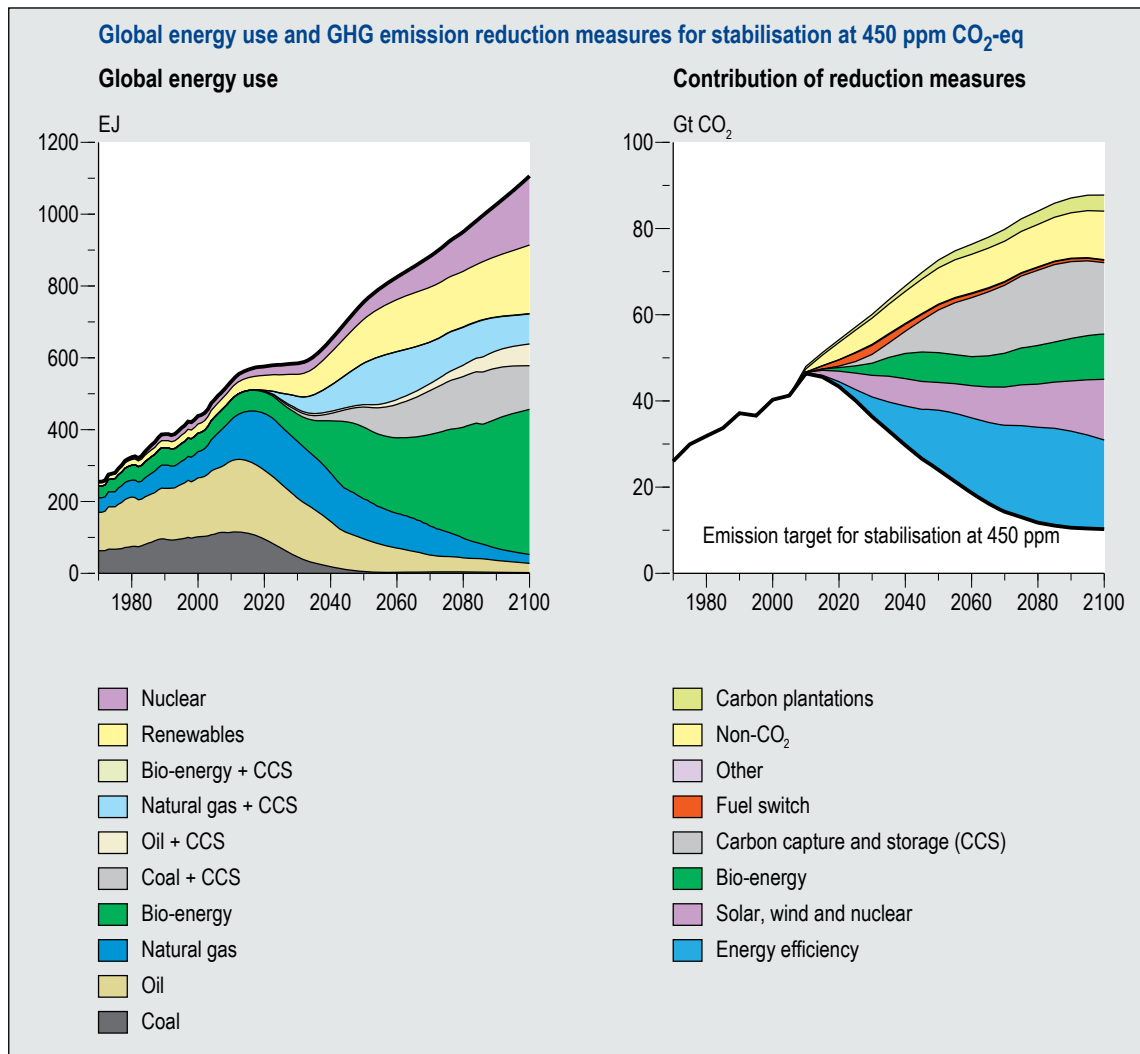


FIGURE 19: Energy sources in the baseline scenario and reduction measures in the climate change mitigation option, necessary to reach 450 ppm CO₂-eq (Metz and Van Vuuren, 2006).

The bioenergy intensive climate policy will change the future biodiversity directly and indirectly in various ways:

- The magnitude of changes in relevant climate parameters (temperature, precipitation, CO₂ concentration) and thus of associated ecosystem effects will be smaller than in the baseline. However, the rate of temperature change, an important factor for the possibilities to adapt to climate change, may initially go up as a result of less sulphur emissions as fossil fuel burning is decreased.
- Habitat loss, the most important pressure on natural ecosystems, will be changed.
 - Firstly, because the substantial use of bioenergy and carbon plantation in this scenario leads to additional claims on land for growing biomass resources or growing trees. Energy crops are allocated to abandoned agricultural areas, and the remaining part in natural low-productive non-forested areas. The assumption is made that abandoned areas would otherwise restore to natural systems.
 - Secondly, climate effects on agricultural productivity and other determinants of land-cover will change, i.e. water erosion will be smaller (positive or negative for biodiversity). The impact on agricultural yields directly leads to somewhat lower yields on average globally.

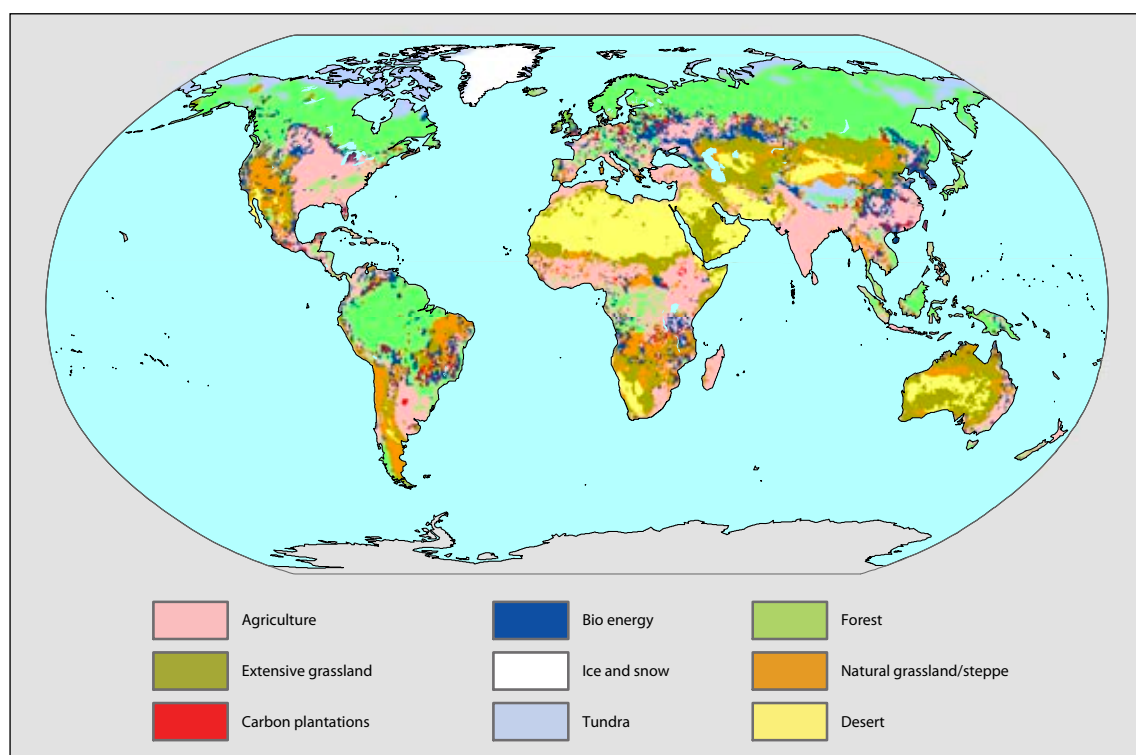


FIGURE 20: Land-cover map including bioenergy production and carbon-plantations in the 450 ppm CO₂-eq. climate change mitigation option (Metz and Van Vuuren, 2006).

The extra costs of the climate policy are estimated by van Vuuren *et al.* (2006) to amount to slightly more than 2% of world GDP. Uncertainties on costs, however, were estimated to be large. Earlier studies on the costs of climate policies typically find costs in the order of 1 to 4% of world GDP for stabilizing greenhouse gas concentrations in the order of 450-550 ppm CO₂-equivalent (IPCC, 2001c, Azar *et al.*, in press; Nakicenovic and Riahi, 2003).

4. Sustainable meat production

Baseline development

In the baseline, a significant increase in demand for animal products is expected in the coming decades (due to the combined effect of population growth and welfare gain). More production will take place in large-scale operations, often in warm, humid and more disease-prone environments (FAO, 2003b). The animal production sector is not only a sector which produces meat, milk and eggs, but also leads to various risks, emissions and impacts. Moreover, because of advantages of scale and vertical integration, intensive dairy farms tend to be concentrated in certain regions (e.g. OECD, 2003), and therefore worsening the problems. In the baseline no policy to address above mentioned problems is assumed.

Description of the policy option

Because of growing population and increased welfare the global consumption of animal products (meat, eggs, dairy) will increase significantly over the coming decades. In the baseline of this study meat consumption will increase with 60% over the period 2000-2030. For the production of this extra meat extra feed is needed, either produced on arable land or on pastures (for ruminants).

Most likely the extension of pig and poultry will take place in large-scale operations (FAO, 2003). The expansion of large-scale operations may in turn lead to more problems in the fields of animal and human health, animal welfare and environment (emissions of nutrients). In turn, this might lead to stricter regulation, which will reduce risks and emissions, but which will also lead to higher production cost better reflecting the external cost. These higher production costs will probably lead to a certain decrease in meat consumption.

The extra costs can be roughly divided into four groups, being the reduction of risk concerning human and animal health; the increase of animal welfare (no cage systems); the reduction of ammonia emissions and manure storage, manure removal and better spreading techniques.

Estimates of costs are not available for different production systems and all groups. As a general approximation, it is assumed that the combined extra cost of all policies is 20%. The measures taken will lead to a 50% decrease of nutrients losses from intensive livestock production.

5. Plantation forestry

Baseline development

In the baseline, no incentives are present to create plantation forestry. Demand for industrial round wood and traditional wood fuel will be supplied by exploitation of semi-natural forests. This means an ongoing pressure on the existing natural forest resource, which will result in a decreasing area of natural forests through logging and regrowth. Due to this type of exploitation, both the forest area and quality are reduced. The baseline is an implementation of the OECD scenario in the IMAGE model.

Policies on Sustainable Forestry

The sustainable use of components of biological diversity is one of the three objective of the Convention. This encompasses sustainable forest management. International coordinated policy processes that directly influence trade and production of sustainable produced wood are not strong, as they are claimed to interfere with WTO trade regulations (although exceptions are allowed when other international agreements come into play, such as CITES on endangered species; see the turtle and shrimp case, WTO case Nos. 58 and 61). Therefore, actions to promote sustainable forest management, such as the promotion of sustainability trademarks, are voluntary and consumer driven.

Implementation of the CBD expanded programme of work on forest biological diversity (decision VI/22) and efforts to promote sustainable forestry are carried out in conjunction with efforts to implement provisions under the UN Forum on Forests (UNFF) and its Non-legally Binding Instrument on All Types of Forests. The UNFF-2005 meeting addressed sustainability issues, and urged partners to take action, without specifying binding regulations or targets. National and regional forestry policies to promote sustainable forest use do exist in many countries. These policies combine combating illegally harvested and traded wood (FLEGT process in the EU and other regions), with promoting the use of sustainability labels (such as FSC; <http://www.fsc.org/en/>). Wood produced under the FSC-logo has to meet ecological and socio-economic criteria. The FSC-trademark allows the use of plantation forestry. Most certified areas lie in temperate and boreal regions. Plantation criteria are under discussion (<http://www.fsc.org/plantations/>), but plantations may never replace natural forests under the logo. This type of labelling is voluntary, as more strict application of labels by importing countries are said to interfere with WTO trade liberalization rules.

Plantation Forestry option

The forestry option is directed at supplying wood from plantation forestry, thereby releasing the pressure on the remaining natural and semi-natural forests. This option is taken, as intensively managed plantations have a much higher production potential (10-25 times) than (semi-)natural forests, especially in the tropics. From the viewpoint of minimizing biodiversity loss, production from sustainable managed forests (selective and reduced impact logging) is an option that needs further research and model development.

Therefore, in the present analysis a high plantation establishment scenario is implemented (adapted from Brown, 2000). For the GBO-2 study, the plantation establishment is maximized to illustrate the biodiversity saving potential of implementing large-scale plantations. Until 2050, wood supply from the high plantation growth scenario is supplemented by wood from managed natural and semi-natural forests, when plantations supply the major part of the global demand. This extreme implementation is not easy to attain in every region when plantations can only be established on abandoned and degraded soils. This and the fact that sustain-

ability criteria for plantations are still under discussion lead to the formulation of this scenario as a “plantation forestry option” instead of “sustainable forestry”.

The most significant plantation costs are likely to be land, labour and harvesting costs, as well as finance costs (e.g. interest paid on project loans). In certain instances, other costs may be important, for example water charges. A robust analysis of alternative plantation investment projects requires an in-depth assessment of the costs and revenues associated with each alternative. Information available in the public domain about comparative plantation costs in different countries is scattered and very difficult to compile. On a macroeconomic scale the costs of increasing the area of plantations will not show. Even in countries with a relatively strong forestry sector, the added value of forestry is below 2 percent of GDP (FAO, 2004). Still, sectoral effects may be considerable. Maturana (2005) examines the total economic costs and benefits of five large pulp plantation projects in Sumatra, Indonesia. The estimated economic costs represent over 30 times the actual financial payments the Government receives from each company. The allocation of over 1.4 million hectares of forestland to conversion for tree plantations generates net losses of over US\$3 billion for the country. Government subsidies and tax exemptions are important incentives for sustainable forest management. An average of about 2000 \$ per km² could be used as a ballpark figure for subsidizing funding and tree planting in the USA (Enter and Durst, 2004).

6. Protected areas

Baseline development

The baseline assumption for this policy measure is that current system of protected areas is maintained during the coming decades, including their management regimes. The assumption is made that the protected areas will effectively be excluded from land conversion while allowing for current extensive use such as selective logging, small-scale hunting and gathering and tourism to continue where this is appropriate to each site's management objectives. The full set of protected areas from the October 2005 version of the World Database of Protected Areas (UNEP-WCMC, 2005) will be included.

Description of the policy option

The Durban Action Plan (IUCN, 2004) emerged from the Vth IUCN World Parks Congress in 2003, a meeting of protected area professionals. Main target 4 of this plan is ‘A system of protected areas representing all the world's ecosystems is in place by the time of the next World Parks Congress.’ Amongst other points, the plan proposes that quantitative targets are set for each ecosystem by 2008, and that all Red List species are protected *in situ*, with priority given to Critically Endangered Species confined to single sites.

In February 2004, the Seventh Conference of the Parties to the CBD adopted decision VII/28 on Protected Areas (CBD 2004a), which includes an annexed Programme of Work (PoW). The PoW's overall objective is ‘the establishment and maintenance by 2010 for terrestrial and by 2012 for marine areas, (not dealt with here), ‘of comprehensive, effectively managed, and ecologically representative national and regional systems of protected areas that collectively, *inter alia* through a global network contribute to achieving the three objectives of the Convention and the 2010 target to significantly reduce the current rate of biodiversity loss.’

Decision VII/28 requests individual countries to ‘elaborate outcome-oriented targets for the extent, representativeness and effectiveness of their national systems of protected areas...’ The PoW suggests that Parties complete gap analyses and establish protected area targets by 2006. Decision VII/30 gives a global context, specifying a provisional target of effective conservation of at least 10% of each of the world's ecological regions (UNEP, 2004a).

For protected areas an optimistic option has been implemented: extension of the PA network to a cover at least 20% of each ecological region. As the IMAGE-GLOBIO models compute effects on concrete areas, the new protected areas have been indicatively located to cover a representative selection of the earth's ecosystems

(e.g. Olson *et al.* 2002), and in areas with concentrations of threatened and endemic species (e.g. Orme *et al.* 2005; Rodrigues *et al.* 2004; Birdlife International 2005; Stattersfield *et al.* 1998).

Present human land-use is removed from the allocated protected areas, and is allocated elsewhere in the same region (mainly by a shift of agriculture). Formerly affected areas that are now protected are assumed to restore to 90% of original MSA within the projection period up to 2050. Human pressures related to infrastructure (settlement and encroaching) are not taking place within protected areas, but pressures as N-deposition, fragmentation and climate change can continue to exert their effects.

The overall cost of a protected area network includes establishment, management and systemwide costs (Bruner *et al.* 2004). Opportunity costs and tangible / intangible benefits may also be included in the calculation. There may also be revenues (e.g. from tourism). Costs vary with protected area size, accessibility, national GDP / purchasing power parity and population (James *et al.* 1999b; Balmford *et al.* 2003; Blom, 2004; Bruner *et al.* 2004). There is a huge need for better methods to demonstrate the value of biodiversity conservation and to investigate the distribution incidence of costs and benefits (Pearce, 2005).

ANNEX 2: GLOSSARY

Assessment frameworks provide a systematic structure for organizing indicators so that, collectively, they paint a broad picture of the status of biodiversity. These consist of assessment principles (baselines), indicators (and underlying variables), and methods of aggregation.

Baselines are references or 'starting points' and can be used, for example, to measure change from a certain date, state or trend. For instance, the extent to which an ecosystem deviates from the natural state or certain year. The used baseline strongly determines the meaning of the indicator value results. Another example is the use of a baseline scenario, that serves as a contrast to show the effects of alternative scenarios that result from different assumptions on developments or from different policy interventions.

Biodiversity (or biological diversity) is the variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, 1993).

Bioenergy: In this report, the term bioenergy is used to encompass all forms of modern energy from crops. This includes the use of specific crops (also wood) grown to produce energy but also the use of agricultural residues for commercial energy purposes, such as use in electric power plants or conversion to liquid biofuels. In this report the effects of bioenergy only concerns crops grown to produce energy (bioenergy crops).

Bioenergy crops/biofuel crops: Crops specifically grown to produce energy.

Biome a generalized natural ecosystem type. Biomes are defined by soil types and climatic conditions. In the IMAGE model, 14 biomes are distinguished, based on a static natural vegetation model (Prentice *et al.*, 1992) that predicts the potential occurrence of natural biomes.

Driving Force- Pressure-State-Impact-Response assessment framework is an analytical framework which considers various different stages in the causal chain:

Driving force or indirect drivers: socio-economic factors which cause pressures

Pressures or direct drivers: changes in the environment caused by humans which affect biodiversity

State/Impact: current and future status of biological diversity and the abiotic environment

Responses or policy options: measures taken in order to change the state.

Eco-region An ecoregion is "a relatively large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions" (WWF, 1999). Bailey's (1998) classification is one of the most widely adopted. It is a hierarchical system with four levels: domains, divisions, provinces and sections. Olson and Dinerstein (2002) identified 238 terrestrial or aquatic ecoregions called the "Global 200" that they considered to be priorities for global conservation. These ecoregions were selected because they harbor exceptional biodiversity and are representative of the variety of the earth's ecosystems.

Ecosystem quality is an ecosystem assessment expressed as the distance to a well-defined baseline state. Ecosystem quality is calculated as a function (for example the average) of the quality of many underlying quality variables.

Ecosystem quantity is the size of biome or an ecosystem type in ha or as percentage of the area of a country, a well-defined region or global.

Habitat type is a specific type of vegetation. Major habitat types are forest, tundra, grassland, (semi) desert, inland waters, marine and agriculture.

Homogenization is a process of biodiversity loss, which is characterized by the decrease in abundance of many species and the increase in abundance of a few other –human favoured– species, due to human interventions. As a result, different habitats are becoming more and more alike. Extinction is one step in this long degradation process.

Land cover is the way the terrestrial surface is covered by either natural ecosystems or by human land-use types. In spatial explicit models such as IMAGE and GLOBIO, each cell that represents an area of the global terrestrial surface, gets a land-cover assigned based on monitoring or on allocation rules.

In GLOBIO, a system of 22 land-cover types is used taken from the GLC2000 database that contains data on the present land cover for the whole world (Bartholomé *et al.*, 2005). In IMAGE, a system of 21 land-cover types is used, with 6 human dominated land-cover types, and 15 natural occurring land-cover types that are similar to biomes (and including ice). IMAGE land-cover data comes from different sources, and is compiled in the HYDE database (MNP, 2006).

Land use is the way in which land is used for human needs. The purpose of human land-use is extraction of natural resources (i.e. wood harvest from forests) or the conversion of natural ecosystems to fully human dominated forms of land use (such as intensive and irrigated agriculture). Land-use types are a way of expressing the human impact on biodiversity. In GLOBIO, the different land-use types have been related to the abundance of original occurring species (based on literature research).

Plantation forestry is a forestry management system using planted endemic or exotic tree species and including activities that improve productivity.

Policy options: see driving forces

Pressure: see driving force

Region a geographical area, used to divide the world into more or less homogeneous socio-political units. In IMAGE 2.4, a total of 26 regions are used to cover the whole terrestrial world (including Greenland and Antarctica). Greenland and Antarctica are excluded from the regional and global calculations in this report.

Scenarios are applied to explore possible futures in which particular factors and developments are considered as autonomous, and not to be influenced by the policy makers. Developments which can be influenced by policy measures are considered as policy options. Policy options can be combined with a scenario. See also driving forces.

Species abundance is the total number of individuals of one-single species in a particular area or per spatial unit. It can be measured in various ways such as numbers of individuals, total biomass, distribution area, density, etc.

Species richness is the number of the various species present in a particular area or per spatial unit. For it is practically impossible to count all species, species richness is generally determined for some selected taxonomic groups such as birds, mammals and vascular plants.

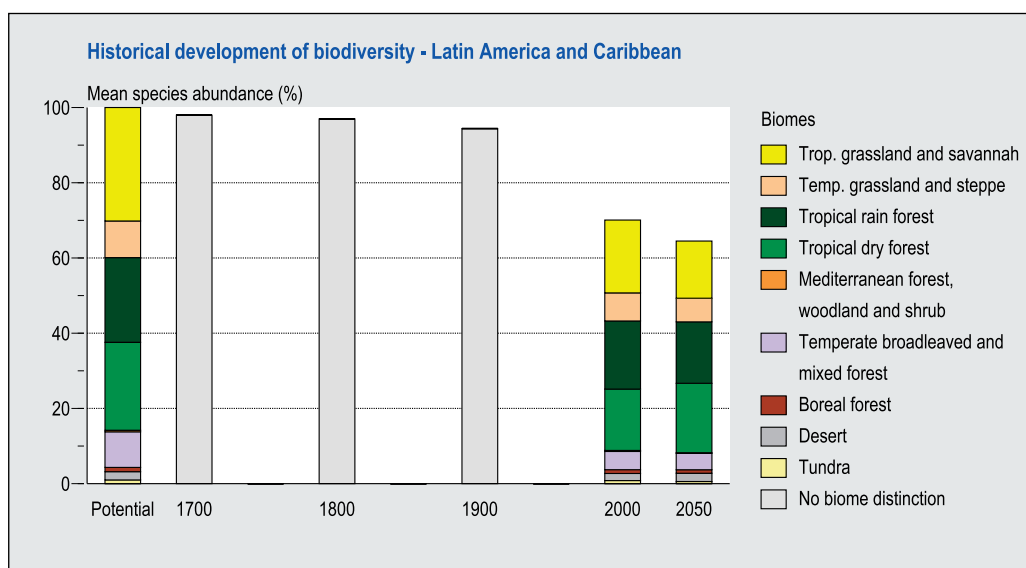
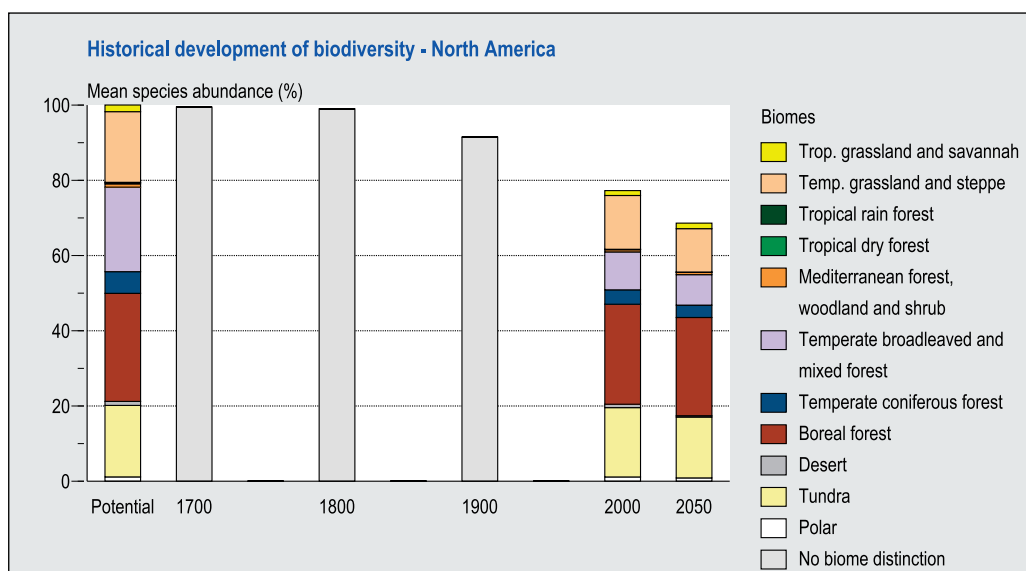
Targets often reflect tangible performance objectives, developed through policy-planning processes. For example, a country has established a target of protecting at least 10% of each habitat type.

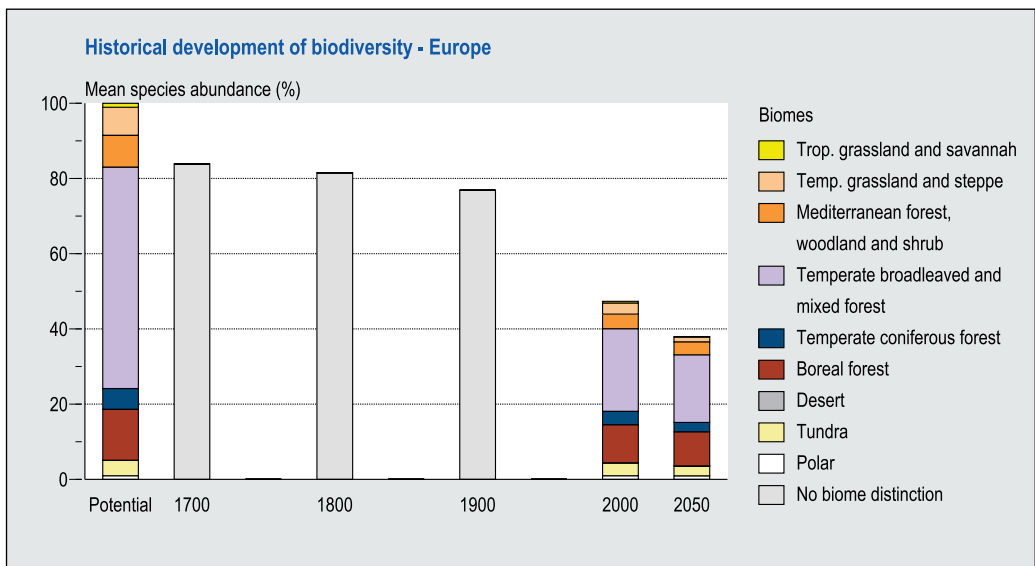
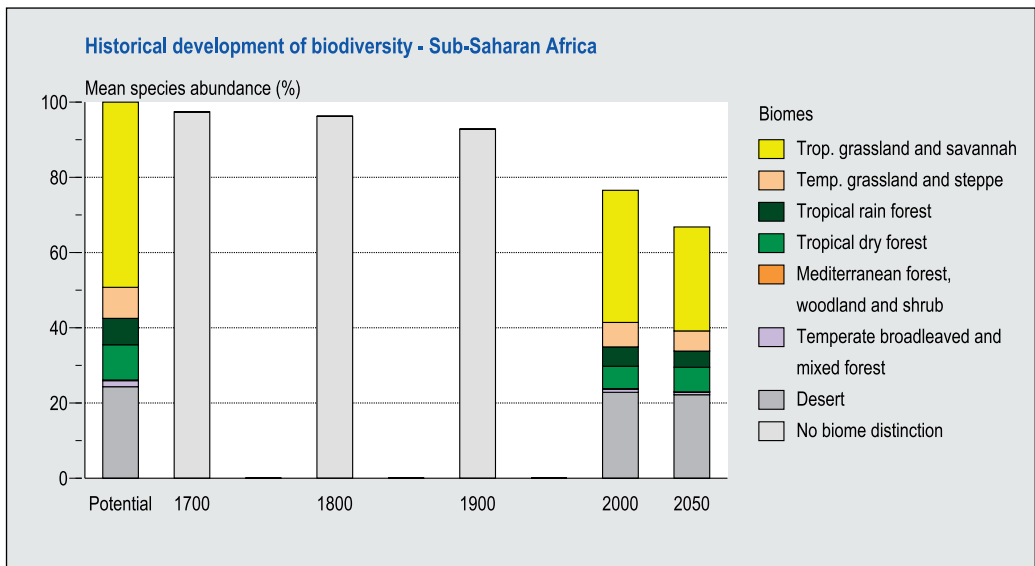
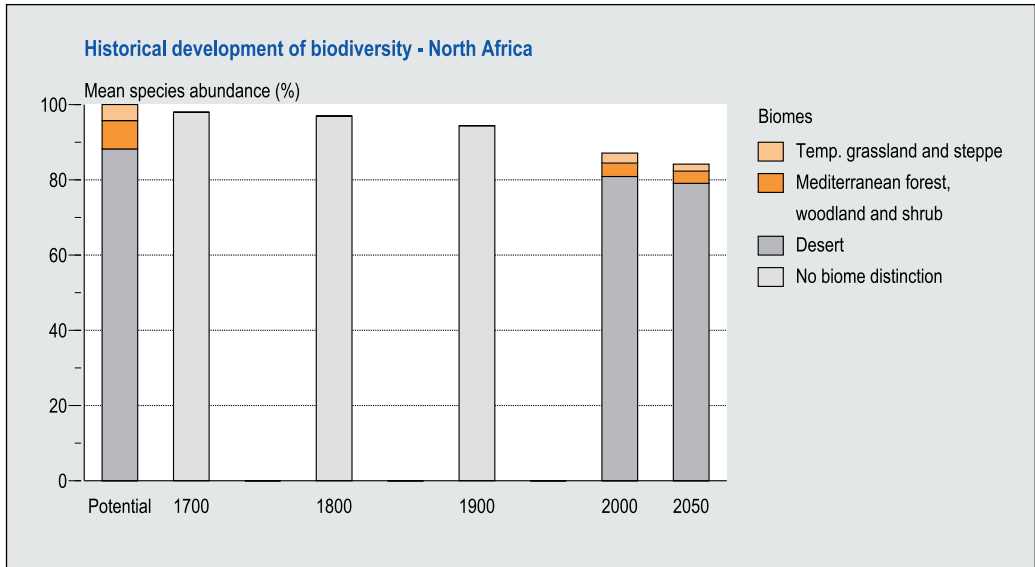
ANNEX 3: REGIONAL DEVELOPMENT OF BIODIVERSITY

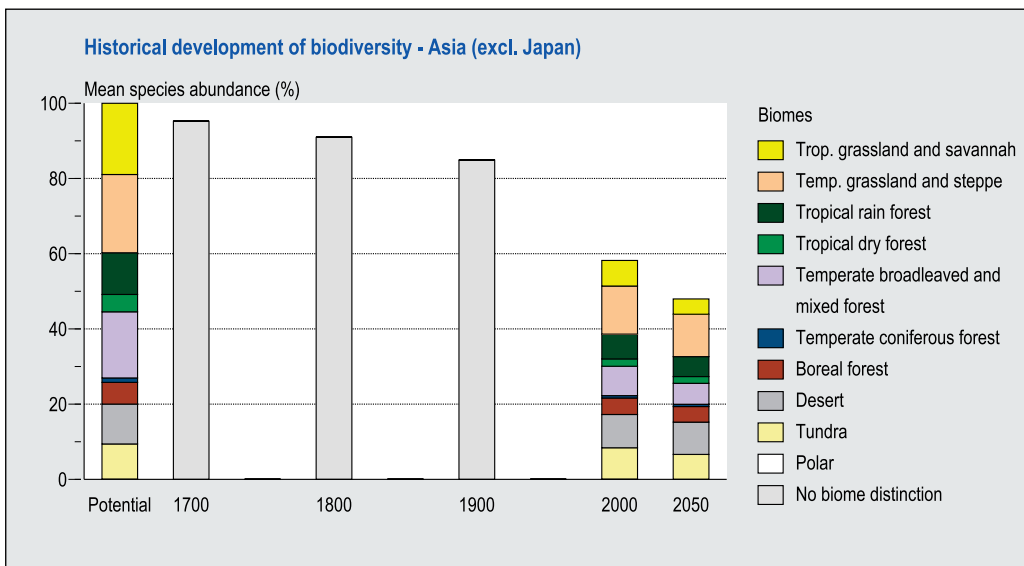
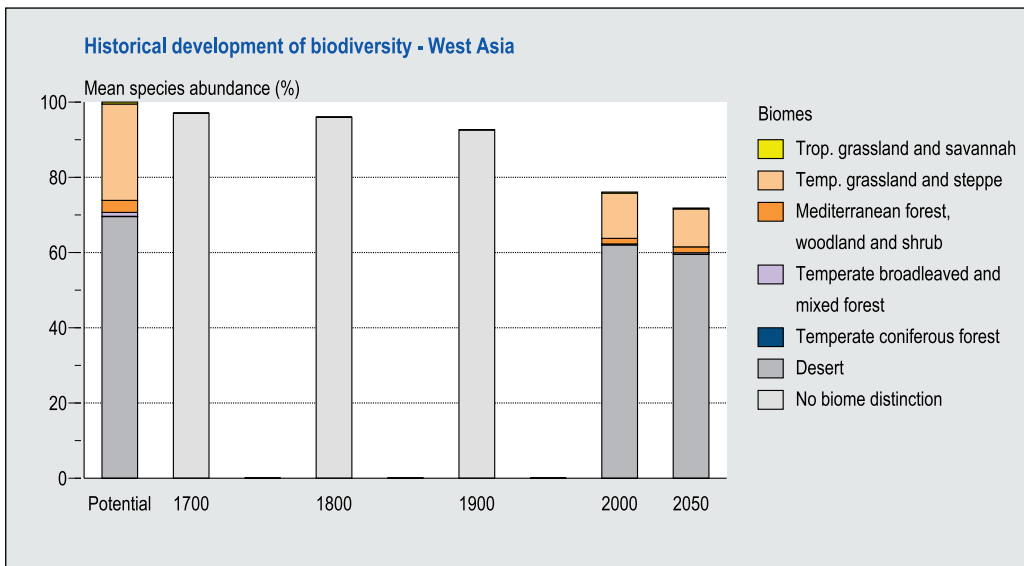
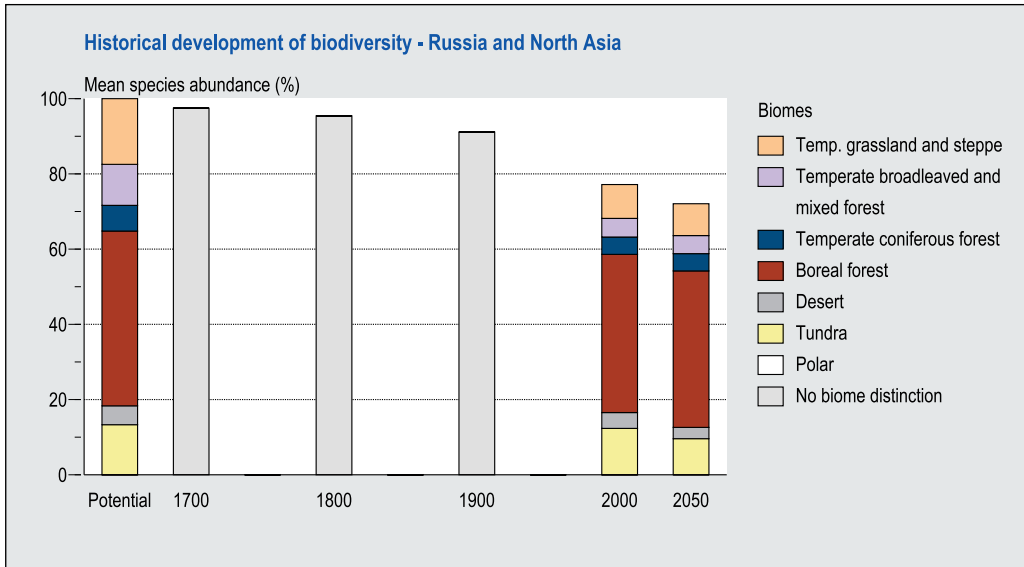
The figures below show regional trends in biodiversity within each biome (in terms of mean abundance of the original species—MSA) from 1700–2050, according to historical land-use changes (HYDE database; Klein Goldewijk 2001) and the baseline scenario.

Historical changes in biodiversity are based on land-use changes only, as there are no historical data on all the other different pressures (N-deposition, infrastructure etc).

For the future development (baseline scenario), the remaining biodiversity in human-dominated land-use types (i.e. arable land and extensively used grassland) in a specific area is added to the biodiversity value in the naturally occurring biome for that area.







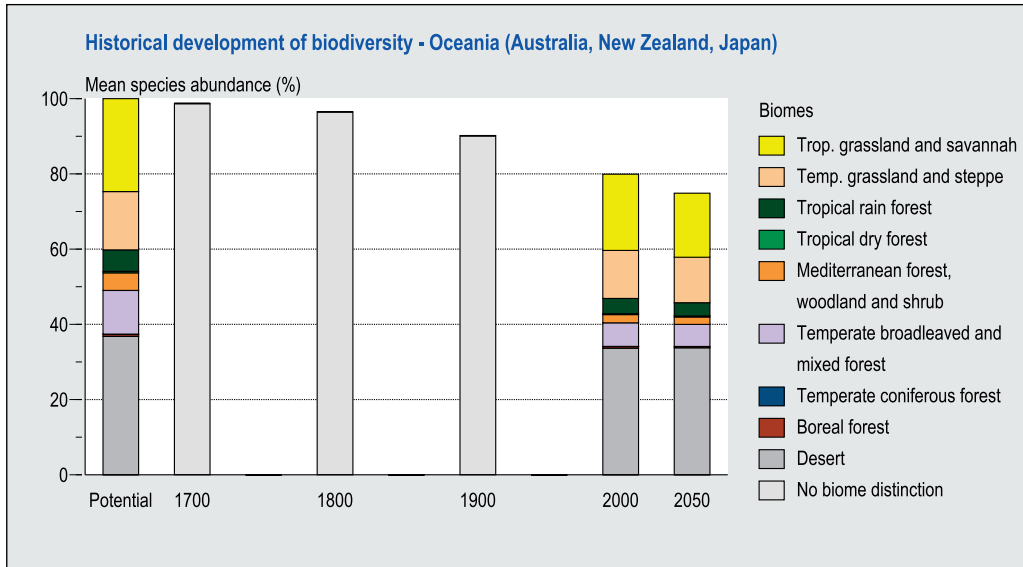


FIGURE 21: Regional trends in biodiversity from 1700–2050. Biodiversity is given in terms of mean abundance of the original species (MSA) per natural biome. Remaining biodiversity in human-dominated land-use types is added to the biodiversity value of the natural biomes.

ANNEX 4: REGIONAL BIODIVERSITY MAPS

This annex shows the spatial distribution of biodiversity per region in 2000 and 2050 according to the baseline scenario, and facultative, according to one marked policy option.

See Boxes 1 and 2 and figure 6 for further explanation of methodology and indicators scales.

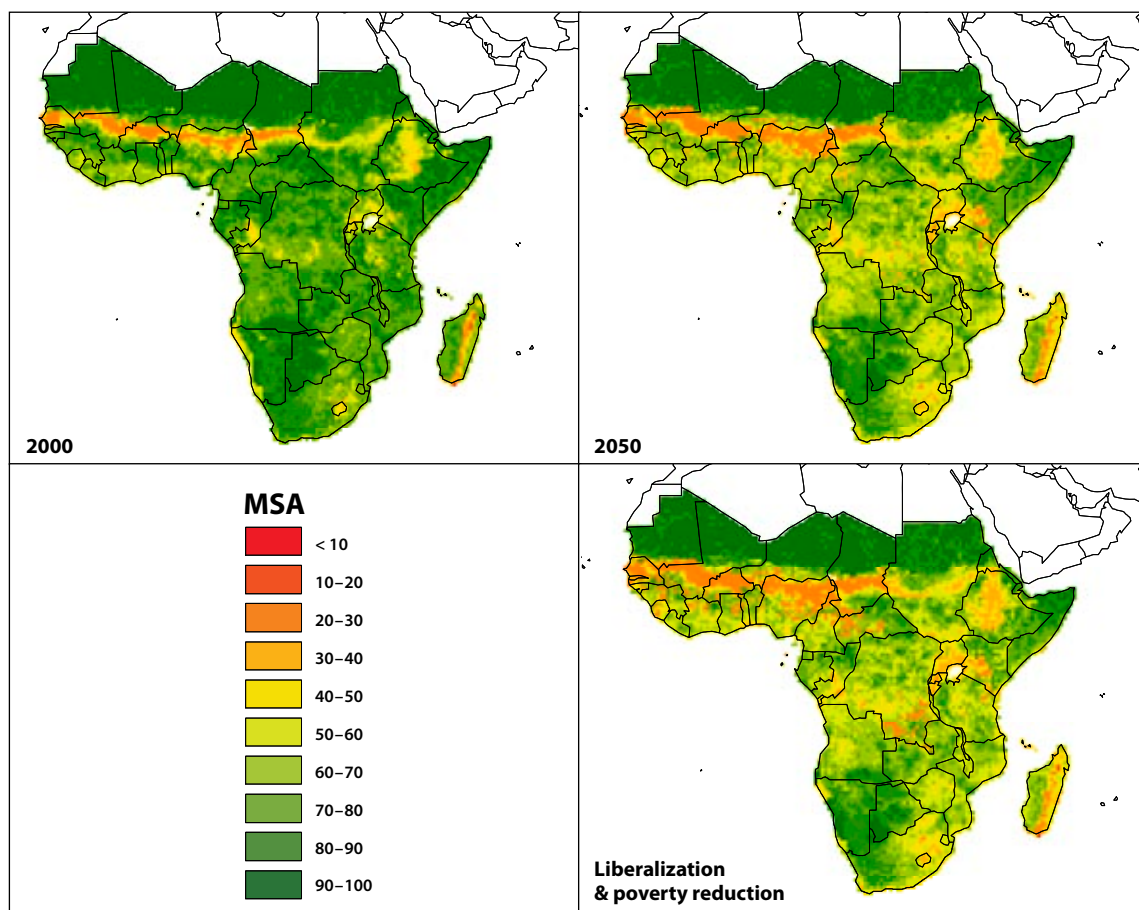


FIGURE 22: Spatial distribution of biodiversity (MSA) for Sub-Saharan Africa, in the baseline development (2000-2050), and change in biodiversity due to liberalization in combination with poverty reduction.

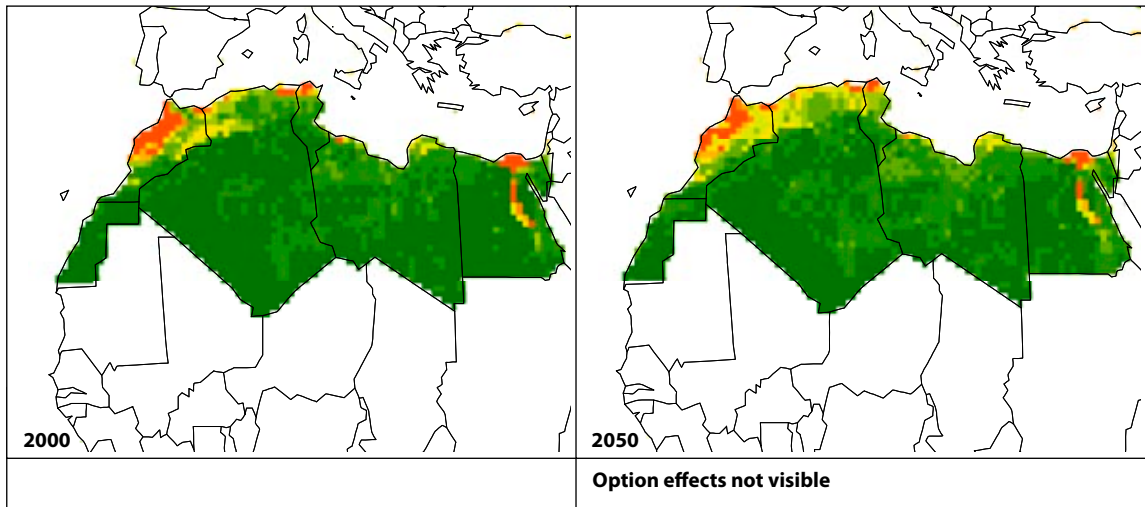


FIGURE 23: Spatial distribution of biodiversity(MSA) for North Africa, in the baseline development (2000-2050).

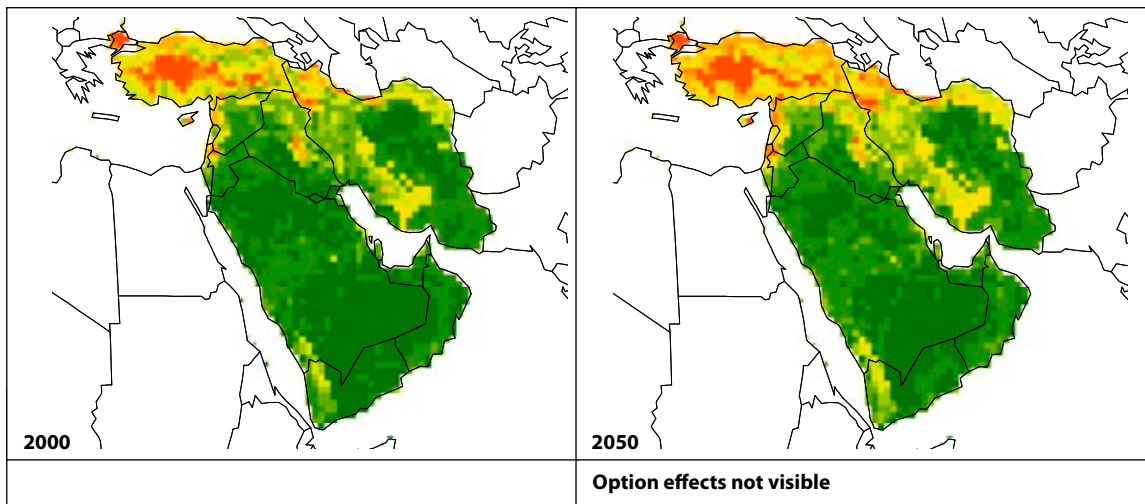


FIGURE 24: Spatial distribution of biodiversity (MSA) for South and East Asia, in the baseline development (2000-2050).

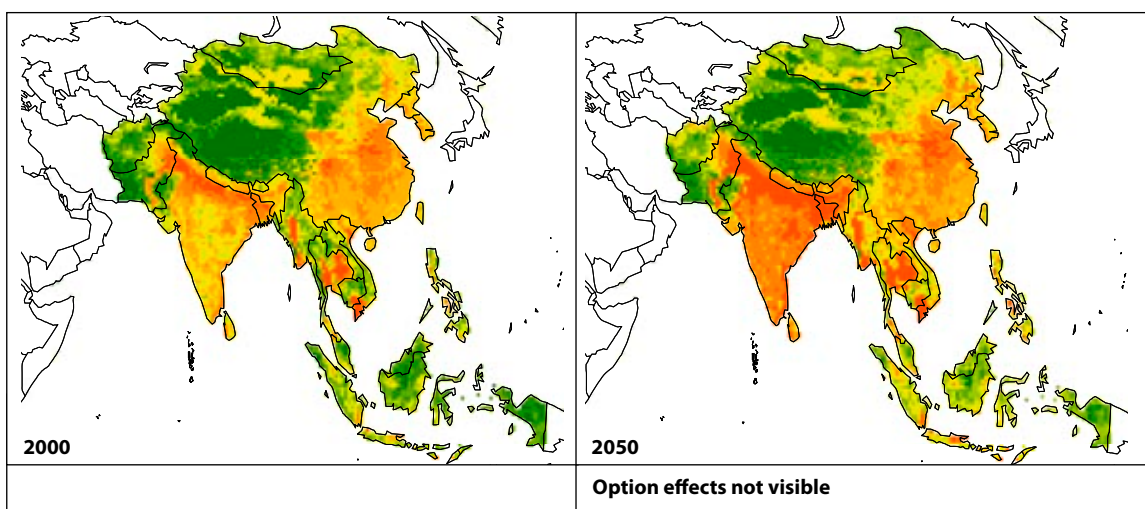


FIGURE 25: Spatial distribution of biodiversity (MSA) for South and East Asia, in the baseline development (2000-2050).

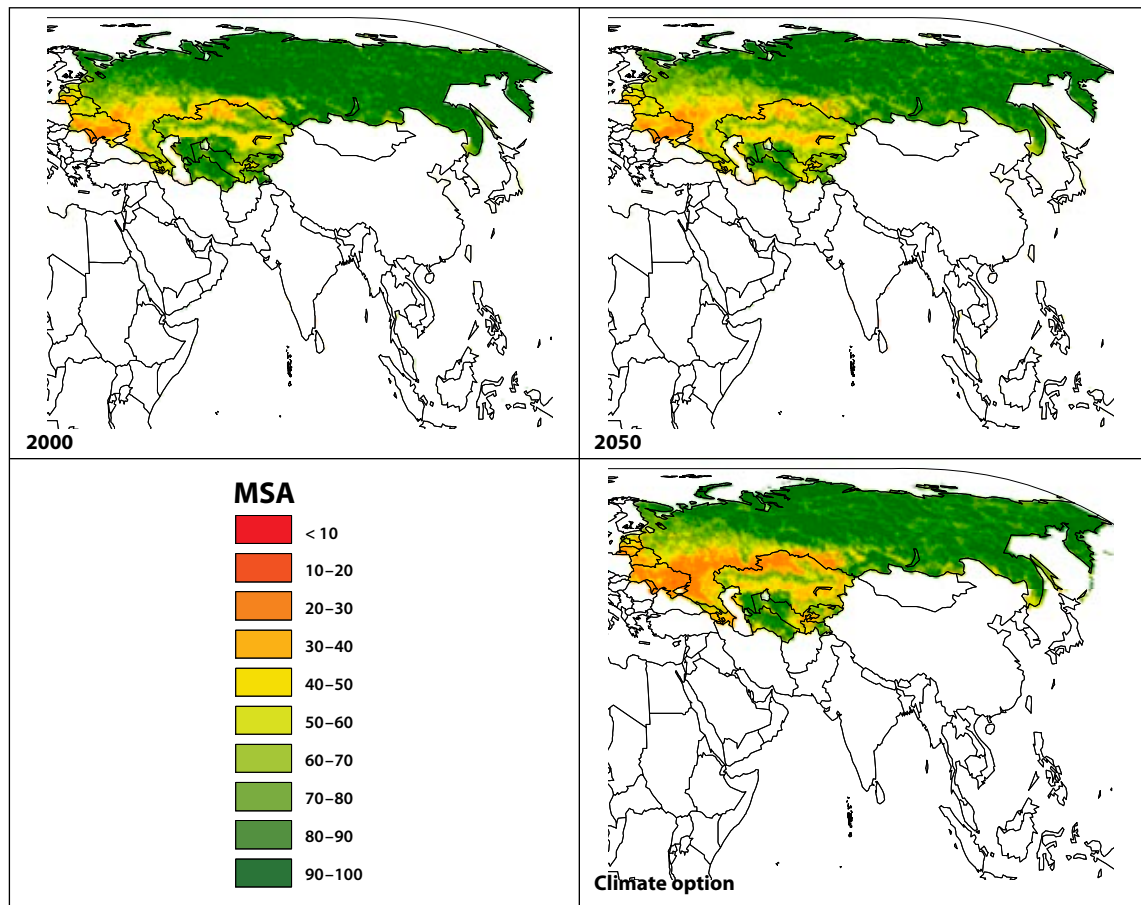


FIGURE 26: Spatial distribution of biodiversity (MSA) for Russia and North Asia, in the baseline development (2000-2050), and change in biodiversity due to the climate change mitigation option.

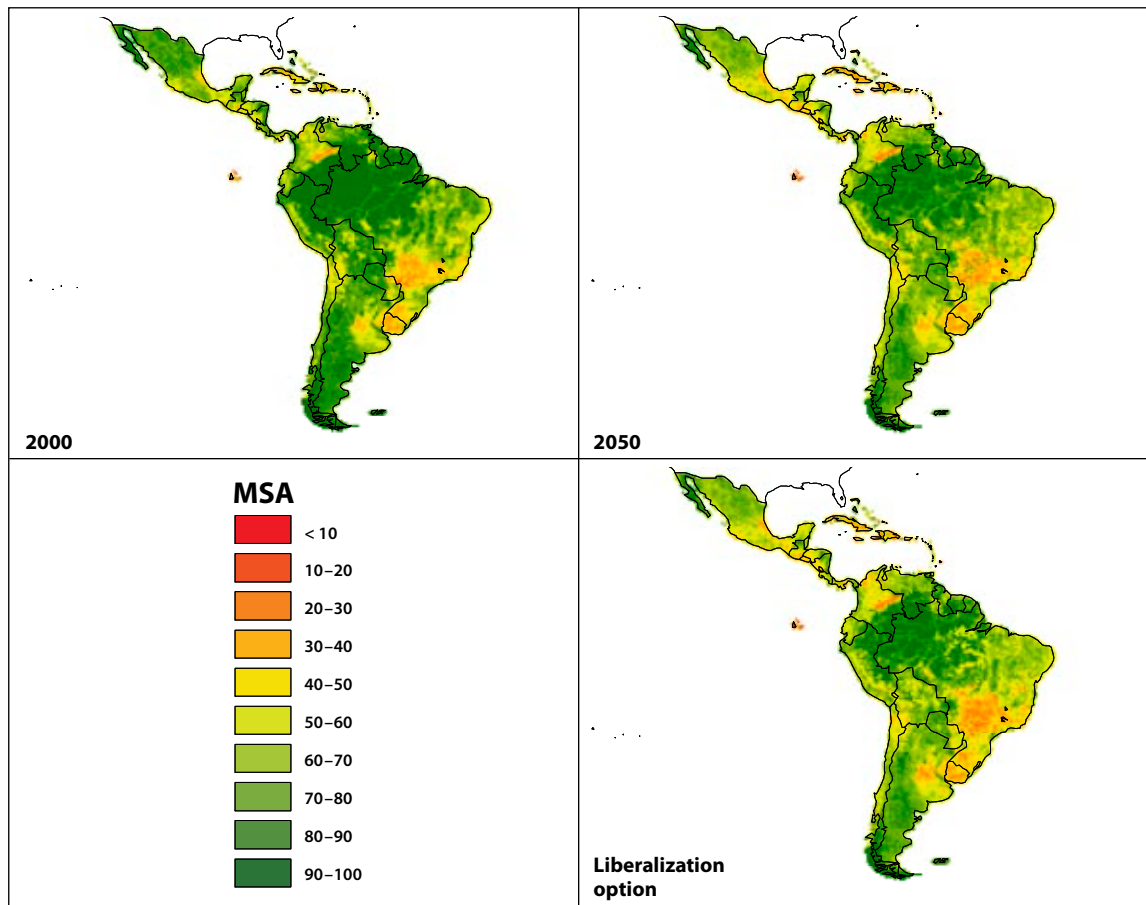


FIGURE 27: Spatial distribution of biodiversity (MSA) for Latin America and the Caribbean, in the baseline development (2000-2050), and change in biodiversity due to liberalization.

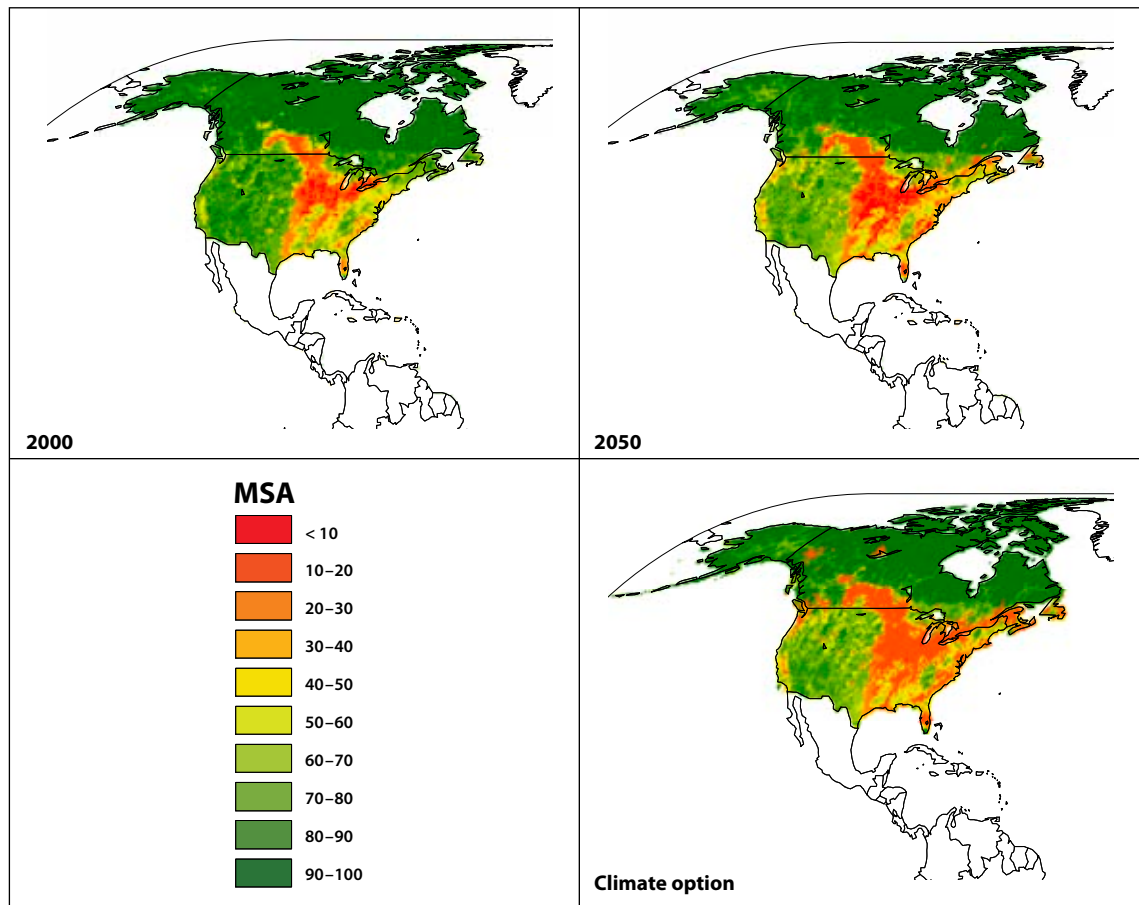


FIGURE 28: Spatial distribution of biodiversity (MSA) for North America, in the baseline development (2000-2050), and change in biodiversity due to climate change mitigation.

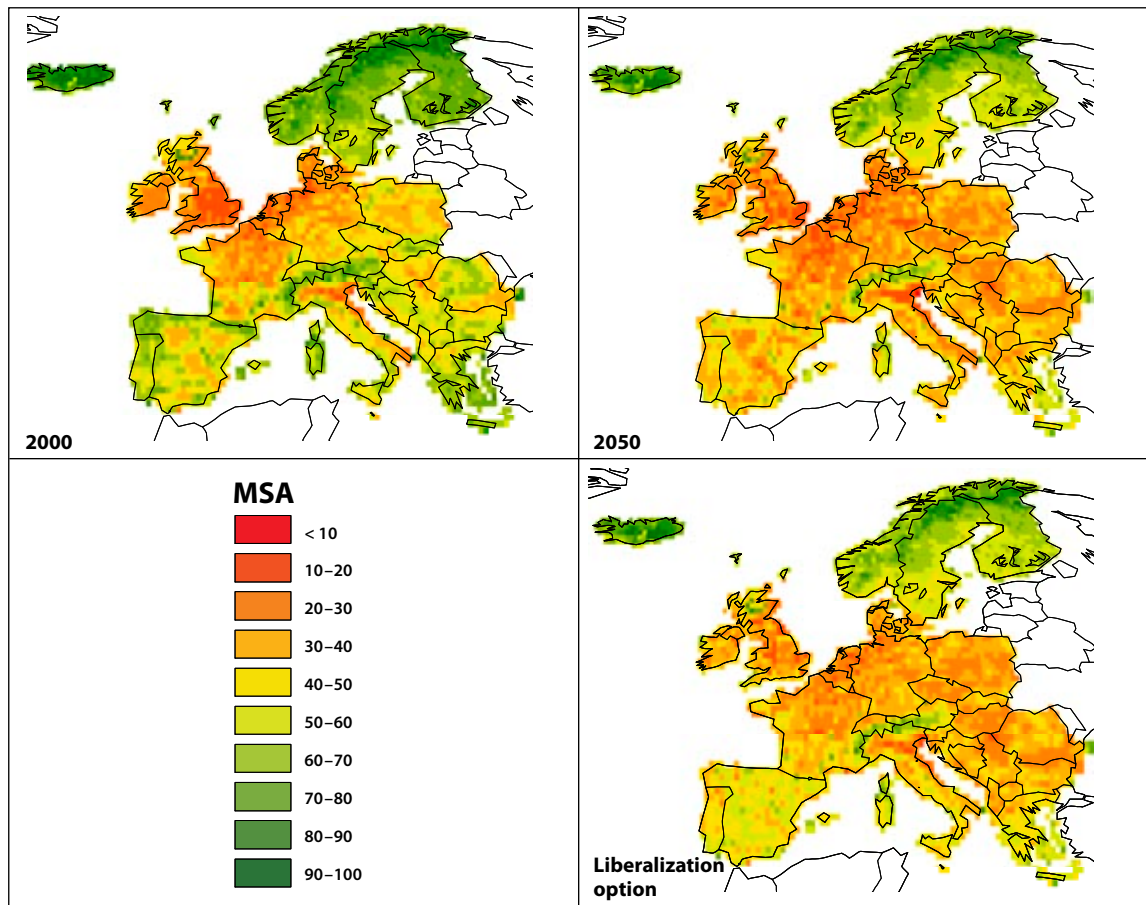


FIGURE 29: Spatial distribution of biodiversity (MSA) for Europe, in the baseline development (2000-2050), and change in biodiversity due to liberalization of the agricultural market.

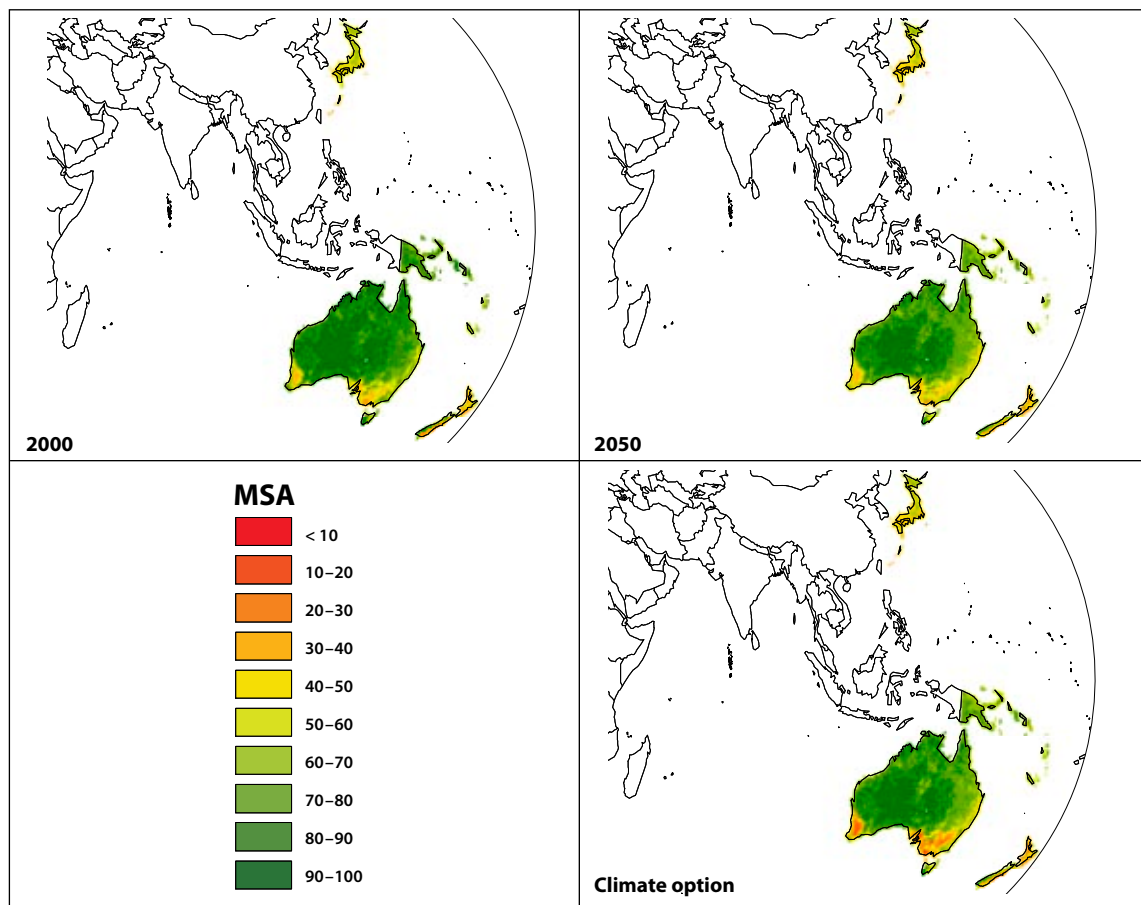


FIGURE 30: Spatial distribution of biodiversity (MSA) for Oceania (including Japan), in the baseline development (2000-2050), and change in biodiversity due to climate change mitigation.

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