Cross-roads of Planet Earth's Life

Exploring means to meet the 2010 biodiversity target

Study performed for the

Global Biodiversity Outlook 2

Chapter solution-oriented scenarios

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Will be internationally reviewed under supervision of the secretariat of the Convention on Biological Diversity

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" If science has taught us anything, it is that the environment is full of uncertainty. It makes no sense to test it to destruction.
While we wait for the doctor's diagnosis, the patient may die"

Prince Charles

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Exploring means to meet the 2010-biodiversity target

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Abstract

A scenario study from 2000 to 2050 has been performed to explore the effects of future economic, demographic and technical developments on environmental pressures and global biodiversity. Policy options that affect global biodiversity were analysed on their contribution to the 2010 biodiversity targets agreed upon under the Convention on Biological Diversity (CBD). The mean species abundance of natural occurring species was used as indicator for biodiversity. It combines the extent of natural biomes and the quality of these biomes. The assessment was performed using global models, allowing a quantitative approach.

The policy options were assessed against a business-as-usual baseline scenario with a moderate economic and demographic development, and a considerable improvement in agricultural productivity. The following policy options were implemented: full agricultural trade liberalisation, idem combined with poverty reduction in Sub-Sahara Africa, climate change mitigation by improved energy efficiencies and a large share of bio-fuel production, reducing meat consumption by 5% (the consequence of higher prices due to implementing several measures), creating plantations for global wood production (taking the pressure of semi-natural forests), and increasing the area of protected areas to 20% of the main ecosystems.

Under continuing present policies, global biodiversity declines in the baseline from 70% in 2000 to 63% in 2050, mostly due to increasing climate change and land use changes. This loss applies to the total natural capital, and should not be confused with species extinction. The decline is enhanced by policies such as trade liberalisation, poverty reduction and climate change mitigation, mainly because of shifting agricultural production areas and additional land use for food and bio-fuel production. Only after 2050, avoided climate change will result in less biodiversity loss. Likewise, implementing wood plantations will result in additional land-use in the short-term, but can avoid further biodiversity loss in the long-term, as semi-natural forests are set-aside to recover. Reduced meat consumption is results in a modest improvement of biodiversity in the short term. The only option that substantially reduces biodiversity loss on the short-term is increasing the extent of protected areas and effectively enforcing their protection status.

The agricultural productivity improvement was implemented optimistic in the baseline. Implementing a moderate improvement will results in an even stronger biodiversity decline. Taking other indicators for biodiversity will show a similar pattern of general decline, as the main drivers of global biodiversity loss are the same.

Although not all possible measures and measure combinations could be assessed, the main picture becomes clear. A worldwide network of large protected areas in combination with efficient production in agricultural areas seems to be a good strategy to reduce the future biodiversity loss. Effectively avoiding the effects of future climate change, with a limited additional claim on natural areas for bio-fuel production, is necessary to reduce biodiversity loss in the longer term.

Contents

Summary

Introduction

The aim of the assessment study reported here is to explore policy options for achieving the 2010 biodiversity target at global and regional levels as agreed on under the Convention on Biological Diversity. The longer term effects of these options are also taken into account using a time horizon of 2050. The assessment has been carried out using models allowing a quantitative approach. The findings, expressed in terms of the 2010 indicators according to CBD decision VII/30, function as input for the second Global Biodiversity Outlook (GBO2) to support policy makers in determining effective manners in achieving the 2010 target. The assessment of the policy options forms the main result of this study, with the outcome of the baseline scenario analysis as runner-up. 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, NL).

Key findings: general

1. According to the baseline scenario and options examined in this study it is unlikely that the 2010 CBD target of “*a significant reduction in the current rate of loss of biological diversity*” will be met for terrestrial biomes at the global and regional levels. The loss of biodiversity is expected to continue at an unchanged pace in the coming decades as a consequence of economic and demographic trends.
2. Six policy options which potentially reducing the rate of biodiversity loss have been analysed separately for their impact. *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* (bio-fuels), and realising *sustainable forest management* (wood plantations) and *poverty alleviation* (increasing GDP) seem inevitably to lead to losses of biodiversity in the medium term (2010 -2050. *Full trade liberalisation in agriculture* will lead to loss of biodiversity by ongoing land conversion in low-cost areas.

Key findings: biodiversity change in the baseline scenario

3. A moderate socio-economic scenario has been used as baseline to evaluate the effectiveness of policies. Key indirect drivers, global population and economic activity are assumed to keep on growing. Between 2000 and 2050, population is projected to grow by 50%, the global economy quadruples[1].
4. 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 expected to decrease from about 70% in 2000 to about 63% by 2050[2].
5. The baseline assumes a considerable increase in agricultural productivity. 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 case of the latter scenarios (MA), global biodiversity is expected to decrease further by several percentage points.

[1] It should be stressed that the purpose of the baseline was to serve as a reference for evaluating policy options, not as a precise prediction of the future.
[2] In terms of the mean species abundance of the original species, derived from the CBD list of indicators for immediate testing (CBD Decision VII/30). See also section 2.3.

Increase of agricultural productivity will therefore be a key factor in reducing the rate of biodiversity loss in the future.

6. 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 changes over the next 50 years. It should be noted that inland waters and marine ecosystems have not been not considered here. Much of the world's remaining natural capital will consist of mountainous, boreal, tundra, and ice and (semi-)arid ecosystems, generally considered as less suitable for human settlement.

Key findings: do options reduce the rate of loss?

7. Six policy options have been evaluated on their potential for slowing biodiversity loss. The options 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. Their implementation will require strong international commitment and coordination:
   - Effective implementation of **full trade liberalisation in agriculture from 2015 onward**, driven by free-trade and development considerations following the current WTO Doha Round. Implementation leads to an additional[3] biodiversity loss of 1.3% until 2050 due to a 6.5% global increase in land used for agriculture, concentrated in Latin America and Southern Africa[4]. The production shift and expansion in these regions is driven by cost-efficiency reasons, since labour and land costs are particularly low. This shift of production is at the expense of production in the USA, Europe and Japan, resulting in higher 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 forest and grassland areas. About 1.3 million km^2 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 the land previously used for agriculture will, initially, have a low biodiversity.
   - In order to **alleviate extreme poverty**, as targeted in the Millennium Development Goals, direct investments from developed countries into Sub-Saharan Africa are **combined with trade liberalisation of agriculture of option 1** in line with proposals by the Millennium Project (UN Millennium Project, 2005). Assuming effective implementation of these additional direct investments, including 10% higher land productivity 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, mainly produced in the region itself, implying a 10% increase in agricultural land and an additional biodiversity loss of about 5.7% in the region[5]. 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. It is estimated that this will result in a 10% increase in consumer prices of meat

[3] Compared to the baseline.
[4] All changes are in percent points.
[5] This is 2% additional loss in the region compared to the option of trade liberalisation of agriculture only.

products and a decrease of the global meat consumption by about 5%. This lower consumption 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 **bio-energy intensive climate change mitigation policy** option, stabilising CO_2-equivalent concentrations at a level of 450 ppmv in line with the goal of keeping the global temperature increase below 2 ^oC 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 bio-energy. A scenario has been explored in which bio-energy plays an important role in reducing emissions. In this scenario major energy consumption savings are achieved and 23% of the remaining global energy supply is produced from bio-fuels in 2050. By 2050 the biodiversity gain (+1%) from less climate change and reduced nitrogen deposition due to less fossil-fuel burning does not compensate for the natural habitat loss (-2%) for producing bio-fuels crops in about 10% of the global agricultural area. This leads to an additional biodiversity loss of around 1%.
- The continuing demand for wood (30% increase 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 **a large-scale wood plantation** option in which almost all wood produced in 2050 comes from intensively managed productive plantations leads to additional biodiversity loss through plantation establishment. As plantations gradually take over global production, the previously exploited semi-natural forest is 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 role of deforestation and underlying factors such as fires and transmigration in global biodiversity loss is not taken into account. Deforestation is attributed to agriculture as conversion takes place primarily to create room for agricultural uses.
- **Protecting 10% area of all biomes,** a provisional target agreed upon in the CBD, has limited effect on slowing the loss of biodiversity. As this target has almost already been achieved in the Baseline, the option has not been further analysed here. **Effective conservation of 20% area of all the ecological regions** will reduce the loss by about 1%, yielding the best result of the six options considered. Effective conservation reduces land conversion, extensive use and human settlement in still intact areas, and also enables restoration of partly degraded protected areas. However, the gains from effective conservation are partly lost due to over-exploitation of adjacent areas to fulfill human needs. Or simply said, gains within the protected areas are partly offset by losses outside the protected areas, which in terms of area is many times larger. 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 are 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.

8. 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 liberalisation and poverty reduction higher economic growth comes at the expense of global biodiversity. Economic costs and biodiversity gains may be spread over time. Climate change policy will decrease 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 forest management and sustainable meat production) have a negligible effect on a macro-economic scale. However, these options might involve huge structural changes and large shifts in government spending and spending of the sectors involved.

Options in perspective

9. From this preliminary assessment, promising policy options have emerged for progressing towards the 2010-target.
   - Protected areas and sustainable meat production have immediate positive effects. Climate change mitigation and sustainable forest management show beneficial effects, but only after several decades. In the short term, these options will exert increasing pressure on biodiversity.
   - Ways to keep the long-term benefits of some options for safeguarding biodiversity, whilst reducing their short term pressures need to be found. For example, the climate change mitigation option considered in this study relies strongly on substitution of fossil fuels for renewable bio-fuels. 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.
   - Direct options should be made more effective. For example, a substantial increase in the number and extent of effectively managed protected areas will provide a quick and positive outcome for the 2010 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 functions.
   - The trade-off between economic growth and biodiversity to be limited:
     - More attention for agricultural productivity and stimulating 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 a pre-condition to that. 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 and risks of land degradation.
     - Full liberalisation of the agricultural market. This contributes to poverty alleviation, although unbalanced and direct liberalisation may hinder poverty alleviation in those regions where sufficient institutions and government control are not available. In order to achieve complete poverty alleviation and to avoid unnecessary and persistent loss of biodiversity by

land conversion in low-cost areas, trade liberalisation needs to be combined with controlled policy interventions.
- o Targeting the distribution of economic growth and investments on 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 remains[6].
- o Solving the value problem. Conserving biodiversity depends crucially on what societies are willing to pay for conservation. More emphasis could go into demonstrating value and designing markets to capture the value of these commons.

10. A concerted effort is essential if the rate of loss in the coming decades 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 bio-fuels, establishing wood plantations and sustainable meat production, along with a major increase in effective protected areas. This combination of options could not be assessed within the time limitation of this study. Local tailor-made measures might provide additional opportunities.
11. The decline of global biodiversity is probably underestimated as the scenario explored is optimistic on agricultural productivity increases. Obviously, not all pressures could be taken into account. Other biodiversity indicators will show similar general patterns of overall biodiversity decline, with the same main drivers in this decline, but the exact number will vary between indicators. 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 when production is moved to other areas).

[6] 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).

1. Aims and limitations of the report

1.1. Aim

The secretariat of the CBD assigned the Netherlands Environmental Assessment Agency (MNP) to explore candidate policy options which could contribute towards the achievement of the 2010 target at global and regional levels as agreed on under the Convention on Biological Diversity (see Annex 2). The long term effects of the policy options, with a time horizon of 2050, should be taken into account.

The assessment was carried out with use of the IMAGE-GLOBIO model, allowing a quantitative approach. Within the limits of the model, the results should be expressed where possible in terms of the 2010 indicators according to CBD decision VII/30. The results serve as input for the Global Biodiversity Outlook 2 to support policy makers in determining cost-effective manners in achieving the 2010 target[7]. 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 to achieving the 2010 target on global and regional scales.

The exploration of options documented in this report is not exhaustive; significant limitations are included:

- Restricting aim to the gain of 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. The currently applied models do not yet include these factors. Possible policy options to reduce these pressures were therefore not considered. Neither were the effects on inland waters and marine ecosystems taken into account, or possible extreme events resulting from climate change.
- 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 liberalisation of the agricultural market.
- a baseline scenario that assumes high food production rates, compared to the four scenarios of the Millennium Ecosystem Assessment.
- The results for year 2010 were interpolated from 2000 and 2030, as actual model outputs hardly differentiate between global and regional scales.
- The longer term benefits for biodiversity of reducing climate change and poverty reduction probably will occur beyond the time horizon of this study (2050), and should be taken into account in the interpretation of the results.
- The consequences of several assumptions are elaborated upon in Chapter 6, where uncertainties and model sensitivity are treated.

[7] The GLOBIO model was developed in cooperation with UNEP-WCMC and UNEP-GRID Arendal (REF).

2. Methodology: framework, models, indicators and scales

The model-framework will be elaborated on in sections 3.1 and 3.2, while the context of indicator choice is found in section 3.3, after which 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 bio-fuels, infrastructure, nitrogen-deposition and fertiliser use. These direct drivers affect ecosystems and biodiversity. Indirect and direct drivers as well as changes in ecosystem services affect human well-being parameters like 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).

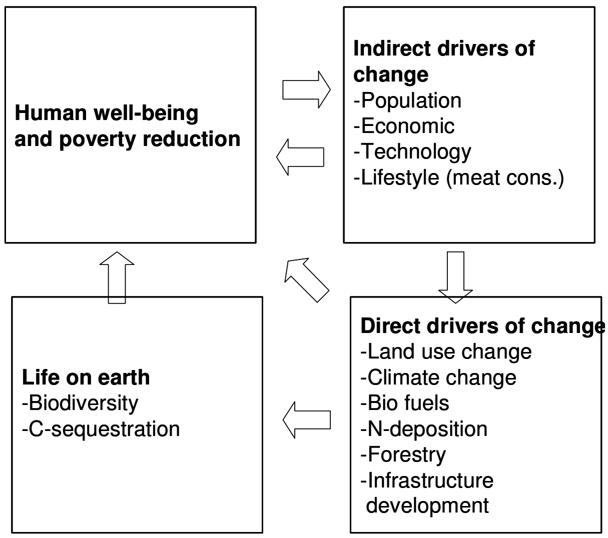


Figure 1: ***Framework for analysis of solution-oriented policy options using the GTAP-IMAGE-GLOBIO model (interpreted from MEA, 2005). Not all factors are reported in this study.***

The framework we use 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) and Eickhout *et al.* (2006). The standard GTAP model (Hertel, 1997) is characterised 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). For this study an extended version of the standard GTAP model was developed that improved the treatment of agricultural production and land-use (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 a 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.

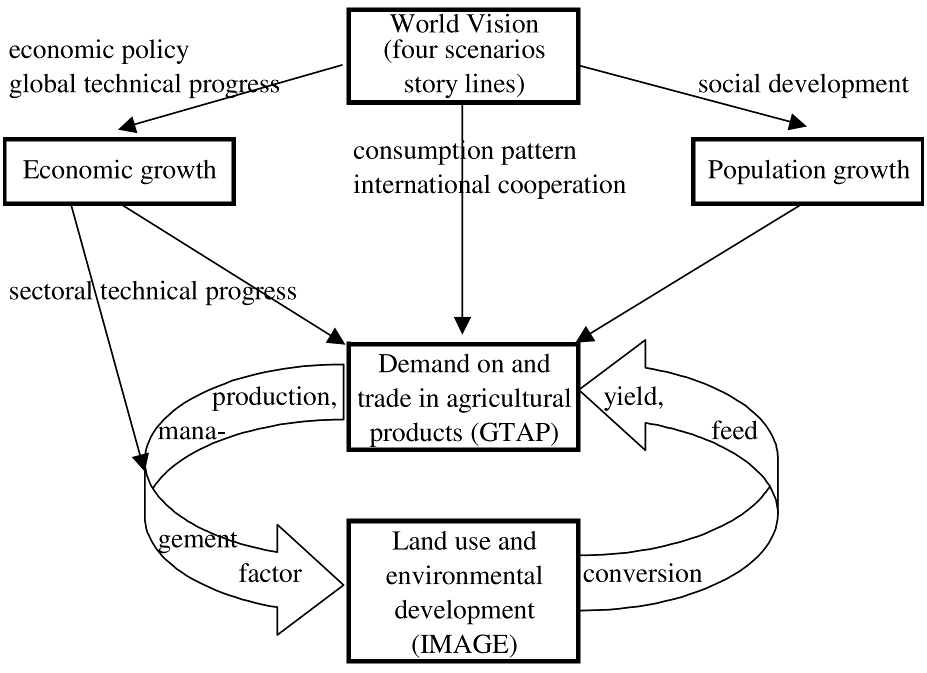


Figure 2: ***The GTAP-IMAGE modelling framework (Van Meijl et al., 2005)***

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 that there are substitution possibilities among production factors. If land gets more expensive, the producer uses less land and more of 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 the 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 increase above 3 to 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 homogenously distributed.

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 use in the IMAGE land-use model. Therefore, a fixed map of protected areas (taken from UNEP-WCMC) is also used as input of the IMAGE model. IMAGE simulations deliver an amount of land needed per world region and the coinciding changes in yields resulting from changes in the extent of used land and climate change.

Next, these additional changes in crop productivity are given back to GTAP, therefore 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 near 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 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, such as sulphate adsorption, are not considered here. Hence, this approach aims at providing long-term protection of ecosystems. Further information on our nitrogen impacts is given in Bouwman *et al.* (2002).

Climate change is modelled in IMAGE 2.2 with an upwelling diffusion model. It 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. Based on the MAGICC model of the Climate Research Unit (CRU) (Hulme *et al.*, 2000), the MAGICC model is the most widely used simple climate model within the IPCC (IPCC, 2001). 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 with 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 standardised 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.*, in prep) 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 in 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. 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 by 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 spcies (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, taxon under study, biome and region. The model is static rather than dynamic, and deterministic rather than stochastic. To estimate the impact on biodiversity of pressures under a given scenario at, for example, 2020, a map of each of the pressures in 2020 is required , which 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 within the model are: i) land-cover 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 and vi) climate change (both taken from IMAGE).

Table 1: Categories of land cover / land-use and the relative mean abundance of species, on the basis of ca. 120 published datasets

Main land cover / use category	Sub land cover / use category	Description	MSA
Ice and snow (I)	Undisturbed	Areas permanently covered with snow or ice. Considered as undisturbed areas	1.0
Bare land (D)	Undisturbed	Areas permanently without vegetation due to originally occurring natural processes (e.g. deserts, high alpine areas).	1.0
Forests (F)	Undisturbed	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 like hunting and selective logging, where timber extraction is followed by a long period of regrowth with naturally existing tree species	0.7
	Secondary forests (S)	Areas originally covered with forest or woodlands where vegetation has been removed now forest regrowth or having a different cover and no longer in use.	0.5
	Forest plantation	Planted forest often with exotic species	0.4
Shrubs and grasslands (G)	Undisturbed	Grassland or shrubs dominated vegetation (e.g. Steppe, tundra or savannah)	1.0
	Livestock grazing	Grasslands where naturally occurring grazing is replaced by livestock	0.7
	Secondary grasslands (S)	Areas originally covered with low vegetation, where vegetation has been removed now regrowth or having a different cover and no longer in use.	0.5
	Artificial pastures (p)	Forests and woodlands that are converted to grasslands for livestock grazing.	0.1
Cultivated land (C)	Agroforestry	Agricultural production intercropped with (native) trees. Trees are kept for shade or as wind shelter	0.5
	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 specialisation.	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 specialisation.	0.05
Built up areas (B)		Areas more than 80% built up	0.05

We found ca. 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 categorised into six globally consistent groups: i) primary vegetation; ii) lightly used primary vegetation; iii) secondary vegetation; iv) pasture; v) forest plantations 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 accounts for a specific biodiversity value. Table 1 summarises and describes the different categories. These figures do 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 mean species abundance (MSA) is calculated in steps. First the MSA is calculated on the bases of the land-use intensity classes. 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 is so far 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 temperature. These model outputs are compared with the predicted biome shifts in the IMAGE model. This European bias is the most obvious area for model improvement. 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 describing a biome (EUROMOVE). We used the regression lines with the lowest regression slope (have less effect), which yielded conservative estimates.

*Table 2. Slopes of the regression equations between "stable area" and ΔT for each biome (MSA = 100 – slope * ΔTemperature)/100). Slopes marked * are used in the GLOBIO 3 model.*

	Slope	
Biomes	**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 dessert	3.6*	-
Scrubland	12.9*	17.4
Savannah	9.3*	-
Tropical woodland	3.9*	-
Tropical forest	3.4*	-

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 that the addition of nitrogen in those studies is equivalent to N-deposition occurring in the field. The N-deposition impact factor applies only to natural land and to 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 (Bartholome *et al.*, 2004), 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 relation between nitrogen deposition exceedance above Critical loads for three ecosystems

Ecosystem	Equation*	Applied for land-cover classes
Arctic-Alpine ecosystem	N = 0.9 - 0.05 x Nitrogen exc.	Ice
Boreal coniferous forest	N= 0.8 – 0.14 $\log_e$ (Nitrogen exc.)	Forest
Grassland ecosystems	N = 0.8 – 0.08 x $\log_e$ (Nitrogen exc.)	Grassland and shrub

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 In GLOBIO 2 relationships were constructed between the distance to roads and mean species abundance for different biomes. They used 309 reviewed articles to establish the relationships, comprising information on 204 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 impacts zones along linear infrastructure (roads, railroads, power lines, pipe lines). The fraction of species found to decline was calculated for each impact zone in terms of MSA. Table 4 shows the biodiversity MSA for the different impact zones in the biomes.

Table 4: Zones (in km) along linear infrastructural objects, showing impacts on mean species abundance (MSA) from infrastructure (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 through a relationship between habitat area and the percentage of species requiring the area (table 5). In a large area all original species may find suitable area sufficient to support at least a minimum viable population, whereas a small area may only support a few species. The minimum area requirement of 156 mammal and 76 bird species is used to construct a general relationship between patch size and the percentage of species with sufficient area for at least one viable population, which is used as a proxy for MSA. Data are derived from Allen *et al.* (2001), Bouwma *et al.* (2002), Verboom *et al.* (2001) and Woodroffe and Ginsberg (1998). We assumed a much smaller area requirement (1 km^2) for plant species than for animals.

Table 5: The relationship between area and the MSA

Area (km^2)	MSA
1	55
10	75
100	85
1000	95
>10000	100

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, which means that the individual MSA values are multiplied for each square km grid cell. The resulting figure is an estimate for the mean species abundance as a result of all pressures.

2.3. Indicators

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. We focused 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 for selected biomes, ecosystems and habitat” indicator. It shows the trend in all major biomes, covering all terrestrial areas without mutual overlap. We did not focus on specific small-scaled ecosystems or habitats.

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. For example, 0.5 indicates that the biodiversity effects of nitrogen deposition decrease by 50% compared to the baseline. The issue of official development assistance is taken into account in all options due to a significant technology transfer on food production technology. Additional economic and technology support to the poor and hungry in Sub-Saharan Africa is worked out for one option and calculated for its effects.

Table 6: Set of headline indicators agreed on by CBD (UNEP, 2004b).

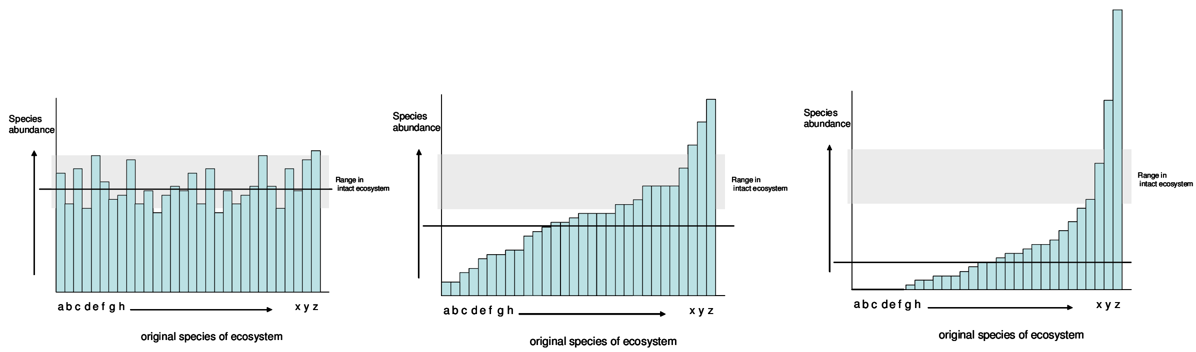
A: Focal area	**B: Indicator for immediate testing ***	**C: Possible indicators for development by SBSTTA or Working Groups**
Status and trends of the components of biological diversity	**Trends in extent of selected biomes, ecosystems and habitats** **Trends in abundance and distribution of selected species** **Coverage of protected areas**	Change in status of threatened species (Red List indicator under development) Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance
Sustainable use		Area of forest, agricultural and aquaculture ecosystems under sustainable management Proportion of products derived from sustainable sources
Threats to biodiversity	**Nitrogen deposition**	Numbers and cost of alien invasions
Ecosystem integrity and ecosystem goods and services	Marine trophic index Water quality in aquatic ecosystems	Application to freshwater and possibly other ecosystems Connectivity/fragmentation of ecosystems Incidence of human-induced ecosystem failure Health and well-being of people living in biodiversity-based-resource dependent communities Biodiversity used in food and medicine
Status of traditional knowledge, innovations and Practices	Status and trends of linguistic diversity and numbers of speakers of indigenous languages	Further indicators to be identified by WG-8j
Status of access and benefit-sharing		Indicator to be identified by WG-ABS
Status of resource transfers	**Official development assistance provided in support of the Convention** (OECD-DAC-Statistics Committee)	Indicator for technology transfer

** Bold indicators have been assessed in this study.*

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 of poverty, which is assumed to be a prerequisite for maintaining biodiversity. 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: e.g. 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 too to structural effects; 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, biodiversity encompasses the overall variety found in the living world and includes the variation in genes, species and 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 their species abundance. Obviously a tropical rainforest 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 characterised by the decrease in abundance of many original species and the increase in abundance of a few other -opportunistic- species, as a result of human activities. Extinction is just the last step in a long degradation process. Countless local extinction (“extirpation”) precedes the potentially final global extinction. As a result, many different ecosystem types are becoming more and more alike, the so-called homogenisation process (Pauly *et al.*, 1998; Ten Brink, 2000; Meyers and Worm, 2003; Scholes and Biggs, 2005; MEA, 2005). Decreasing populations are as much a signal of biodiversity loss as highly expanding species, which may sometimes even become plagues in terms of invasions and infestations (see the figures showing this process from left to right.



Until recently, it was difficult to measure the process of biodiversity loss. “Species richness” appeared to be an insufficient indicator. First, it is hard to monitor the number of species in an area, but more important it may sometimes increase as original species are gradually replaced by new human-favoured species. Consequently the Convention on Biological Diversity (VII/30) has chosen a limited set of indicators for 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* (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, 2003, 2004). Paragraph 5.3 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, 2004a, b). 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 asessment 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 the 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 are distinguished (figures 3 and 4), the latter covering the thematic areas and their sub-divisions of the Convention as much as possible. The status and trends of biomes will be presented by region. The thematic areas of marine and coastal, inland waters, mountains and islands could not be assessed because of model limitations.

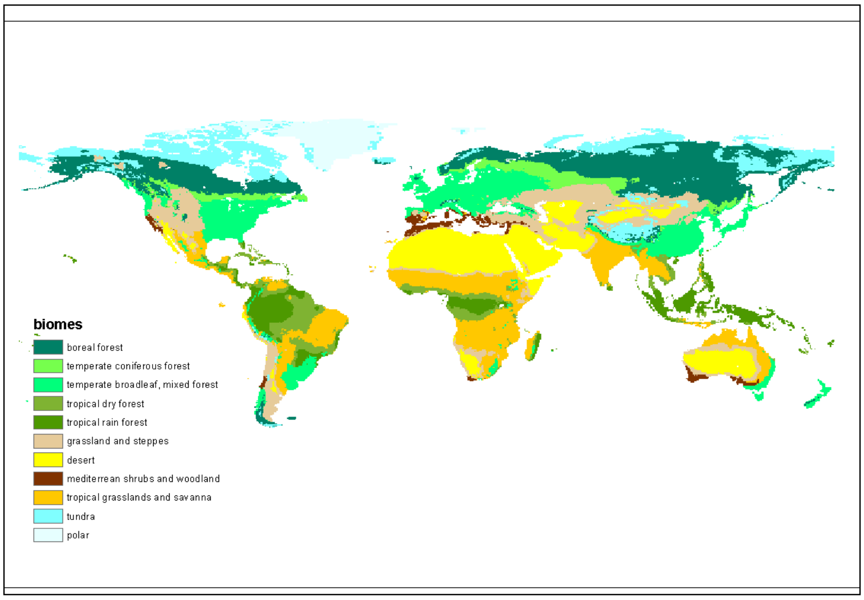


Figure 3: ***The biomes distinguished in the present IMAGE-GLOBIO model analysis .***

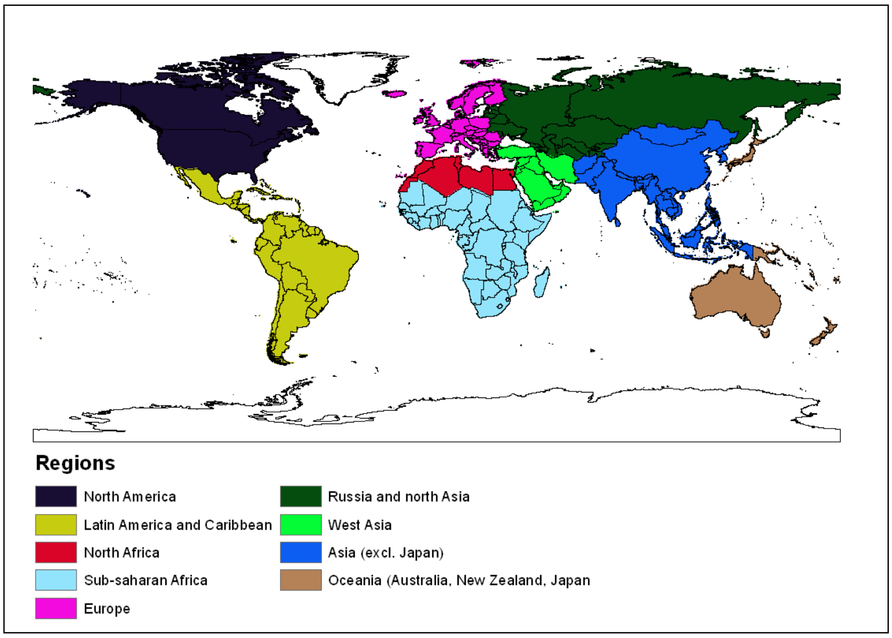


Figure 4: ***The regions considered: Greenland and Antarctica are excluded.***

The biomes considered (figure 3) are modelled on a grid level of 0.5 by 0.5 degrees within the IMAGE model. Within GLOBIO3, the IMAGE maps are downscaled to a 1-km scale, following some simple rules and using Global Land Cover 2000 as a base map. These maps are used to estimate the response to changes in 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 of 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, which is the favoured indicator as it is closest to those specified by CBD.

3. Baseline scenario and policy options

A “baseline scenario” is used to explore candidate policy options on their effects on and contributions to the 2010 CBD 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 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, economics 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 over 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 be taken at the baseline.

Consumption of agricultural products lags behind overall economic growth, but the combined effect of more people eating more calories, especially in currently undernourished regions, and the shift towards more animal products in the diet at higher income levels implies 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 World Bank to launch an assessment process (IAASTD) aimed at investigating in more depth and (regional) detail the opportunities for further enhancement of agricultural productivity. The outcome of the IAASTD process can produce insights to update this crucial factor.

As far as nature conservation policies are concerned, the current protected area map is not extended in the baseline. Rising timber demand is met by production from (sustainable) use of (semi-)natural forests. A part of the demand comes from conversion of forests, while there is no wood production from (current or future) plantations.

Policy options that aim at realizing the 2010 target of a significant reduction of the loss of biodiversity can be numerous. Effective measures preferably aim at the reduction of pressure factors that affect biodiversity. The main pressure factors are land-use change and intensification of land-use; land degradation; climate change; economic and population growth and corresponding infrastructural development; pollution. Policy measures on these fields often have multiple goals.

We selected a number of policy options initiated, proposed and discussed in international fora, and aim at reducing biodiversity loss (at least partly) or drivers that can be expected to have a large impact on biodiversity. The selected policy options influence several of the major pressures on biodiversity loss: habitat loss, (over-)exploitation of natural resources, agriculture and eutrophication, climate change, fragmentation and infrastructural development. The options 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 from are (from indirect to direct drivers, see Annex 1):

1. **Liberalisation of the agricultural market** has an effect on economic drivers and influence changes of food production, land-use, agricultural intensification, habitat loss, and nitrogen deposition, and is accompanied by high rates of technology transfer.
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 liberalisation of the agricultural market.
3. **Limiting climate change** includes more stringent application of measures aiming to comply with the ultimate UNFCCC goal, including an increase in bio-fuels in order to mitigate climate change[8].
4. **Sustainable meat production**: standards on meat production will reduce health effects and nitrogen deposition and will increase meat production costs and reduce meat consumption.
5. **Sustainable forest management** will mainly affect the way of producing wood products through increased wood plantations.
6. **Protected areas**: two options in the extension of the protected areas network to a coverage of at least: 1) 10% and 2) 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 such as abatement measures on: pollution, invasive alien species, overgrazing, forest fire, habitat destruction, illegal logging, deforestation and trade, making a selection indispensable. 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 options' coverage of the major causes of biodiversity loss according to the CBD, iv) current political discussions 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.

[8] Bio-fuels (or bio-energy) are assumed to be produced on the basis of both bio-energy crops and agricultural residues. In this study we assumed that around 50-100 EJ bio-energy can be produced from agricultural residues. The remainder is produced from bio-energy crops. Only the latter leads to additional use of land; it is discussed in this report.

4. Future biodiversity

4.1. Planet Earth

4.1.1. Results for planet Earth

<u>Baseline development</u>

- The last 300 years our planet's biodiversity has dropped to 70%. Initially, extensive use such as hunting and gathering, and conversion into extensive agriculture were the main factors. In the last century, infrastructure, human settlement, intensification of agriculture and forestry, pollution and fragmentation have added to the decline[9].
- Up to 2050 a further decline in biodiversity from about 70% to 63% is projected. 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- 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 of agriculture remains constant, provided that agricultural productivity shows a considerable rise.
- The linearity of the biodiversity loss in the 2000-2050 period is remarkable, while both population growth and economic development are exponential processes. This can be seen in the decreasing rates of the population growth. Simultaneously, the economic growth rates are increasing. Together, this results in a roughly linear effect

<u>Effects of options</u>

- 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, sustainable forest management and poverty alleviation initial losses in the short and medium term (2010 - 2030) are followed by improvements on the much longer term. Eventually, the long-term benefits will offset the medium-term losses. This is not yet found for the climate change option and for 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 productivity increase is part of the baseline scenario. 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%).
- It is unlikely that the CBD target for 2010 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 demographic development trends. Delays in institutional and ecosystem changes can be expected to play a role as well[10], as they will delay the necessary changes until after 2010.

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[9] The so called "first, second and third strike"
[10] These are not part of this study.

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 liberalisation is beneficial for economic growth. Especially developing regions reap the benefits from free trade in agriculture. According to our evaluation, the world economy will experience a growth of 1% in 2030. GDP in developing countries is higher.

Addressing extreme poverty and hunger in Sub Saharan Africa, not only involves trade liberalisation, but also an increase in aid from industrialised countries. This increase in official development assistance will slightly mitigate the positive effects of liberalisation in industrialised 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.

Climate change policy will require dramatic changes in the energy system. This is a costly option, However, costs can be limited by involving all regions (a global coalition) and using efficient and flexible mechanisms (e.g. emissions trading). Abatement costs for the world as a whole are in the order of global GDP percentages. The distribution of costs across regions will depend crucially on the allocation of emission permits (burden-sharing). In a multi-stage approach (den Elzen *et al.*, 2005) developing countries might benefit from the surplus of emission rights and gain from the export of emission permits.

Sustainable meat production, sustainable forest management 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 parts 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 runs very roughly at $6.5 billion per year (in the year 2000 US $). 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.*, 1999). Sustainable forest management would involve government subsidies or tax exemptions in the order of $10 billion (Enters and Durst, 2004).

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

Options/ Issues	Baseline	Liberalisation agricultural trade	Poverty reduction	Limiting climate change	Sustainable meat production	Sustainable forest management	Protected areas 20%
Biodiversity[11]	62.5%	-1.3%	-1.7%	-1.0%	0.3%	0.1%	1.1%
Cost[1]		+	+	–	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-dep	1.00	1.02	1.04	0.53	0.99	1.00	1.00

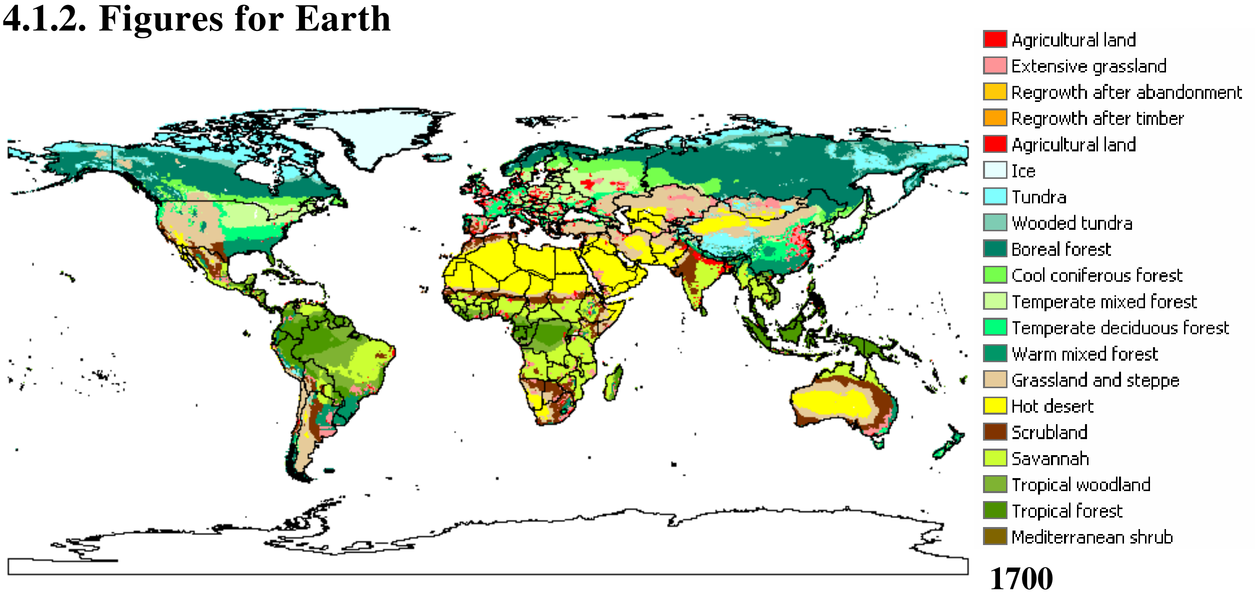
[1] Cumulative changes in GDP relative to the baseline in 2030, + (more than 0.2%), ++ (more than 1.5%), +++ (more than 10%), – (less than -0.2%), – – (less than -1.5%).

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

Region	Biodiversity 2000	Baseline 2050	Baseline loss	Liberalisation	Poverty reduction	Climate change	Sustainable meat prod.	Sustainable forestry	Protected 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%							

[11] Biodiversity in this table and similar tables is per region is measured in terms of mean abundance of the original species.

4.1.2. Figures for Earth



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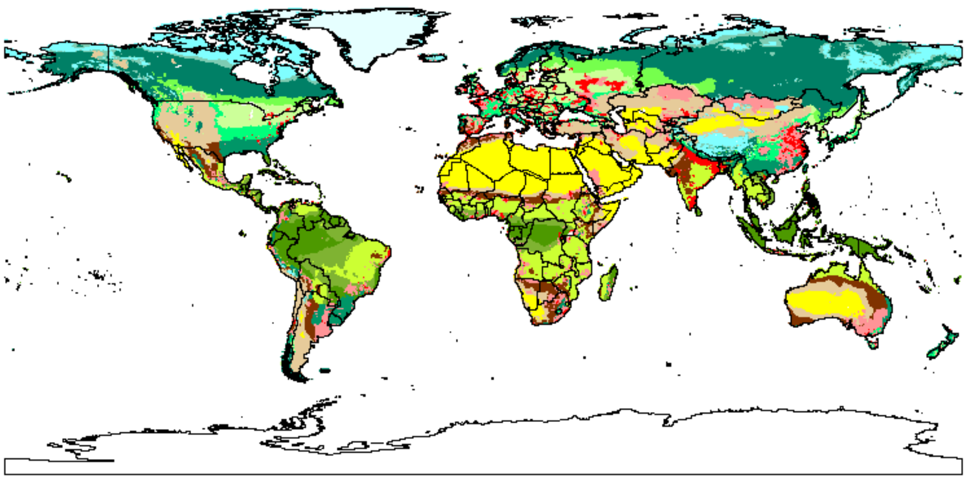
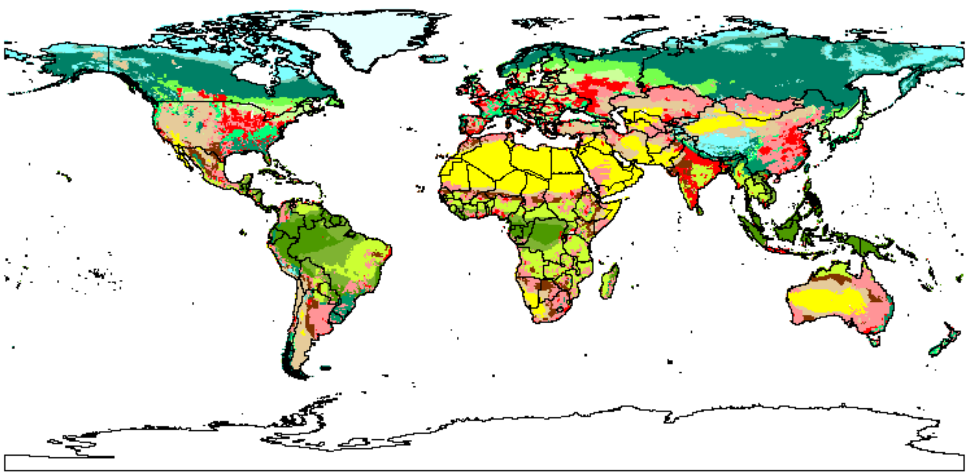
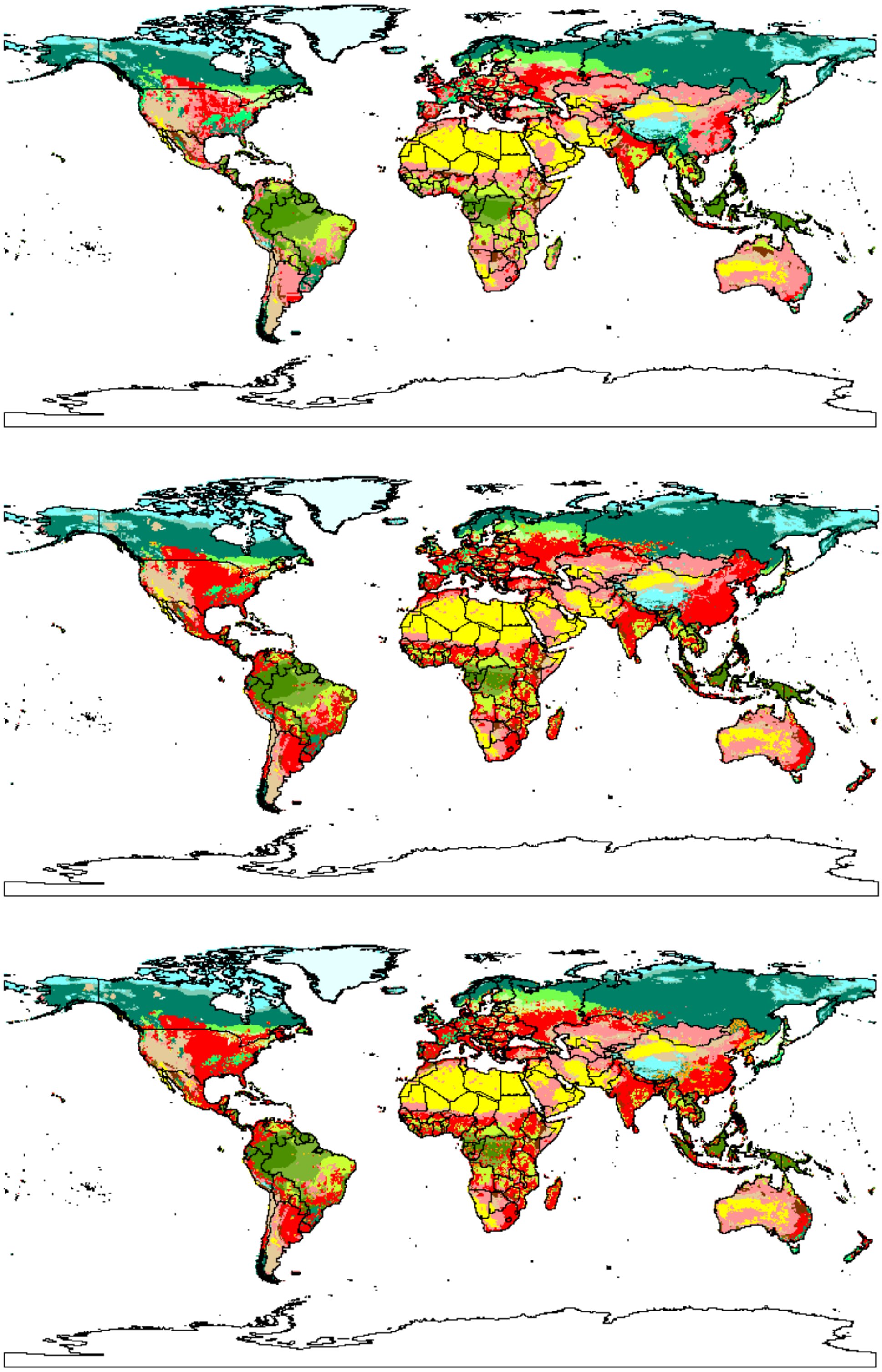


1800



1900



1950

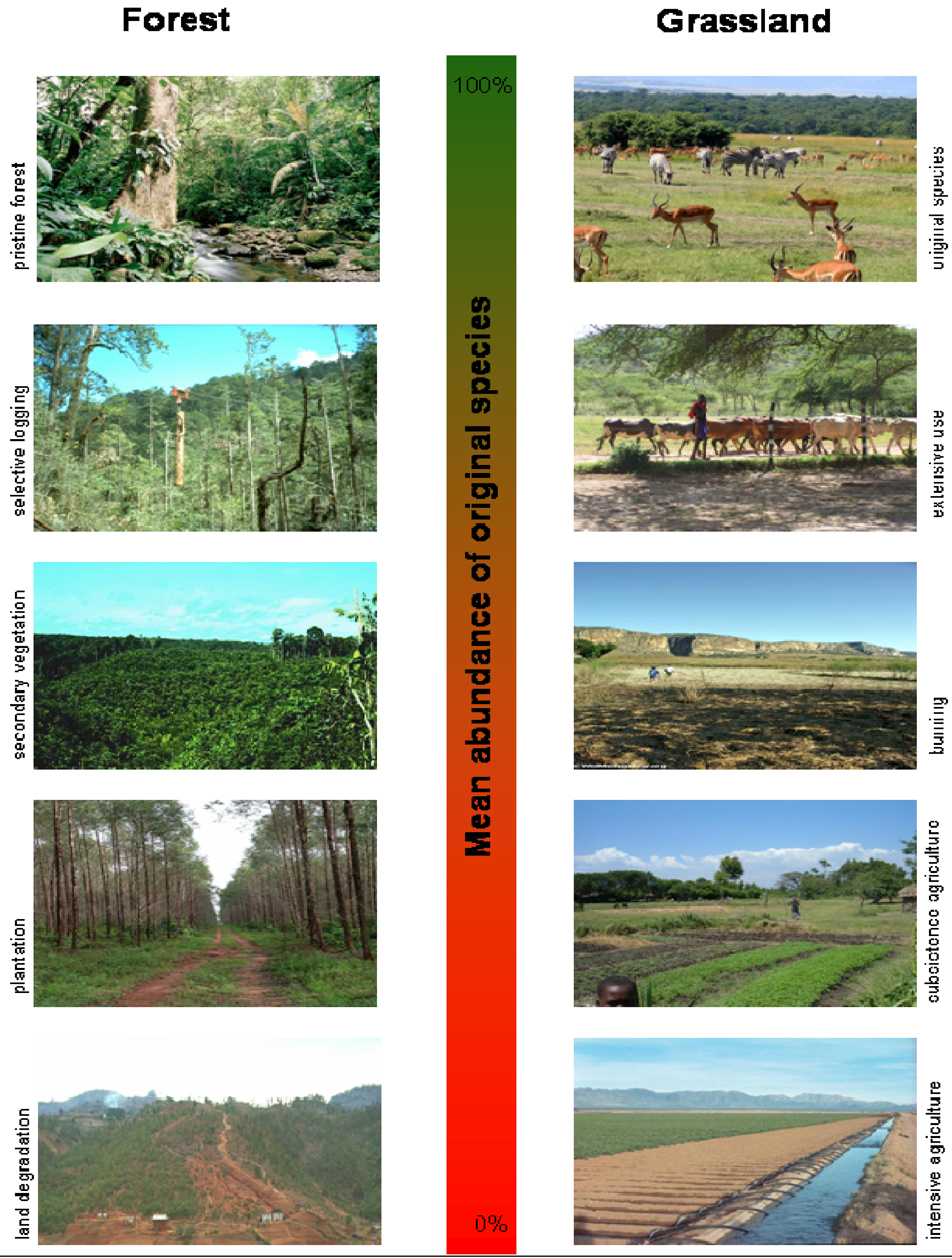
2000

2050

Figure 5: ***Land-use changes since 1700-2050 (Klein Goldewijk, 2001; IMAGE-team, 2001).***

Box 2: Visual impressions of mean species abundance scale 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 the *remaining species-richness of the original species* (RSD; see also Box 1).



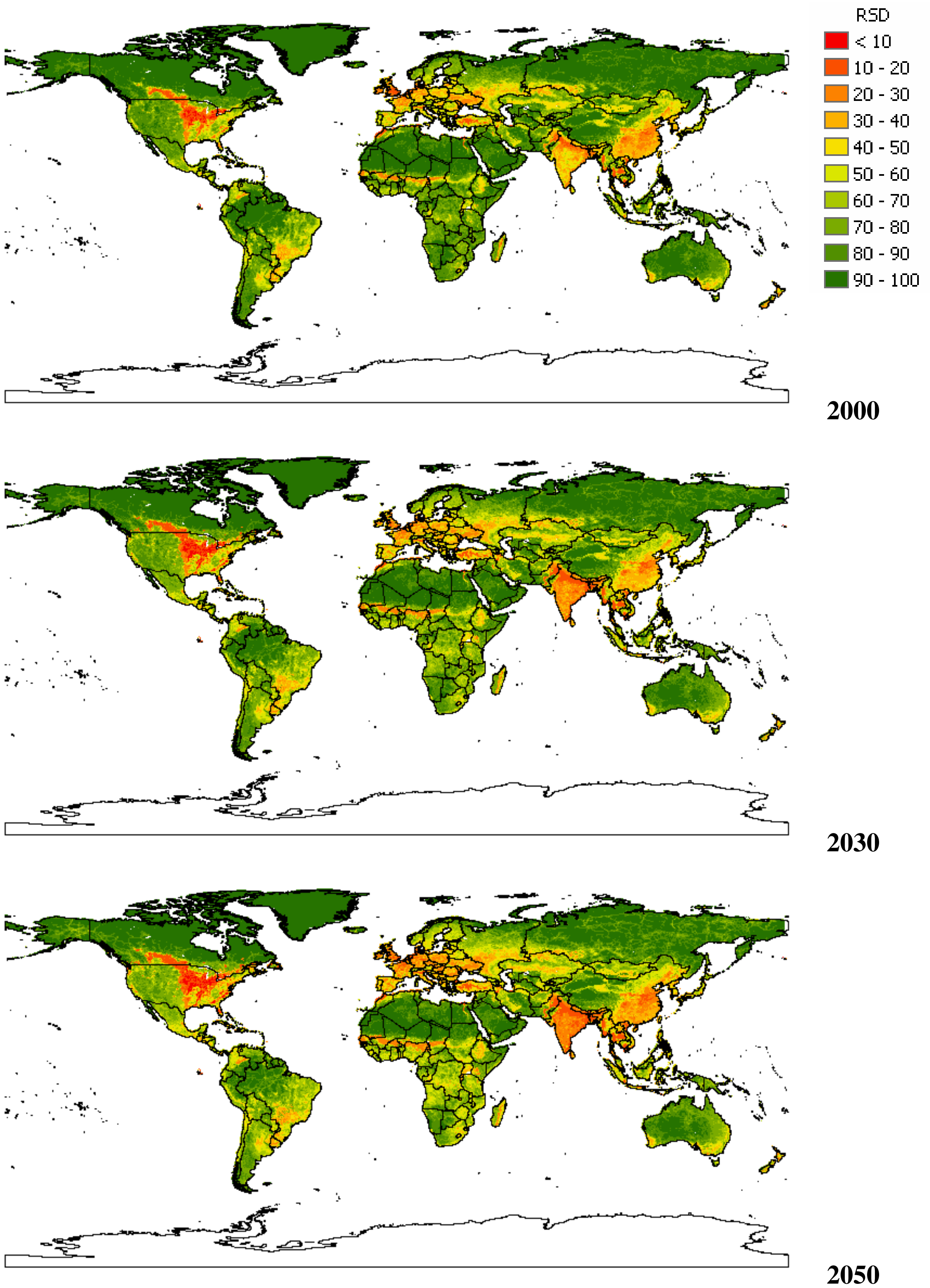


Figure 6: ***Global Maps on remaining species diversity (RSD) in the scenario period 2000-2050 (see Box 1 and 2 for further explanation on methodology and indicator scale).***

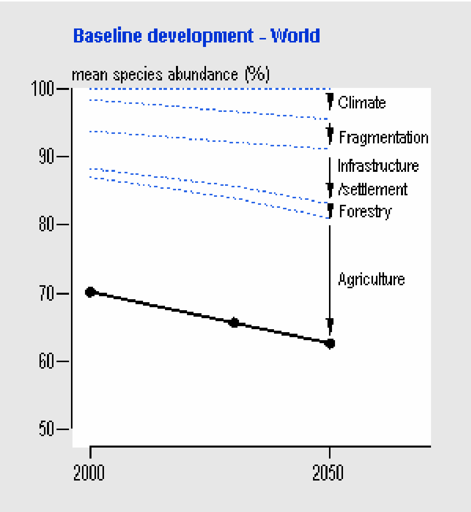


Figure 7a Development of mean species abundance in the baseline scenario from 2000 to 2050; and contribution to the decline per pressure.

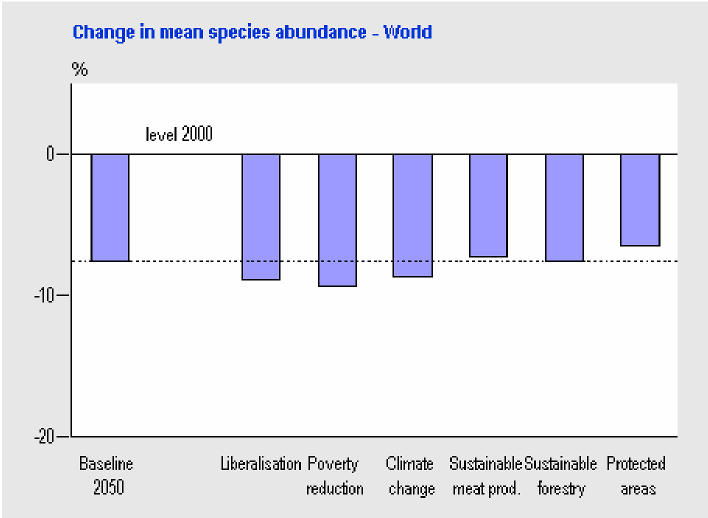


Figure 7b Decline in mean species abundance in the baseline development and options effects in 2050. The zero line represents the 2000 level; the dotted line represents the baseline 2050 level.

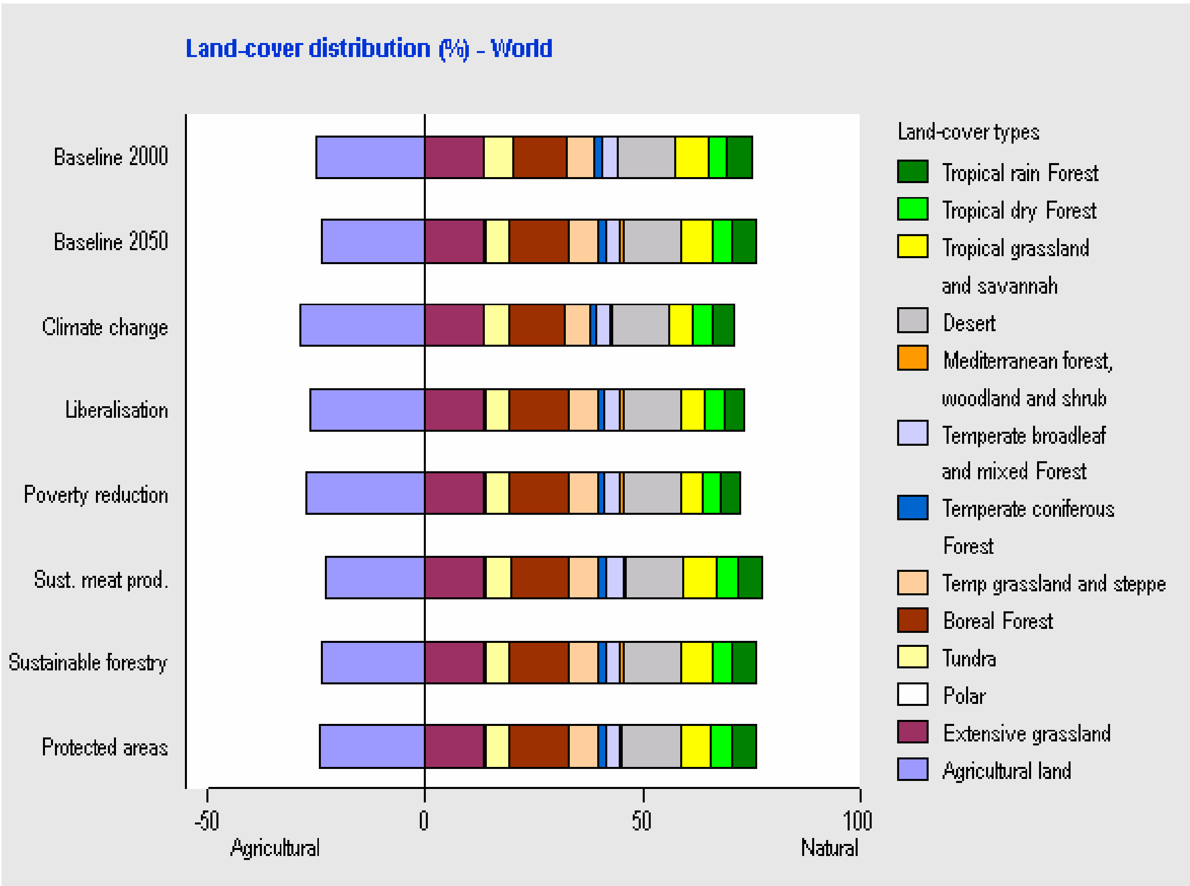


Figure 7c Distribution of land-cover types (in % of total world area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

Figure 7: ***Results for the World: baseline development (a); option effects on NCI (b) and land-cover (c)***

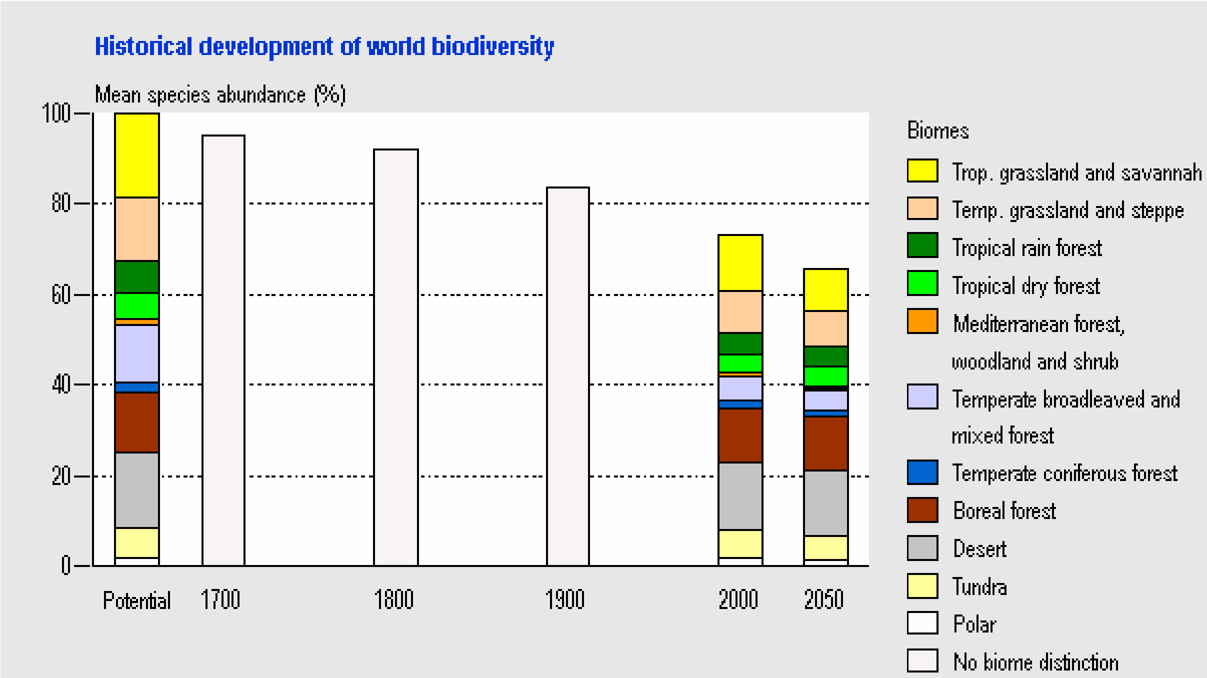


Figure 8: ***Trends in biodiversity from 1700 – 2050. Biodiversity is given in terms of mean abundance of the original species per natural biome. Biodiversity values of land-cover types that do not present a natural biome (arable land and extensively used grassland) are included in the(for the specific region) naturally occurring biome.***

4.2. Sub- Saharan Africa

4.2.1. Figures for Africa

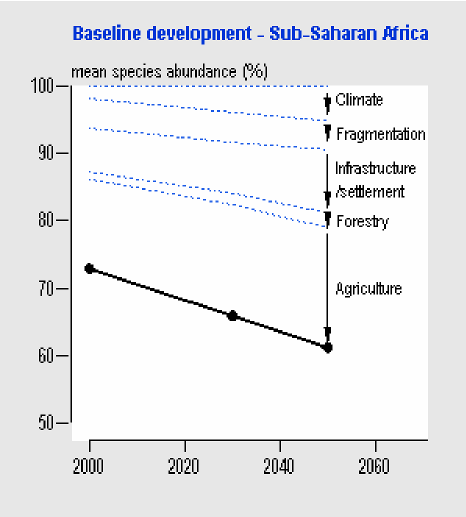


Figure 9a Development of mean species abundance in the baseline scenario from 2000 to 2050 and contribution to the decline per pressure.

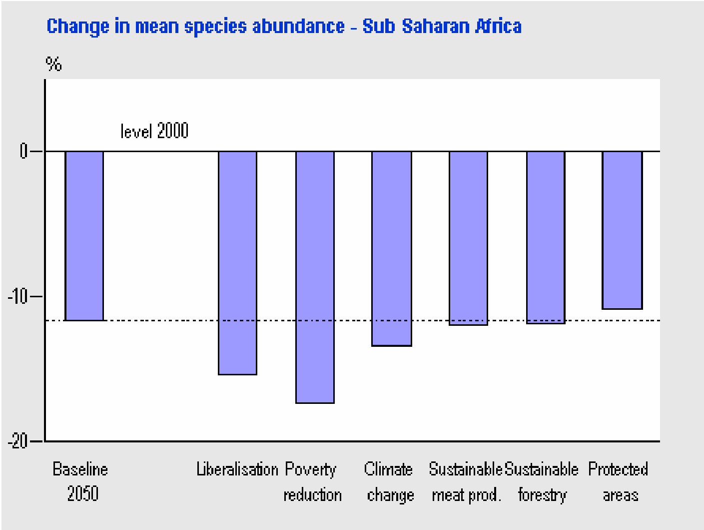


Figure 9b Decline in mean species abundance in the baseline development and options effects in 2050. The zero line represents the 2000 level; the dotted line represents the baseline 2050 level.

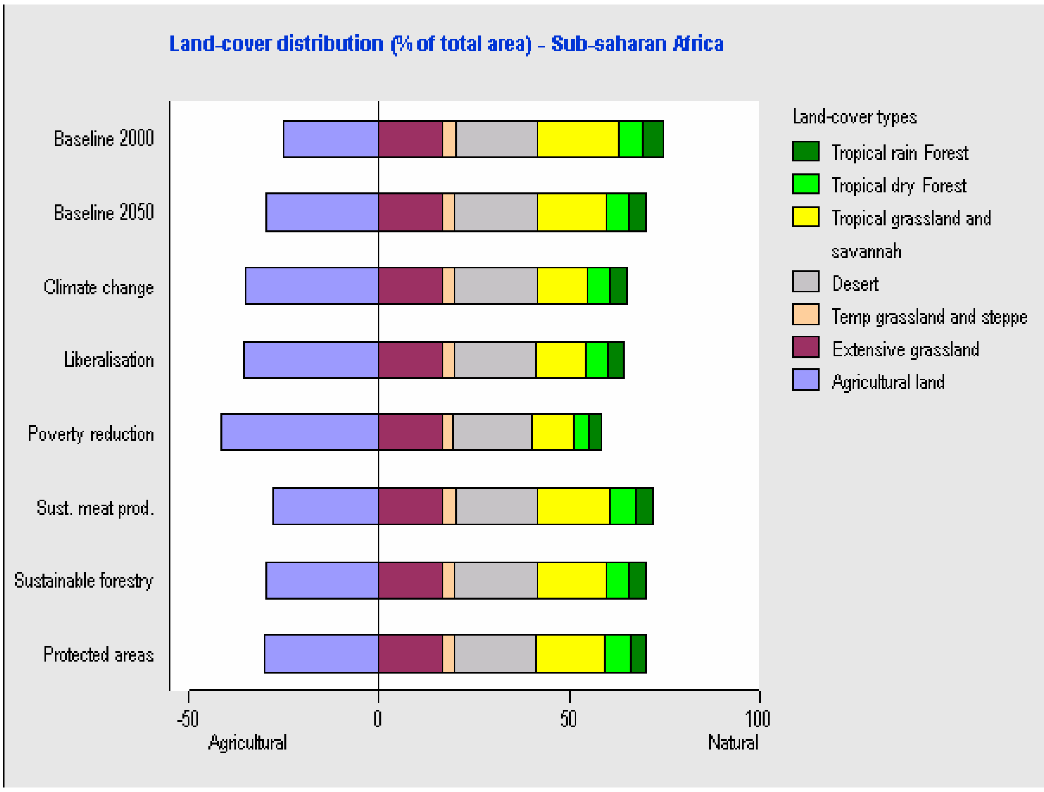


Figure 9c Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

Figure 9: ***Results for Sub-Saharan Africa: baseline development (a); option effects on NCI (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 liberalisation and poverty reduction lead to a significant further reduction of the remaining biodiversity (-3.7% and -5.7%, respectively). Increased agricultural production is the main driving force for both, leading to more conversion. Not surprisingly, tropical forest, grassland and savannah bear the burden, especially in case of poverty reduction.
- The negative effect of liberalisation 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 liberalisation. 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 bio-fuel production at the expense of tropical grasslands and savannah.
- In a climate regime with a global system of emissions trading, a fair burden-sharing rule might allocate a surplus of emission rights to Sub-Saharan Africa. 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 u**p to** 2050 and effects of options in 2050 compared to the baseline*

Options/ Issues	**Baseline**	**Liberalisation agricultural trade**	**Poverty reduction**	**Limiting climate change**	**Sustainable meat production**	**Sustainable forest management**	**Increasing protected areas by 20%**
Biodiversity	60.6%	-3.7%	-5.7%	-1.7%	0.2%	0.4%	0.8%
Cost[1]		++	+++	+	0	0	0
Poverty			+				
N-deposition	1.00	1.04	1.17	0.99	0.70	1.00	1.00

[1] 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

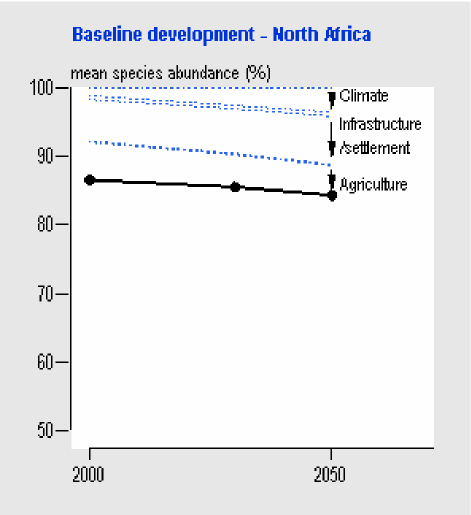


Figure 10a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

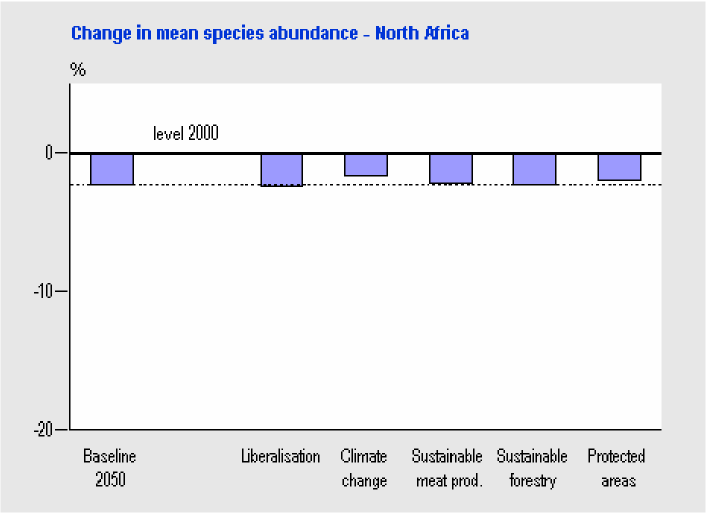


Figure 10b Option effects on mean species abundance. The zero line represents the 2000 level.

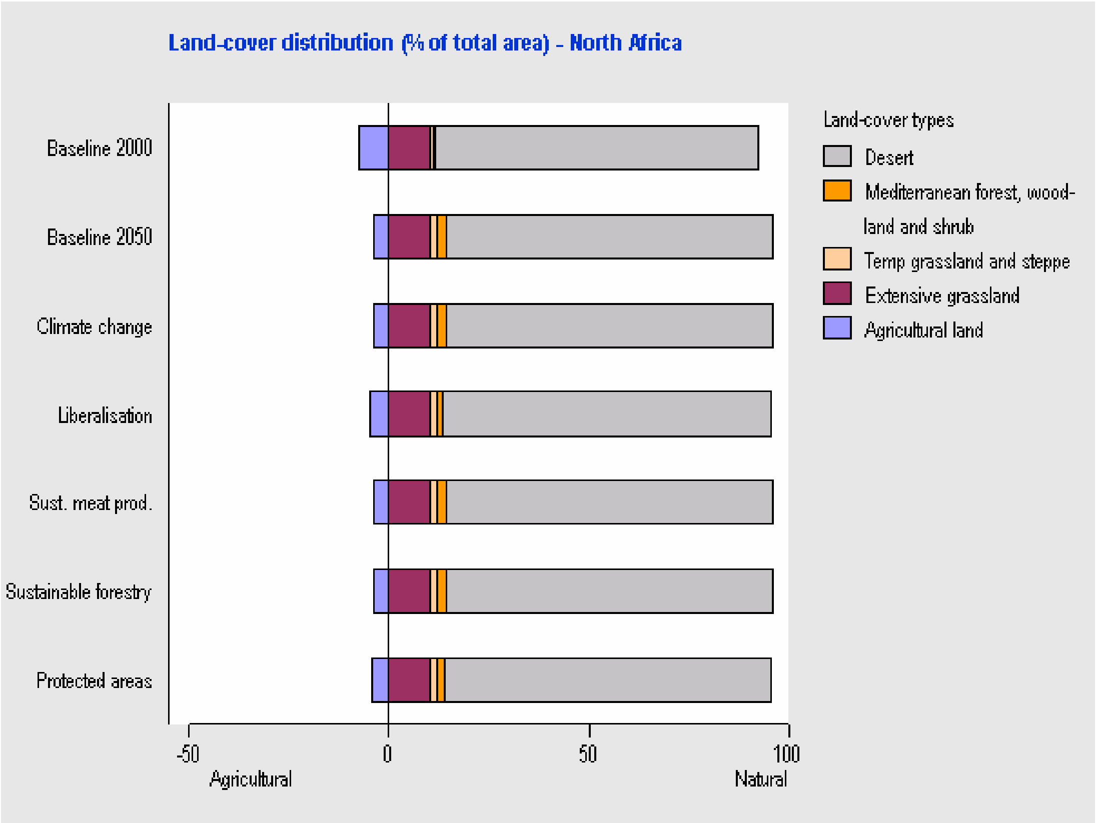


Figure 10c Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

Figure 10: ***Results for North Africa: baseline development (a); option effects on NCI (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 characterised 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 bio-fuel production or increased agricultural activities through market liberalisation.
- 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**	**Liberalisation agricultural trade**	**Limiting climate change**	**Sustainable meat production**	**Sustainable forest management**	**Increasing protected areas**
Biodiversity	84.2%	-0.2%	0.6%	0.1%	0.0%	0.2%
Cost[1]		++	– –	0	0	0
N-deposition	0.00	0.00	0.00	0.00	0.00	0.00

[1] 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

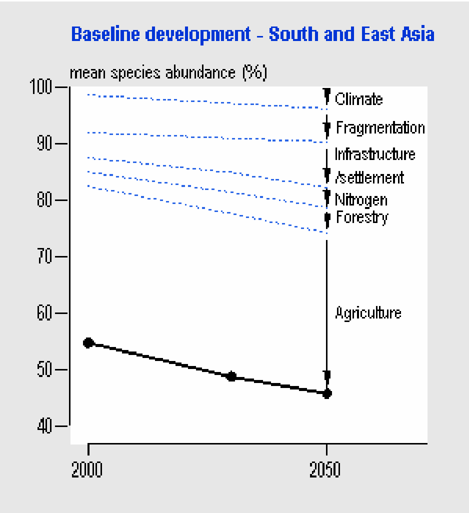


Figure 11a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

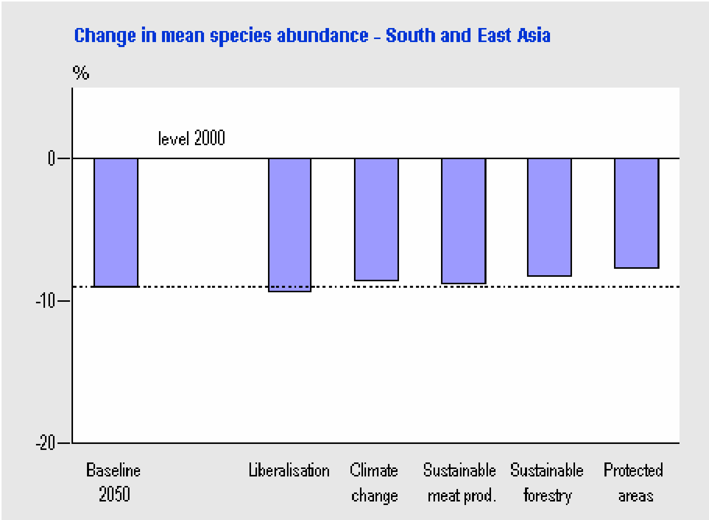


Figure 11b Option effects on mean species abundance. The zero line represents the 2000 level.

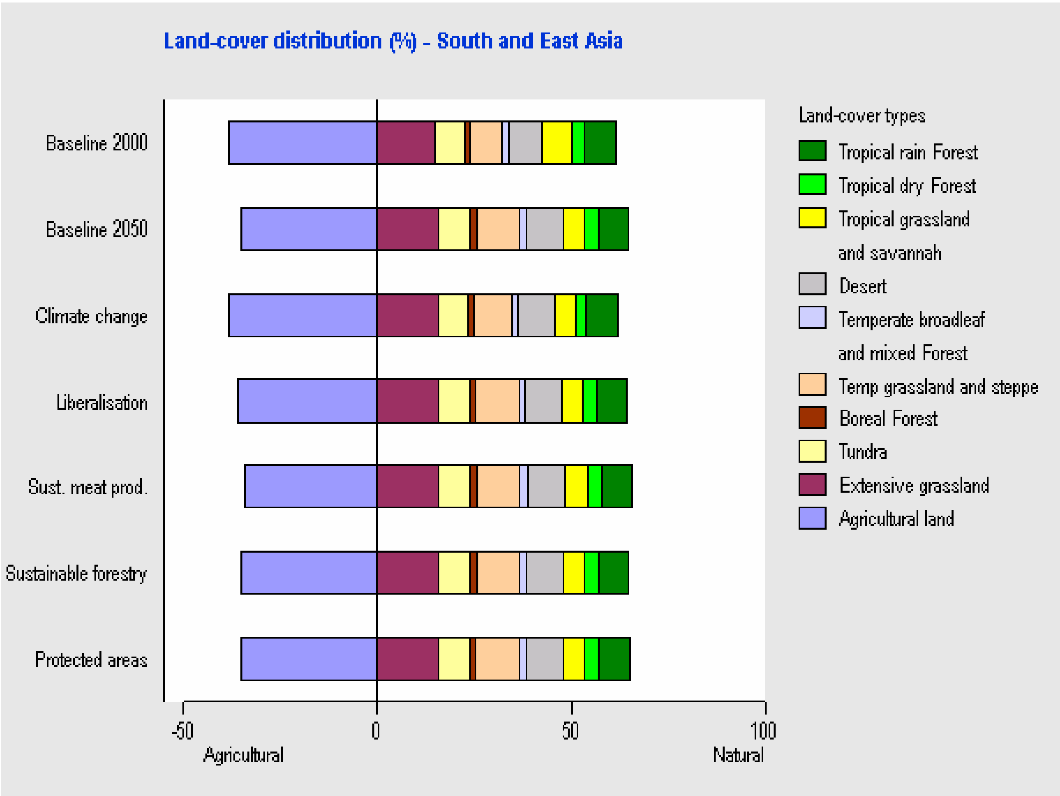


Figure 11c Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

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

4.4.2. Results for South and East Asia

<u>Baseline development</u>

- 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 development 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 a higher biodiversity value.

<u>Biodiversity effects of options</u>

- In the forestry option, Asia is able to effectively produce wood from large areas of plantation forest, thereby substantially reducing the yearly cut forest area. Exploitation of semi-natural forests is gradually declining, and forests can recover to their original biodiversity levels. The biodiversity increase is +0.8% by 2050. The effect will become stronger after 2050 as semi-natural forests take a long time to recover.
- In the climate mitigation option, China becomes an area for bio-fuel 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%).
- Liberalisation has negative effects on Asian biodiversity (-0.4%), which is comparable to what happens in Latin America and Sub-Saharan Africa. This is again mainly because of China, while room for production is made available through productivity increases.

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**	**Liberalisation agricultural trade**	**Limiting climate change**	**Sustainable meat production**	**Sustainable forest management**	**Increasing protected areas**
Biodiversity	45.8%	-0.3%	0.4%	0,3%	0.8%	1.3%
Cost[1]		+	0	0	0	0
N-deposition	1.00	1.01	0.55	1.00	1.01	0.99

[1] 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

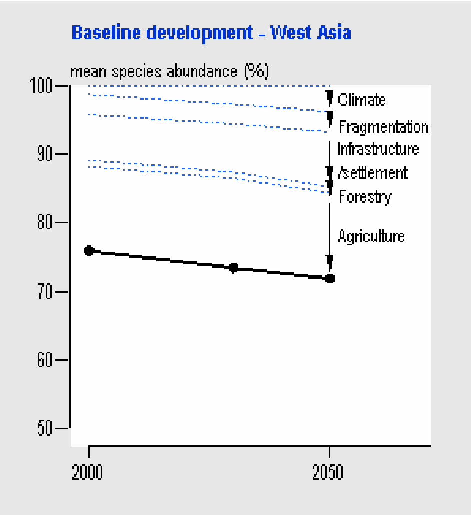


Figure 12a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

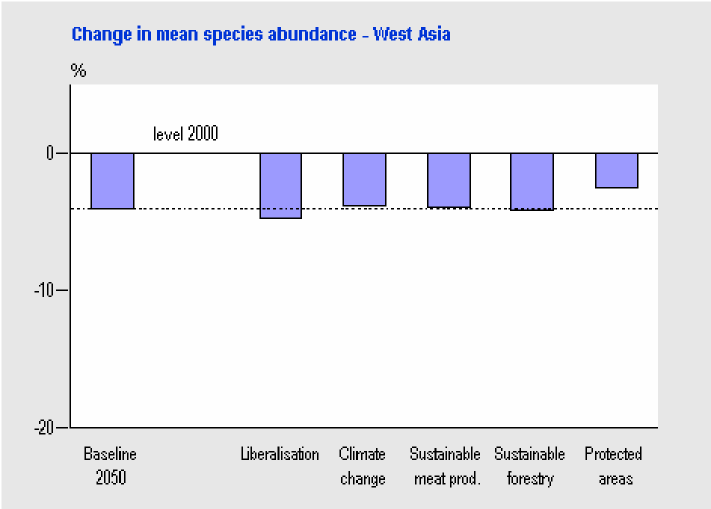


Figure 12b Option effects on mean species abundance. The zero line represents the 2000 level.

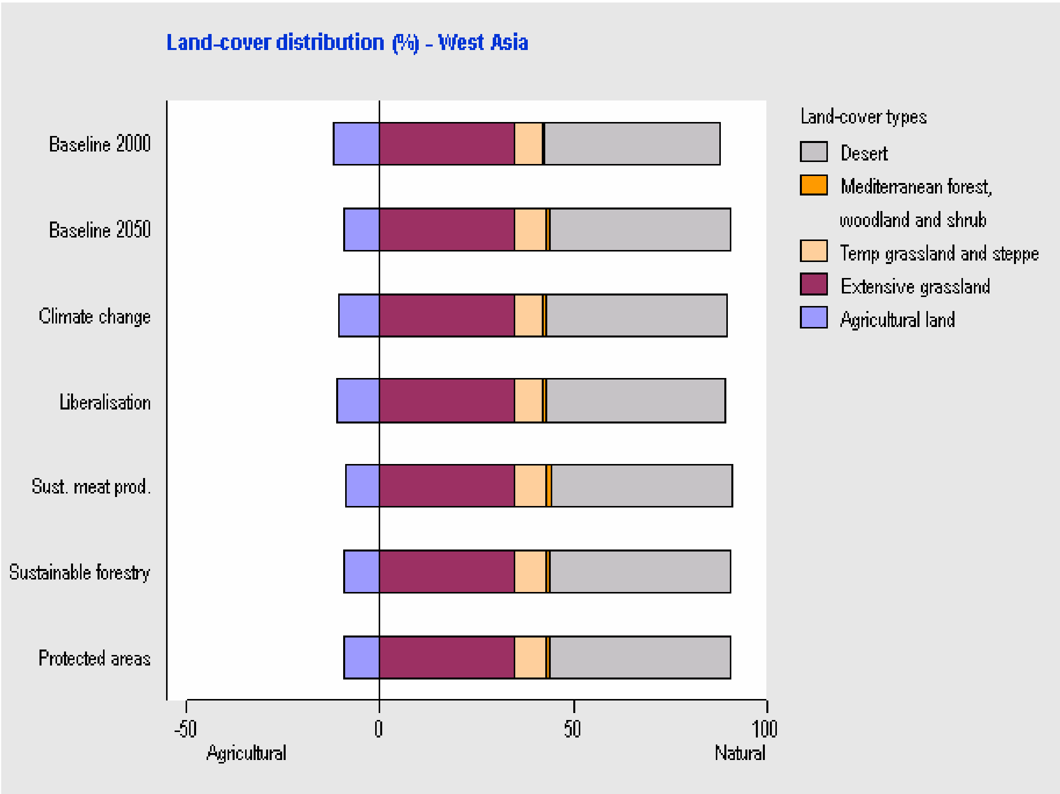


Figure 12c Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land-cover is presented on the left side, while the more natural land cover types are presented on the right side.

Figure 12: ***Results for West Asia: baseline development (a), option effects on NCI (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

- Liberalisation 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 bio-fuel 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**	**Liberalisation agricultural trade**	**Limiting climate change**	**Sustainable meat production**	**Sustainable forest management**	**Increasing protected areas**
Biodiversity	71.7%	-0.7%	0.2%	0.1%	0.0%	1.6%
Cost[1]		0	– –	0	0	0
Climate		0	– –	0	0	0
N-deposition	1.00	1.10	0.16	0.93	1.00	0.93

[1] 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

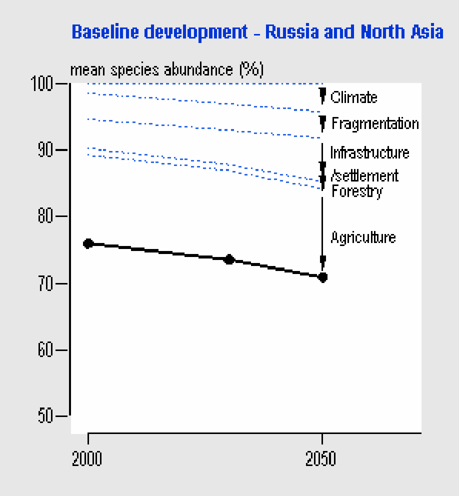


Figure 13a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

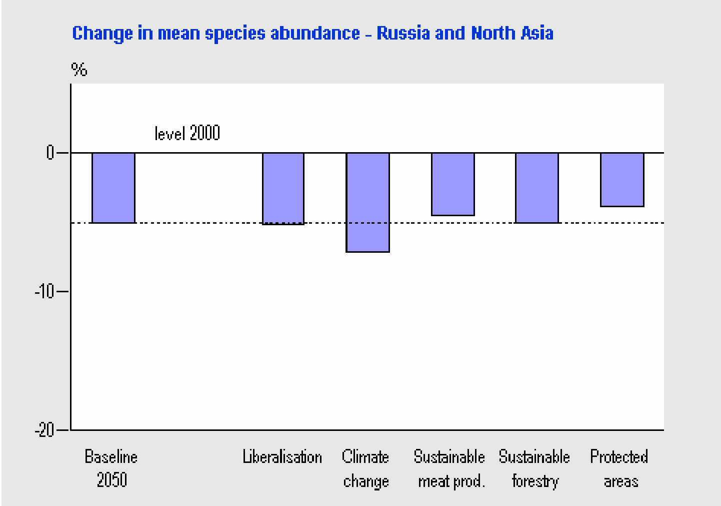


Figure 13b Option effects on mean species abundance. The zero line represents the 2000 level.

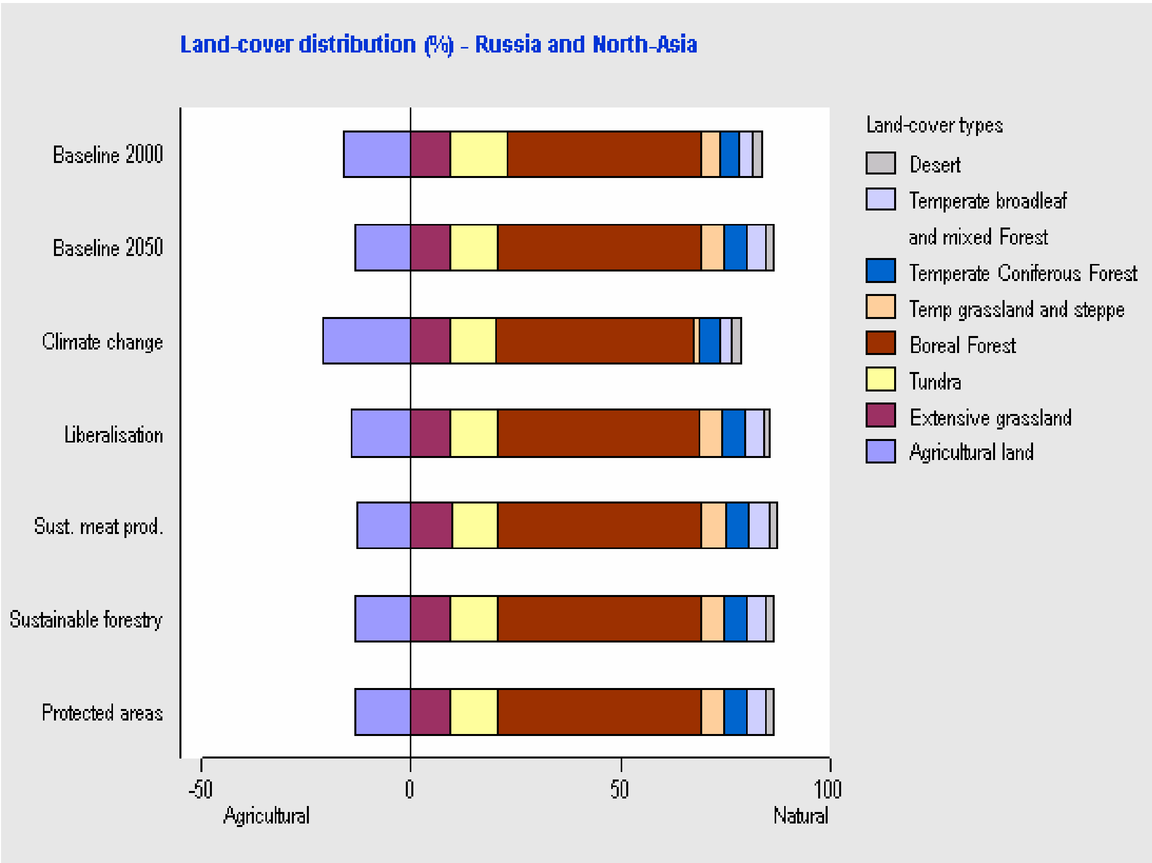


Figure 13c Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

Figure 13: ***Results for Russia and North Asia: baseline development (a), option effects on NCI (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 bio-fuel 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%).
- Liberalisation 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**	**Liberalisation agricultural trade**	**Limiting climate change**	**Sustainable meat production**	**Sustainable forest management**	**Increasing protected areas**
Biodiversity	71.2%	-0.1%	-2.0%	0.6%	-0.4%	1.2%
Cost[1]		+	–	0	0	0
N-deposition	1.00	1.08	0.20	0.95	1.00	1.02

[1] 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

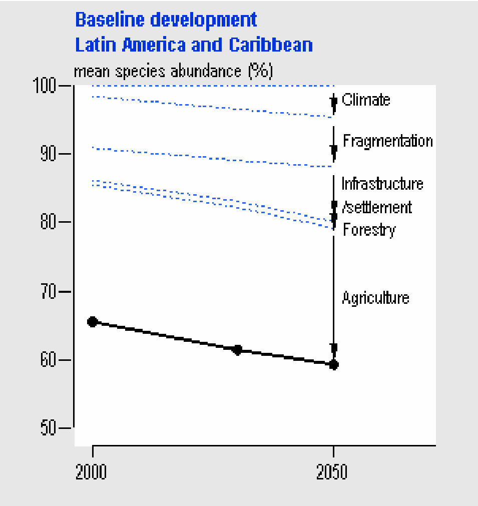


Figure 14a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

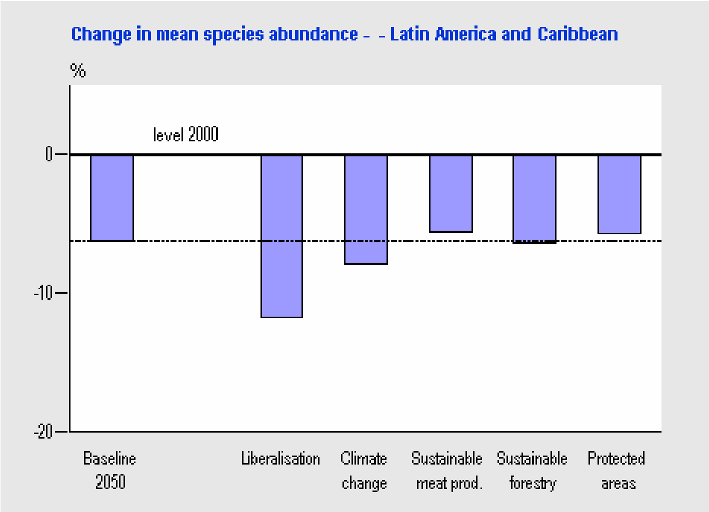


Figure 14b Option effects on mean species abundance. The zero line represents the 2000 level.

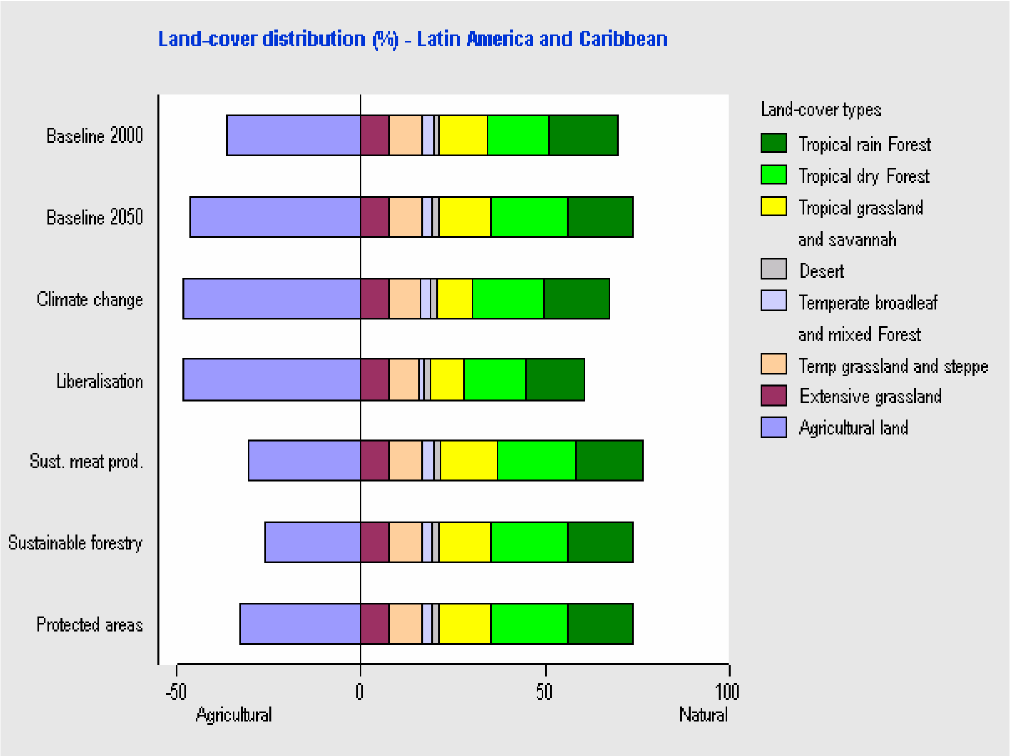


Figure Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

Figure 14: ***Results for Latin America and Caribbean: baseline development (a), option effects on NCI (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 it strong position in international agricultural markets. However, 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. Further, the production function for other regions is neglected. Increased trading in pulp and wood will put an additional pressure on the remaining vast tropical forest biome.

Effects of options

- Liberalisation of the agricultural market has by far the strongest effect in Latin America, reducing the biodiversity by -5.4%. Liberalisation induces a boost in “south-south-trade” in agricultural products, driven by low production costs and an ample supply of productive land. In Latin America, there is a strongly expansion of agriculture, and 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 bio-fuel. This leads to further land-use change, mostly in tropical grasslands and savannah, the preferred location for bio-energy 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	Liberalisation agricultural trade	Limiting climate change	Sustainable meat production	Sustainable forest management	Increasing protected areas
Biodiversity	59.0%	-5.4%	-1.6%	0.7%	0.0%	0.5%
Cost [1]		+	–	0	0	0
N-deposition	1.00	1.15	0.78	0.99	1.00	0.99

[1] 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

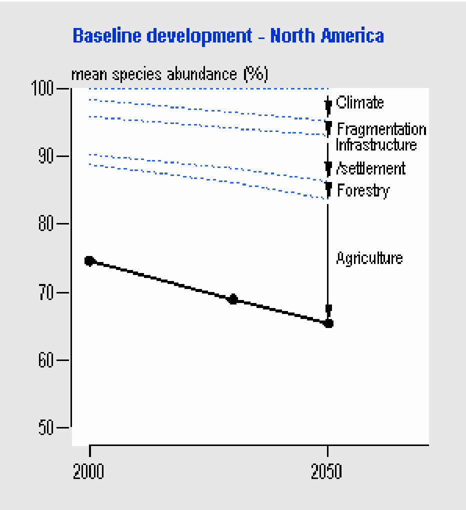


Figure 15a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

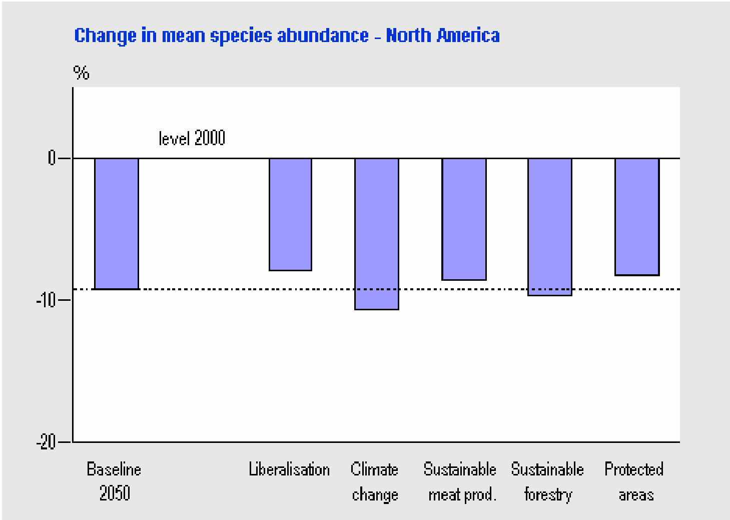


Figure 15b Option effects on mean species abundance (in %). The zero line represents the 2000 level.

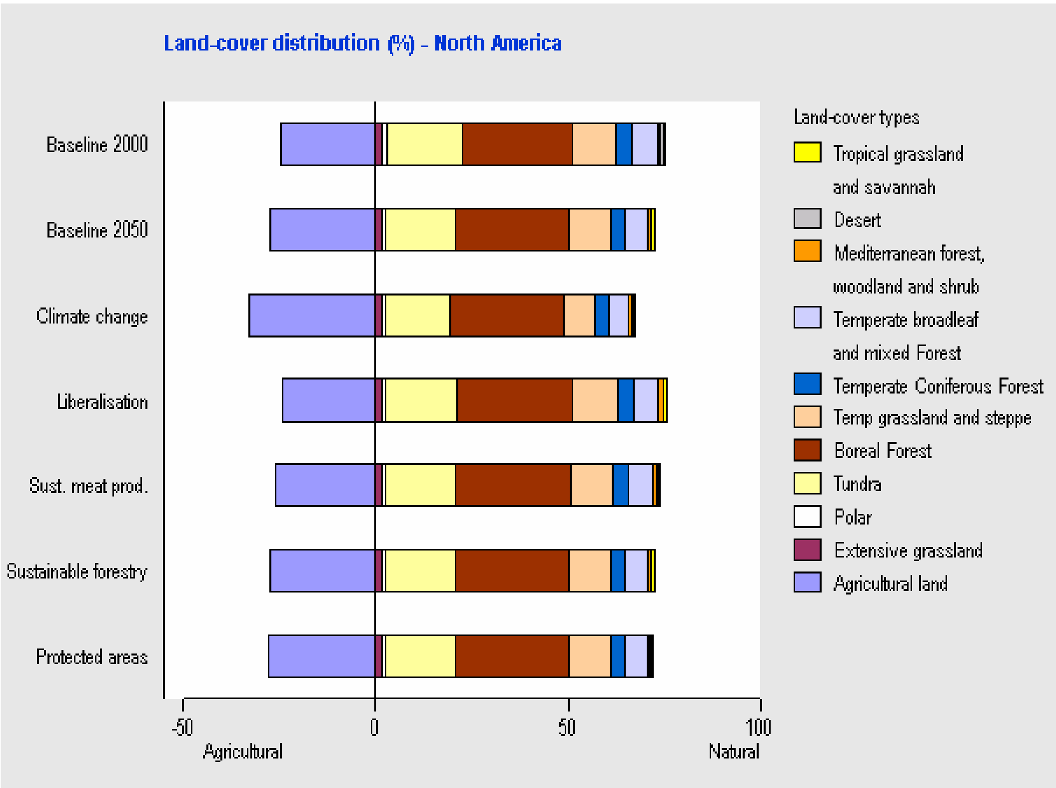


Figure 15c Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

Figure 15: ***Results for North America: baseline development (a), option effects on NCI (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 is more limited than in 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

- Liberalisation 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 bio-energy production is utilised. 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, has 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	Liberalisation agricultural trade	Limiting climate change	Sustainable meat production	Sustainable forest management	Increasing protected areas
Biodiversity	65.6%	1.4%	-1.5%	0. 7%	-0.3%	1.0%
Cost[1]		0	– –	0	0	0
N-deposition	1.00	0.88	0.01	0.95	0.99	0.99

[1] 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

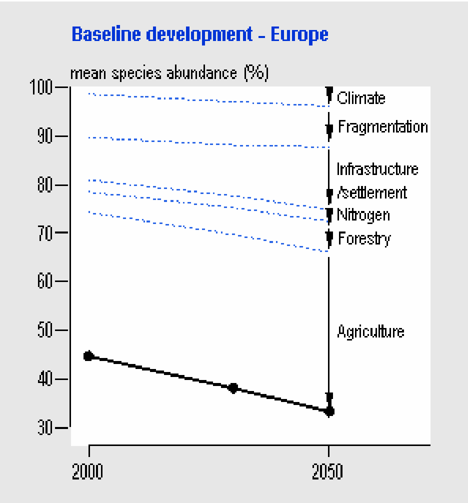


Figure 16a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

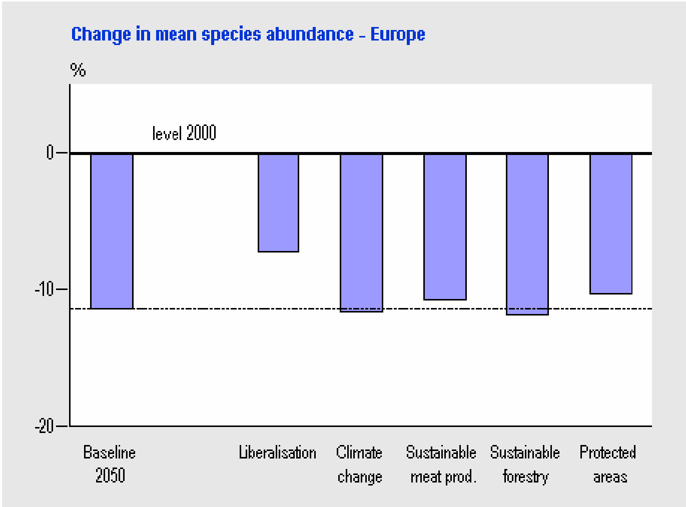


Figure 16b Option effects on mean species abundance (in %). The zero line represents the 2000 level.

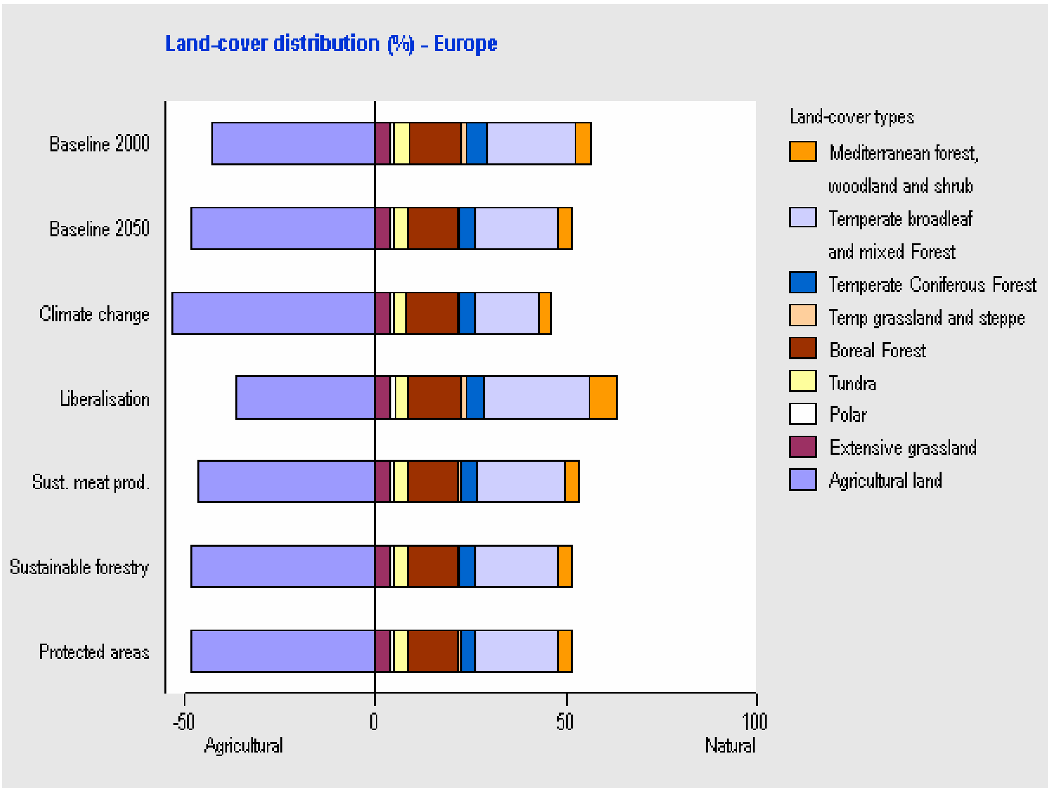


Figure 16c Distribution of land cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land cover types are presented on the right side.

Figure 16: ***Results for Europe: baseline development (a), option effects on NCI (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 affluent and 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[12].
- Several of the distinguished pressure factors contribute to this further biodiversity loss: climate change, infrastructural development and settlement, 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

- Liberalisation 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 biggest improvement.
- Relatively modest volumes of bio-fuel production, relative to the energy consumption, emerge in the climate mitigation case. Suitable land is scarce and 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 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 therefore leads to additional habitat loss that is not yet counteracted in 2050 by biodiversity gains in slowly restoring forests.

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**	**Liberalisation agricultural trade**	**Limiting climate change**	**Sustainable Meat production**	**Sustainable forest management**	**Increasing protected areas**
Biodiversity	33.7%	4.2%	-0.2%	0.6%	-0.6%	1.1%
Cost[1]		0	– –	0	0	0
N-deposition	1.00	0.91	0.36	0.98	0.99	0.99

[1] 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%)

[12] It should be noted that the conversion of forest to agricultural land in the baseline is questionable. Nevertheless it is a consistent part of the scenario. If no conversion take place this will be compensated by conversion in other regions. Given the main goal of this study, being the evaluation of policy options and not the development of a "perfect" baseline this is not a limitation for the use of this study.

4.10. Oceania incl. Japan

4.10.1. Figures for Oceania

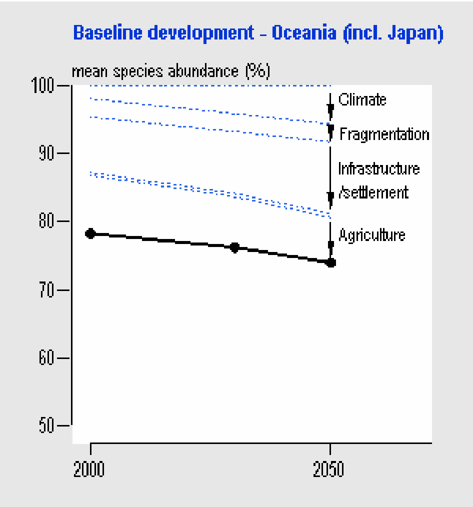


Figure 17a Mean species abundance development in the baseline scenario, with shares in decline per pressure.

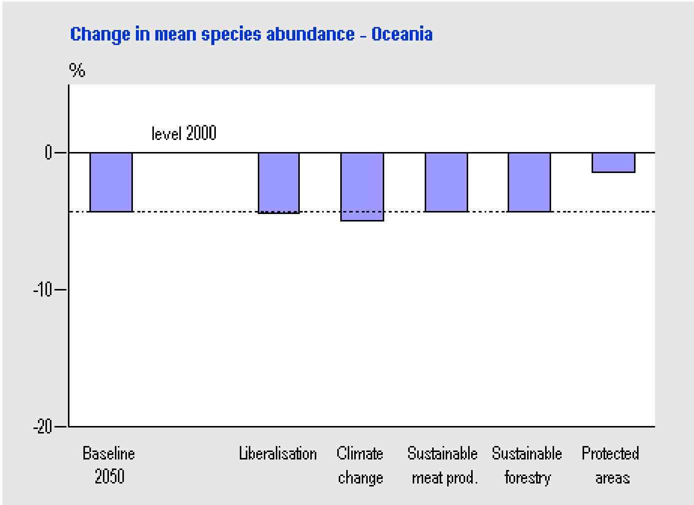


Figure 17b Option effects on mean species abundance (in %). The zero line represents the 2000 level.

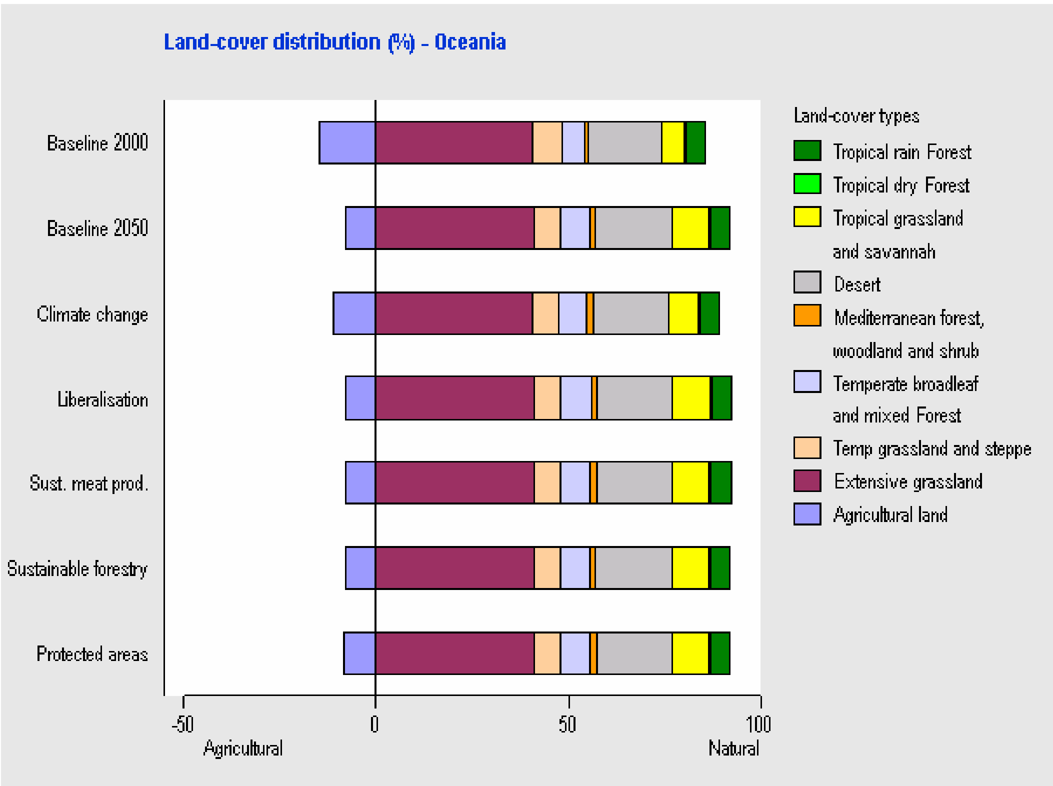


Figure 17c Distribution of land-cover types (in % of total regional area) in the baseline scenario and for the options in 2050. Agricultural land cover is presented on the left side, while the more natural land-cover types are presented on the right side.

Figure 17: ***Results for Oceania: baseline development (a), option effects on NCI (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.
- 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 arable land disappearing 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 bio-fuel production, mainly at the expense of savannah. This increased land-use counteracts the positive effect of climate measures.
- Liberalisation 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 wood 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**	**Liberalisation agricultural trade**	**Limiting climate change**	**Sustainable meat production**	**Sustainable forest management**	**Increasing protected areas**
Biodiversity	73.8%	-0.1%	-0.6%	0.1%	0.0%	2.9%
Cost[1]		+	– –	0	0	0
N-deposition	1.00	1.00	0.00	0.94	1.00	1.03

[1] 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

There are numerous sources of uncertainty that influence the outcome of this analysis, ranging from problem framing, indicator selection, data imprecision, model uncertainties (model parameters and structure, and dose-response relationships), to scenario and option assumptions (ignorance on future developments). These 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. 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.

Main uncertainty message: The key finding for the decline of global biodiversity (7% decrease between 2000 and 2050) is probably an underestimation of the future decline, as the explored scenario is optimistic on agricultural productivity increases. Taking more scenarios into account can shed light on this subject. Most of the options show exaggerated effects, either to the positive or negative side. Not yet known is what the combined effect of options will be. Such an elaborate task demands many different assumptions on combined policy effects.
The used biodiversity proxy indicator combines biome areas with biome quality (in terms of mean species abundance), which make it possible to assess land-use dynamics and impacts of pressures. Other biodiversity indicators 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.
Regional declines in biodiversity and land-cover 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). Changes in land-cover are the result of land allocation rules, and implementing different rules (for instance, making more use of marginal grounds) will result in different shifts.

5.1. Main findings

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 characterised 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 the range that would result from assessing alternative scenarios. The scenario analysed probably presents 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.

Most of the options have an extreme design that overestimates the effects on biodiversity; however, options do not all follow general directions. Negative consequences for biodiversity are overestimated in the options on liberalisation and poverty reduction. 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. If this were to result in a higher deployment of bio-fuels to compensate climate impacts, it would lead –in turn- to higher biodiversity impacts due to habitat loss. The biodiversity-saving potential of sustainable forest plantation is probably underestimated for timber productivity of (semi)natural forests, which is assumed[OK?]. higher than current FAO figures. The effect of forestry (or better: wood exploitation) is also underestimated for deforestation is attributed to agricultural expansion. The negative impact on biodiversity of bio-fuel crops and wood plantations due to habitat loss might be overestimated. The model assumes entire restoration of the original biodiversity after an area has been abandoned. However, in practice not all abandoned land will be restored naturally. If wood plantations and bio-fuel crops are established on these degraded lands this might reduce the impact or even slightly improve biodiversity. In the climate mitigation option bio-fuel crops (20%) were allocated as much as possible in abandoned land. An analysis of option combinations would be a valuable addition to the present study.

5.2. Problem framing

The present analysis is performed according to the CBD assignment (see Annex 2). 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. A complete analysis of different future scenarios, including 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 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. Indicator choice

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 km^2 of each biome contributes equally to the regional or global MSA. If the biomes were weighted on their species richness (weighted MSA), converting a tropical rain forest would probably have more impact than converting grasslands in the same region. Preliminary calculations based on species richness figures from Rodrigues *et al.* (2004a, b), WWF (2006) and Kier *et al.* (2005) show indeed that the impacts on biodiversity at the global level are more severe in both the baseline and policy options. This indicates that human impact is higher in species-rich tropical and temperate zones than in species-poor boreal and polar regions. Remarkable regional changes occur. Weighted-MSA values are lower for all regions than non-weighted MSA values, except for South America, indicating that the relative species-rich Amazon region remains relatively untouched. Based on these preliminary results, we conclude that the main findings do not change significantly when applying weights.
- shows the value of the original species abundance that can occur under natural conditions (climate and soil) as 100%t. The consequence of this choice is that all change due to human interference, except restoration and mitigation, leads to lower indicator values. Not all indicators behave this way. For instance, species-richness can increase due to human interference in specific situations.

Other indicators

- Another often used biodiversity indicator is species richness. This indicator would probably be less sensitive to the homogenisation process. It can be expected that in some regions species richness on local levels will be stable or will increase during the coming decades, as a result of the introduction of many new species due to human activities. New species will become more and more abundant, partly replacing original species without necessarily leading to complete extinction. Consequently the species richness will increase at the local, national and regional level. The homogenization process was observed in 100 years of industrialisation and demographic growth in the Netherlands (Ten Brink *et al.*, in prep.).

- Another often used indicator is the "number of threatened and extinct species". As the status of threatened species depends on both the threat 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 declines when pressures on ecosystems increase due to the limited distribution areas. We expect similar changes as mean species abundance (MSA) but less profound (lags behind).
- Change in the "number and abundance of endemic species" is expected to behave similar as change in threatened species. Both species groups have generally small distribution areas (by definition), making them more vulnerable to habitat loss and the process of homogenisation.

5.4. 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 characterised 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, bio-energy production and forest 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, selective 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 ±20% or ±40% of the mean (triangular distribution for ±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 (± 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 ± 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

5.5. 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 below). 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. 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.

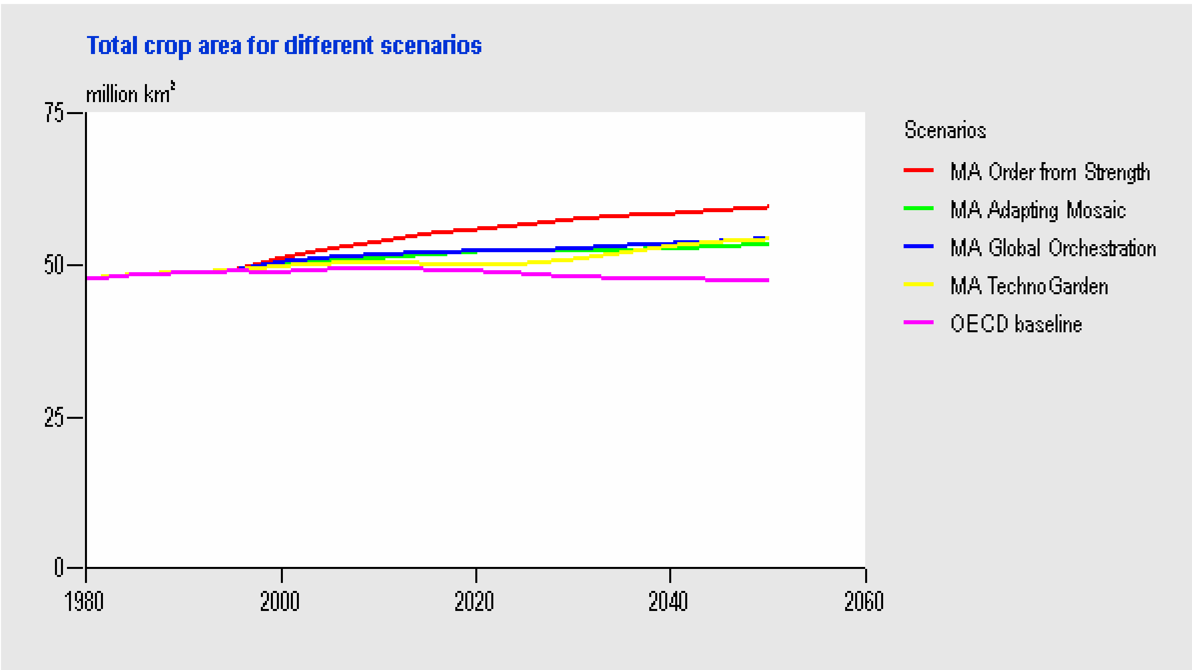


Figure 18: ***Total world crop area for the different MA scenarios, compared with the OPECD baseline used in the present analysis. The OECD baseline uses less area for food production than the MA scenarios (up to 20%).***

5.6. Options and assumptions

Liberalisation option sensitivity

The liberalisation 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 materialise 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 liberalisation are probably smaller as the process will take place along more smoothened 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 liberalisation 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-case 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 bio-energy in mitigation strategies.

In the option analysis we adopt the central assumption that the mean global temperature will increase by 2.5 ^{o}C in response to a doubling of CO_2 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 bio-energy 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, 2001a). 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 bio-energy 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 bio-energy production could occur if competing options are cheaper and more abundant than assumed here.

Finally, if the productivity of agricultural land-use can be further improved, more abandoned land will become available for energy production, with a positive effect on biodiversity. 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.

Sustainable forestry option sensitivity

Plantations are assumed to become established on areas occupied by (semi-)natural forests (deforestation), and not on abandoned land or land in agricultural use (reforestation and afforestation). This practice does not take place according to the sustainability criterion ("FSC-principle 10"). Using only available "free" land (for reforestation and afforestation), will reduce the impact of plantation establishment on the forest biome.

Relatively high standing stocks are used for the semi-natural forests, according to the IMAGE model data. This leads to high yields and corresponding low required areas of semi-natural forest, especially in the baseline. Using lower yields will lead to a higher biodiversity loss in the baseline and, therefore, the plantation option will have a larger effect.

The extent to which burning forest biomes takes place in conversions processes is unknown and will differ strongly between regions. The assumption 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 into account in the forestry option will decrease the area of required production forest and will also reduce the considerable CO_2-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. 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). Total effect is additional use of semi-natural forests in exporting countries, and maybe a less efficiency production improvement through slower investment in the plantation establishment. Altogether, we have assumed mostly conservative assumptions. 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 the 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. In this option, suggested areas for expansion of the network are based on congruity of available existing maps and prioritisation schemes, focused on representation of ecosystems, species, species richness and endemicity. Key uncertainties are effectiveness of management, rate of establishment and location.

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 in protected areas.

Protected areas will be restored to a more natural state through natural succession or human-induced nature development. Effects from climate change and existing infrastructure are taken into account. 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.

Altogether, this means that designating 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 underestimated. 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. Consequences are the effects of correcting for the aforementioned uncertain or ignored factors (assumptions); + means less biodiversity loss; - means more biodiversity loss.

Option	**Assumptions and uncertainties**	**Consequences for baseline biodiversity**	**Consequences for option biodiversity**
Liberalisation 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	??
Forestry option	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	-	-
	More detailed maps	+ ?	+ ?

Annex 1: Description of baseline and policy options

1. Liberalisation 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 on the long-term (WTO, 2001).

Description of the policy option
Liberalisation of trade will have environmental consequences, which might be positive or negative for a region. Positive environmental effects of trade liberalisation 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.

The consequences of trade liberalisation for biodiversity are therefore uncertain and 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 liberalisation will also impact the agricultural practices through intensification of food production, leading to an increased use of fertiliser, impacting quality of nature. The combined effect of trade liberalisation on biodiversity will be assessed for the main global regions.

The economic costs and benefits of trade liberalisation 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 rate 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 liberalisation is considered one the most efficient ways to eradicate poverty. However, most of the studies recommending trade liberalisation 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 liberalisation are calculated at the macro economic - country level of scale. Economic growth at this level cannot directly be translated into improved socioeconomic conditions of the (extreme) poor. We assume for this policy option that negative effects of trade liberalisation on human wellbeing are eliminated by way of government control in case of large-scale production investments in rich natural recourse base as well as extra measures to avoid isolation from market integration of poor people dependent on a low quality natural resource base.

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.
An intensive investment program should directly confront high transportation costs, low agricultural productivity, high disease burden, the weak infrastructure and poor educational attainment.

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

- Liberalisation 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[13].
- Gradual increase in labor 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.

[13] Effect on GDP per capita of implementing MDGs in Sub-Saharan Africa is based on projections in Millennium Project (Millennium Project, 2004).

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, 2001a) 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 recognised risks associated with climate change have resulted in the UN Framework Convention on Climate Change, 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 stabilisation of the greenhouse gas concentration at 450 CO_2-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 exists including energy efficiency improvement, carbon capture and storage, nuclear power, renewable power, reduction of non-CO_2 emissions, carbon plantations and bio-energy (see Metz and Van Vuuren, 2006). The last two options require – next to other sources such as waste- the use of substantial amounts of land for bio-fuel crops. Nevertheless, the use of bio-energy is among the most promising options to reduce emissions. Here, we explore a scenario that uses a very substantial amount of bio-energy 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.*, in prep.). In 2050, the total amount of modern bio-energy used is about 150 EJ – while total energy amounts to about 650 EJ. Compared to other studies, this scenario can be characterised as bio-energy intensive (see e.g. Berndes *et al.*, 2004).

The bio-energy intensive climate policy will change the future biodiversity state directly and indirectly in various ways:

- The magnitude of changes in relevant climate parameters (temperature, precipitation, CO_2 concentration) and thus of associated ecosystem effects will be smaller than in the baseline. The rate of temperature change, an important factor for the possibilities to adapt to climate change, may initially go up however as a result of less sulphur emissions as fossil fuel burning is decreased.
- But also habitat loss, the most prominent pressure on natural ecosystems, will be changed. Firstly, because the substantial use of bio-fuels and carbon plantation in this

scenario leads to additional claims on land for growing biomass resources or growing trees. Secondly, climate effects on agricultural productivity and other determinants of land cover change like water erosion will be smaller (positive or negative for biodiversity). The impact on agricultural yields directly leads to somewhat lower yields on average globally.

The extra costs of the climate policy are estimated by van Vuuren *et al.* (in prep) 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 1-4% of world GDP for stabilising greenhouse gas concentrations in the order of 450-550 ppm CO_2-equivalent (IPCC, 2001b, 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. Sustainable forest management

Baseline development
As a baseline, no incentives are present to create forest plantations. Demand for industrial round wood and traditional wood fuel will be supplied from 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 conversion to agricultural uses and 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.

Forest policy options
The 1992 CBD action-program includes promoting sustainable use of biodiversity, which encompasses sustainable forestry. International coordinated policy processes that directly influence imports and consumption 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, such as CITES, are in danger; turtle and shrimp case). Therefore, actions to promote sustainable forest management, such as the promotion of sustainability trademarks, are voluntary and consumption driven.

Implementation of the CBD-target on forestry is placed with the collaborative parties, under the UN Forum on Forests (UNFF). 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 forest plantations. 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. This type of labelling is voluntary, as more strict application of labels by importing countries are said to interfere with WTO trade liberalisation rules.

Forest management option
The forestry option is directed at supplying wood from forest plantations, thereby removing the pressure on the remaining natural and semi-natural forests. This option is taken, as intensively managed wood plantations have a much higher production potential (10-25 times) than (semi-)natural forests with a sustainable wood-cutting regime. From the viewpoint of minimizing biodiversity loss, production from sustainable managed forests (rotation, selective and reduced impact logging) is not efficient enough.

Therefore, a high plantation establishment scenario is implemented (adapted from Brown, 2000). For the GBO2 study, the plantation establishment is maximised to illustrate the biodiversity saving potential of the option. Wood supply from the high plantation growth scenario is supplemented by wood from managed natural and semi-natural forests, until 2050 when plantations supply the major part of the global demand.

The most significant forest 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 forest 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 standardise. On a macroeconomic scale the costs of sustainable forest management will not show. Even in countries with a relatively strong forestry sector, the value added of forestry is below 2 percent of GDP (FAO, 2004). However 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 Convention on Biological Diversity (CBD) Conference of Parties 7 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.”

The Decision 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, 2004b).

For protected areas two options have been used: extension of the PA network to a cover at least (1) 10% and (2) 20% of each ecological region. For the IMAGE-GLOBIO model can only 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).

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 (Balmford *et al.* 2003, Bruner *et al.* 2004; Blom, 2004; UNEP-WCMC, 2005). 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: Assignment

Convention on Biological Diversity | Secretariat

Ref.: SCBD/STTM/RH/50399 | 30 September 2005

Subject: Preparation of solution-oriented scenarios for the second edition of the Global Biodiversity Outlook

Dear Professor van Egmond,

The second Global Biodiversity Outlook, which is currently under preparation, will provide an assessment of progress towards the 2010 target of a significant reduction in the rate of biodiversity loss at the global level. It will also help to communicate effectively trends in biodiversity related to the three objectives of the Convention. To achieve this, the document will include a section on the prospects for biodiversity in the future, which is based on scenarios, including some your institution has contributed to.

An area that is not adequately elaborated concerns scenarios on combinations of realistic options to curb biodiversity loss, i.e. measures that decision makers can initiate and promote and the associated outcomes for biodiversity. I understand that the IMAGE/GLOBIO model framework is capable of producing scenarios that evaluate policy options and calculate associated biodiversity impacts.

Following discussions of my staff with colleagues at your agency responsible for the project on International Biodiversity as well as with experts at the World Conservation Monitoring Centre of the United Nations Environment Programme, I would appreciate if MNP could calculate such scenarios for the second Global Biodiversity Outlook and possibly other products. I attach for your perusal the draft terms of reference for an agreement for this initiative.

I look forward to our collaboration in this important field and wish to thank you for your continued support to the implementation of the Convention.

Sincerely yours,

Hamdallah Zedan
Executive Secretary

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Annex

Terms of Reference

Preparation of IMAGE/GLOBIO scenarios for the second Global Biodiversity Outlook

Background

At its seventh meeting, the Conference of the Parties to the Convention on Biological Diversity requested the Executive Secretary, with the assistance of the World Conservation Monitoring Centre of the United Nations Environment Programme and other relevant international organizations, to *inter alia* prepare the second Global Biodiversity Outlook for publication prior to the eighth meeting of the Conference of the Parties following peer review and review by the Subsidiary Body on Scientific, Technical and Technological Advice at its tenth or eleventh meeting. The second Global Biodiversity Outlook should provide an assessment of progress towards the 2010 biodiversity target at the global level and communicate effectively trends in biodiversity related to the three objectives of the Convention, based on the focal areas listed in paragraph 1 of the present decision, and making use of the indicators listed in annex I below that are successfully developed and tested, information provided in the national reports, as well as information provided by international organizations.

A draft of this document has been prepared and circulated for a first round of review in early September. The absence of concrete options for realistic measures that decision makers might take and the corresponding biodiversity outcomes has been noted as a shortcoming in the section on biodiversity scenarios. This gap can be partly addressed using the IMAGE/GLOBIO model developed by MNP, UNEP-WCMC and UNEP-GRID Arendal.

Work to be undertaken

1. On the basis of IMAGE/GLOBIO scenario calculations, the Netherlands Environmental Assessment Agency (MNP) explores at the global level, regional level and/or major ecosystem type level (biomes) different scenarios directed on finding combinations of quantified and geo-referenced measures/policies which could make significant contributions towards the achievement of the 2010 biodiversity target, with a view on the long term effects with a time horizon of 2050. The scenarios would in particular involve a baseline scenario and various policy options as variation on the baseline. The baseline scenario involves projections of the following variables: climate change, energy, bio fuels, population growth, economic growth, land use, food production and life styles/consumption patterns/diet, forestry, N-deposition, fragmentation, corridors, national parks, trade (timber, food, fibers). The policy options will concentrate on a few combinations of the most promising measures concerning climate change and bio fuels, agriculture and food production, technology transfer, forestry, protected areas and corridors, and population growth. If possible the analysis will include cost estimates on policy options of agriculture and food production, climate change and protected areas, and how they relate to regional GNP and aid budgets. The work will focus on terrestrial ecosystems. The model will calculate the order of magnitude of effects on biodiversity in

terms of the following 2010-indicators: (i) Trends in extent of selected biomes, ecosystems and habitats, and (ii) Trends in abundance and distribution of selected species.

2. Following an initial scoping of feasibility, MNP will provide, **not later than 15 October 2005**, a list of options of concrete scenarios, which can be calculated including a qualitative judgement of their relevance with respect to the 2010 biodiversity target.

3. Based on the list of options of concrete scenarios and following approval by the Secretariat and agreement with MNP, MNP will fully develop and calculate the agreed scenario(s) and prepare a brief description of the methodology, assumptions, limitations and results, including graphic presentation(s)/map(s) as well as their interpretation for possible inclusion in Section IV of GBO-2, to be received by the Secretariat **not later than 15 December 2005**.

4. MNP will also prepare a detailed description of the methodology and caveats for possible inclusion in the technical annex to the GBO-2, to be received by the Secretariat **not later than 15 February 2005.**

It is understood that the development of these scenarios is an iterative process between MNP, the Secretariat and other relevant partners and experts and that the project initiated through this agreement may yield additional relevant results in a timeframe beyond this agreement. The Secretariat is given the right to use outputs of this project, include those that may be derived beyond the duration of this agreement, in products other than GBO-2 and will be acknowledged as a partner in any other material derived from this project.

MNP will initiate work immediately upon signature of the agreement. The Secretariat agrees to contribute towards the implementation of this project a total of US$12,000 (twelve thousand US dollars) to be paid as follows: 40% (US$4,800) to be paid upon signature of the agreement and the remainder (US$7,200) to be paid within twenty days of submission and acceptance of the final documents.

Annex 3: Glossary

Assessment frameworks provide a systematic structure for organising 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 ”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.

Biodiversity 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).

Biofuels: In this report, the term bio-fuels is used to encompass all forms of modern bio-energy. This includes the use of specific crops 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 bio-fuels. In this report the effects of bio-fuels only concerns crops grown to produce energy (bio-fuel crops).

Bio-energy crops/bio-fuel crops: Crops specifically grown to produce energy.

Cultural area**:** see man-made area.

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.

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 as distinguished under the CBD are forest, tundra, grassland, (semi) desert, inland waters, marine and agriculture.

Homogenisation is a process of biodiversity loss which is characterised 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.

Policy options**:** see driving forces

Pressure: see driving ***force***

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 4: Regional maps

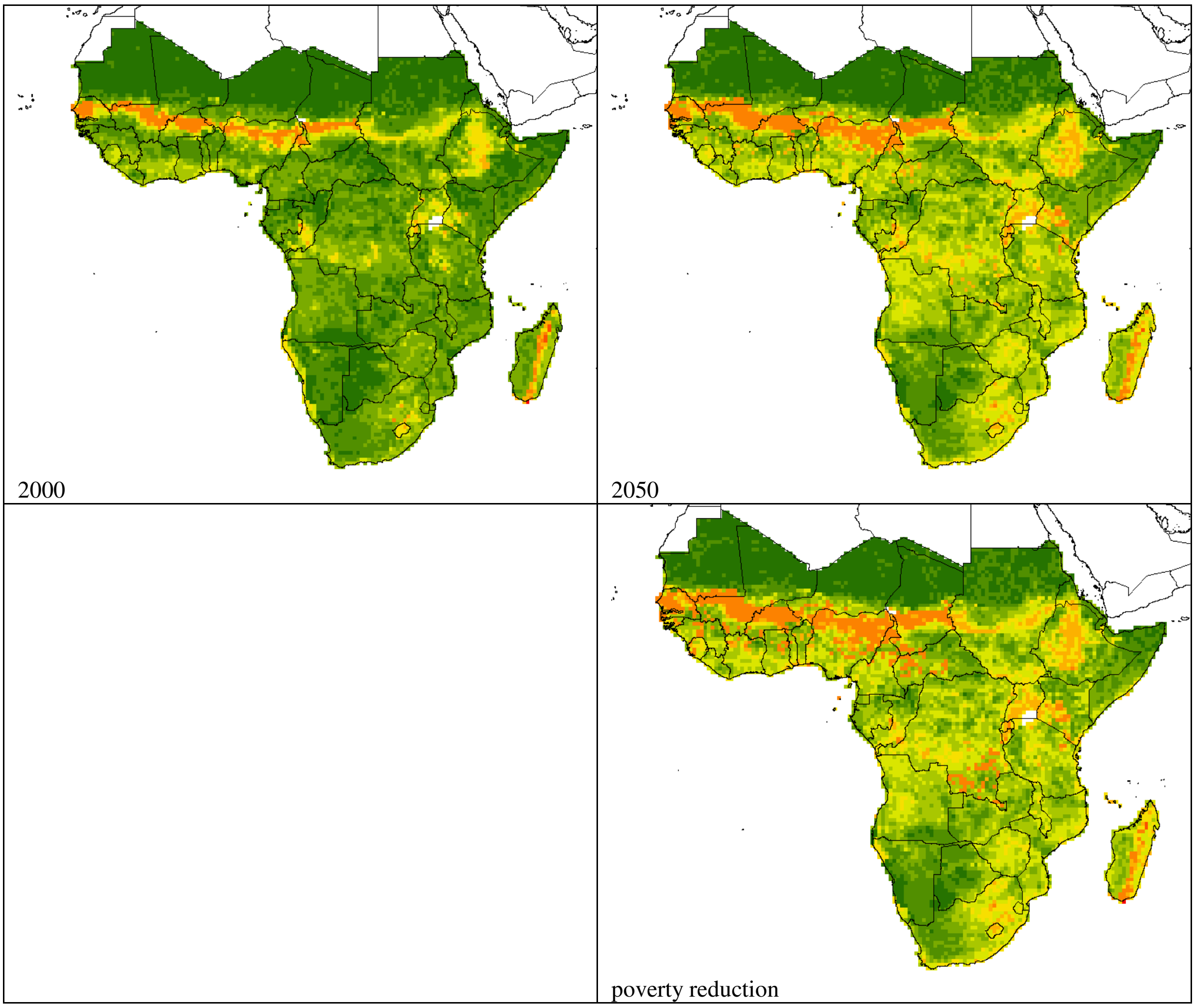


Figure 19: ***Spatial distribution of biodiversity for Sub Saharan Africa, in the baseline development (2000-2050), and change in biodiversity due to poverty reduction***

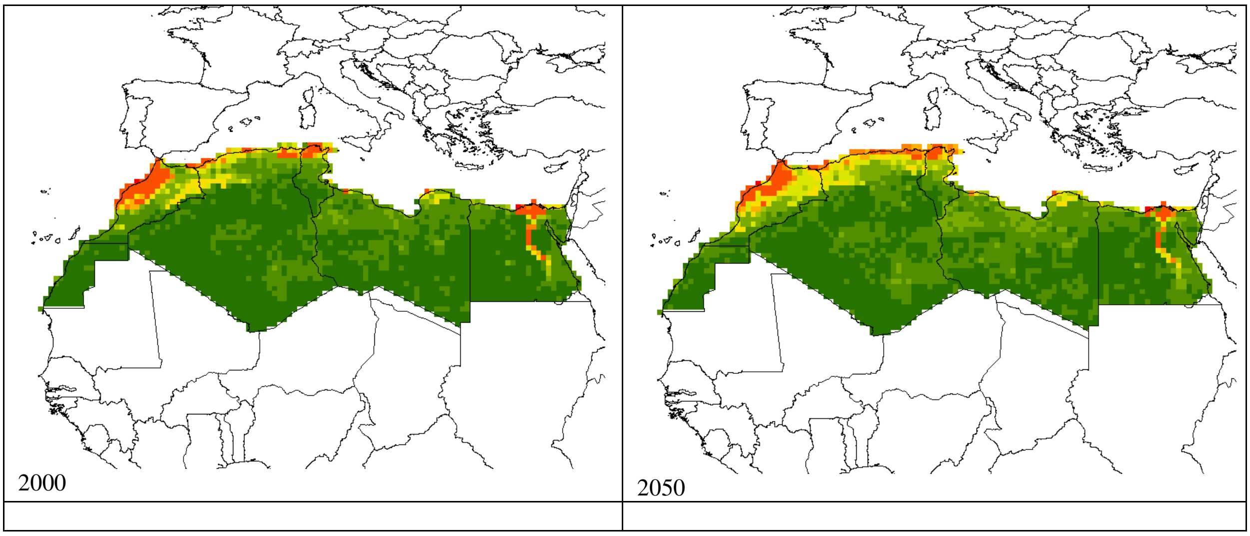


Figure 20: ***Spatial distribution of biodiversity for North Africa, in the baseline development (2000-2050)***

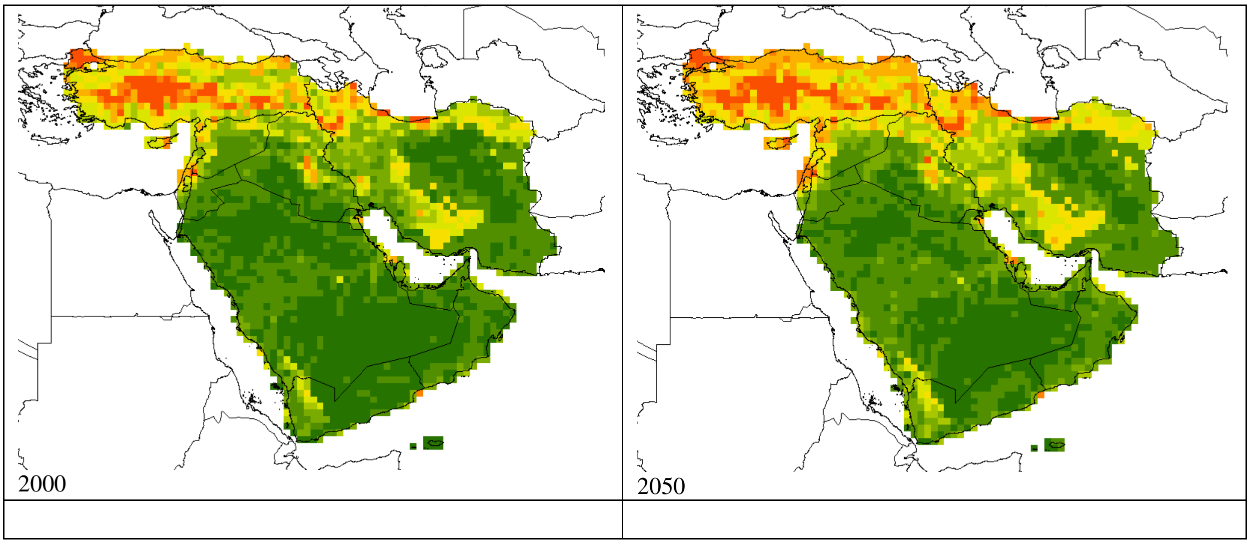


Figure 21: ***Spatial distribution of biodiversity for South and East Asia, in the baseline development (2000-2050)***

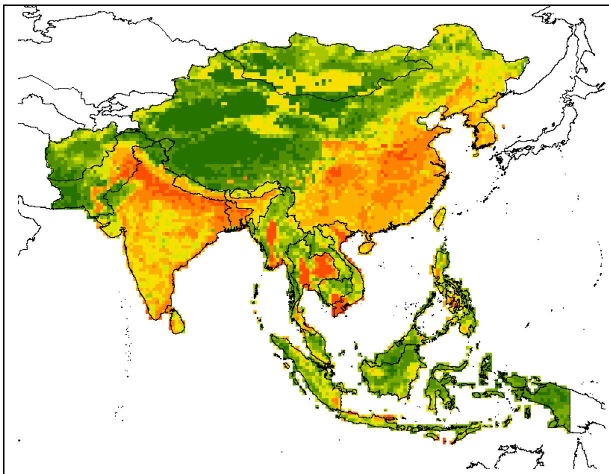
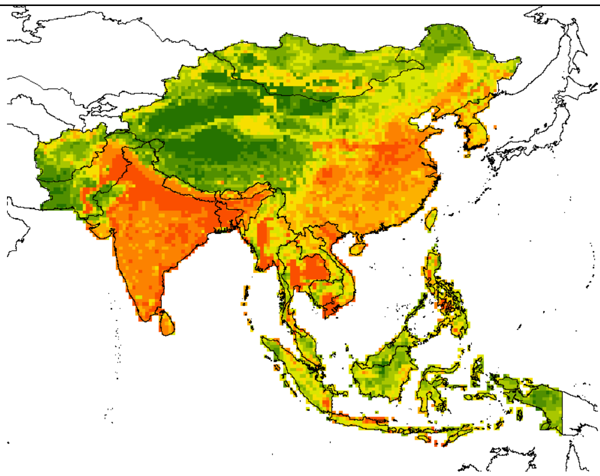
 2000	 2050
	Option effects not visible

Figure 22: ***Spatial distribution of biodiversity for South and East Asia, in the baseline development (2000-2050)***

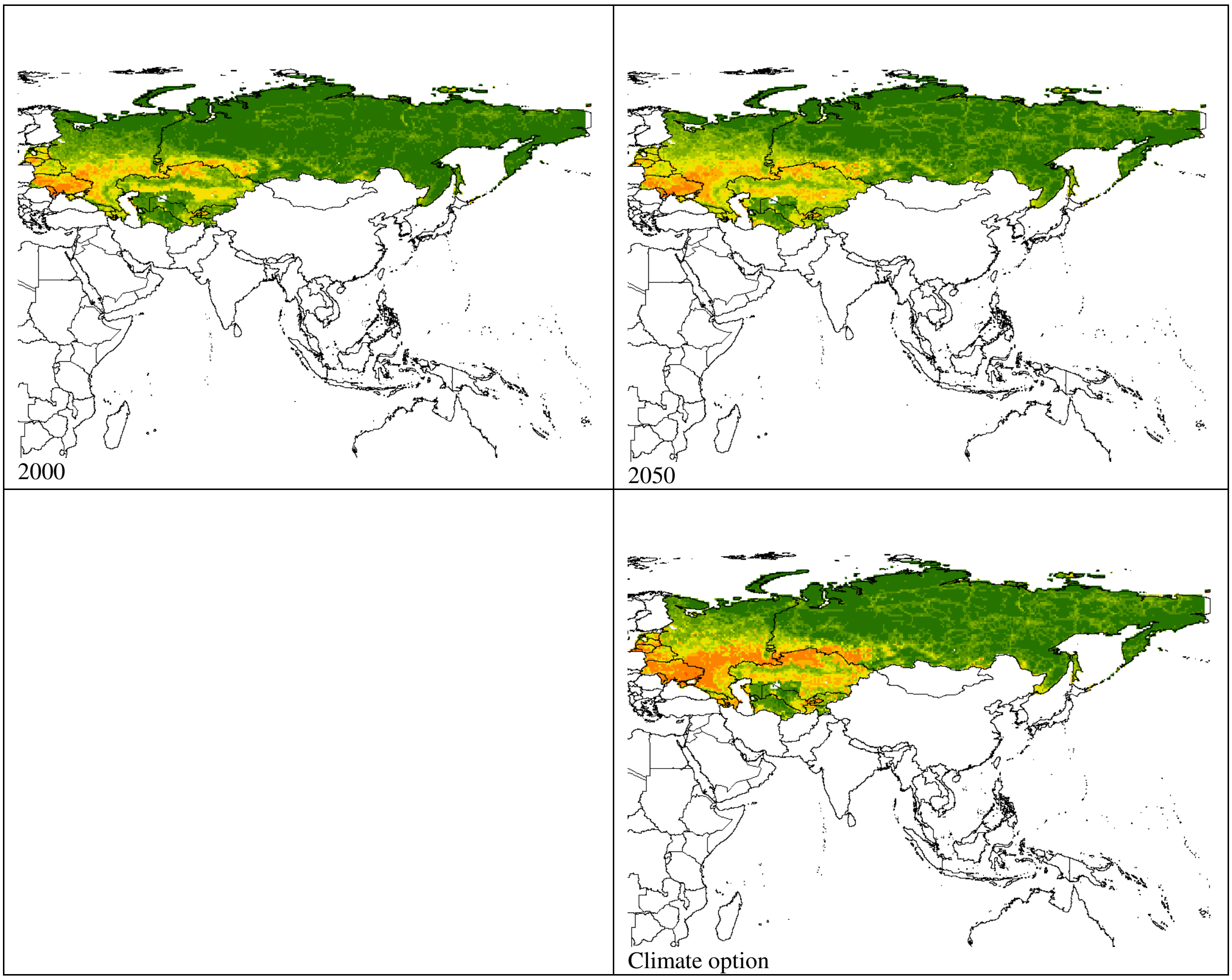


Figure 23: ***Spatial distribution of biodiversity for Russia and North Asia, in the baseline development (2000-2050), and change in biodiversity due to the climate change mitigation option***

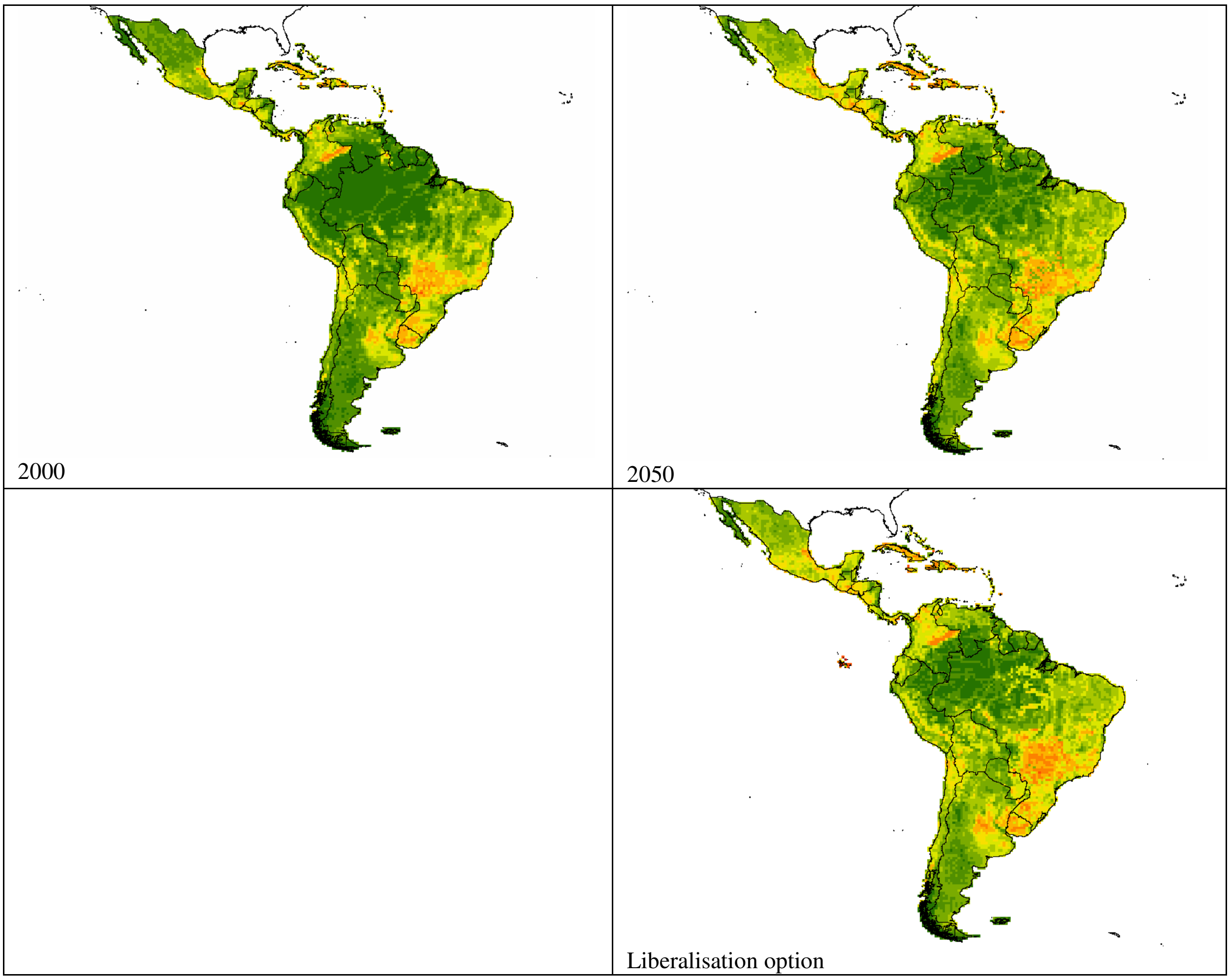


Figure 24: ***Spatial distribution of biodiversity for Latin America and the Caribbean, in the baseline development (2000-2050), and change in biodiversity due to liberalisation***

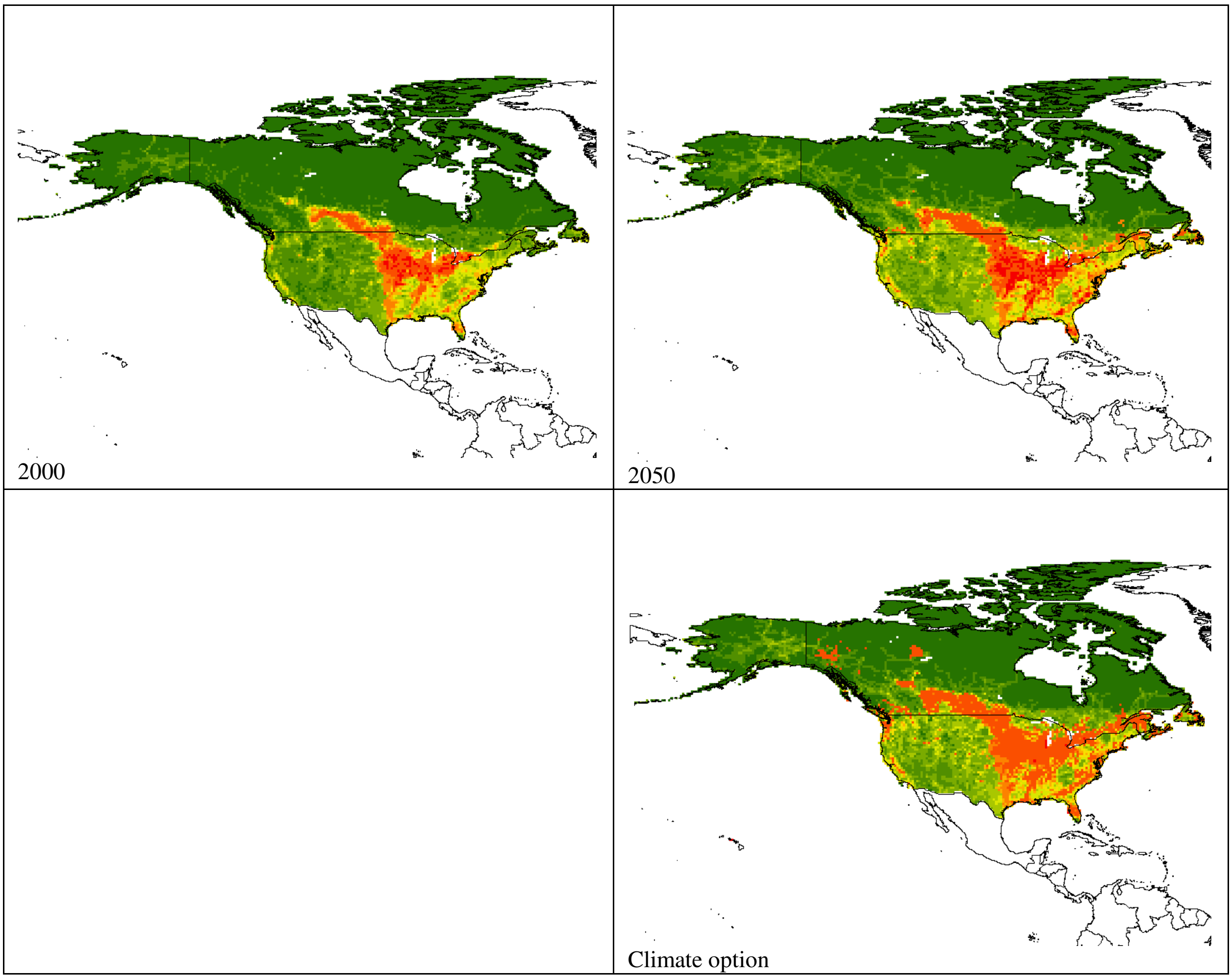


Figure 25: ***Spatial distribution of biodiversity for North America, in the baseline development (2000-2050), and change in biodiversity due to climate change mitigation***

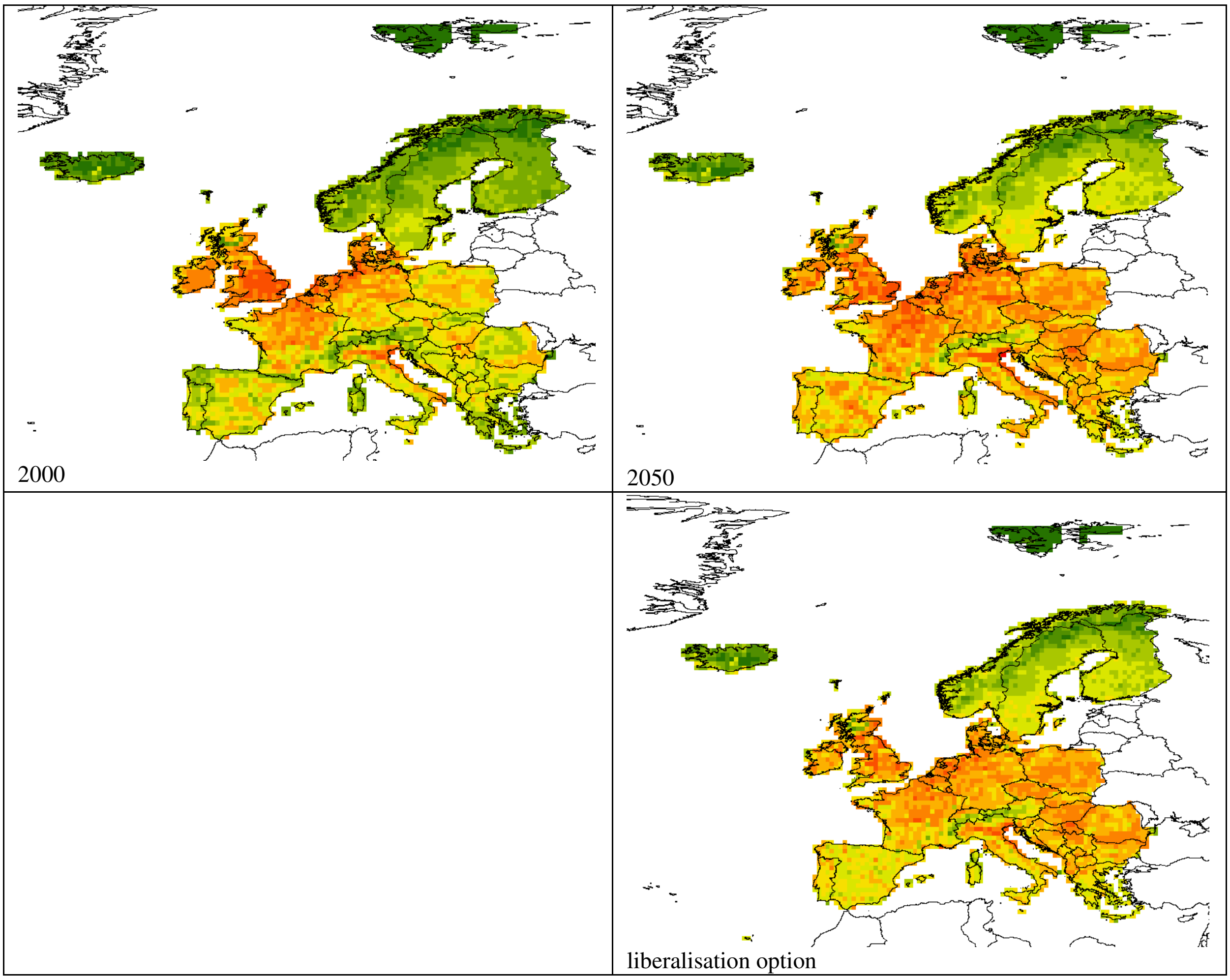


Figure 26: ***Spatial distribution of biodiversity for Europe, in the baseline development (2000-2050), and change in biodiversity due to liberalisation of the agricultural market***

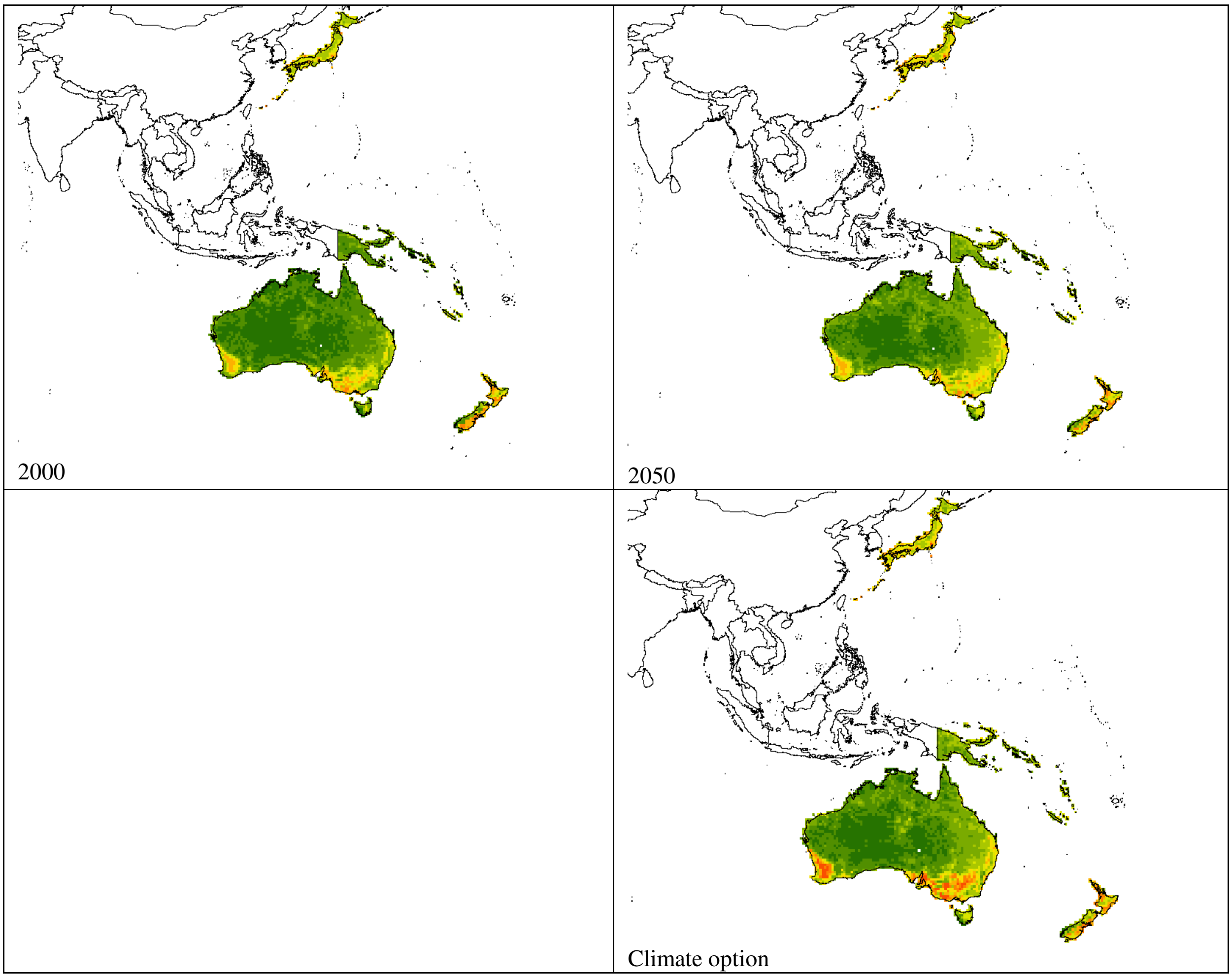


Figure 27: ***Spatial distribution of biodiversity for Oceania (including Japan), in the baseline development (2000-2050), and change in biodiversity due to climate change mitigation***

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