Cross-roads of Planet Earth's Life

Exploring means to meet the 2010-biodiversity target

for the

Global Biodiversity Outlook 2,

Chapter solution-oriented scenarios

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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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1 Summary

Introduction

The aim of this report is to explore candidate policy options which could contribute towards meaningful and lasting benefits for biodiversity. Central concern is the achievement of the 2010-biodiversity target at the global and regional levels as agreed upon under the Convention on Biological Diversity, but in addition their long term effects are taken into account with a time horizon of 2050. The assessment has been executed by means of models which allow a quantitative approach. The results are expressed -if possible- in terms of the 2010 indicators according to CBD decision VII/30. The results are input for the second Global Biodiversity Outlook (GBO2) to support policy makers in determining cost-effective manners in achieving the 2010 target. The study was executed by the Netherlands Environmental Assessment Agency (MNP), in cooperation with UNEP-WCMC (UK), UNEP-GRID Arendal (Normway) and the Agricultural Economics Research Institute (WUR-LEI, NL).

Key findings

1. According to the baseline scenario and options examined in this study it appears unlikely that the CBD target for 2010 of "*a significant reduction in the current rate of loss of biological diversity*" will be met at the global and regional levels for terrestrial biomes. The loss of biodiversity is expected to continue at an unchanged pace as a consequence of continuing economic and demographic development trends. Delays in ecosystem response and in institutional reforms also play a factor in reducing the rate of loss[2].
2. Six policy options which potentially reduce the rate of biodiversity loss, are analysed separately on their impact. Protection of areas and sustainable meat production form an immediate contribution in bringing the 2010-target closer, but not sufficiently to compensate the loss by other factors. Measures for limiting climate change (bio-fuels), sustainable forest management (wood plantations) and poverty alleviation (increasing GDP) seem inevitably leading to losses of biodiversity in the medium term (2010 -2030) though improvements are foreseen in the much longer term. Eventually, these long-term benefits will offset the short and medium-term losses, although this is not yet observed for climate change and poverty alleviation within the time frame up to 2050. Only in the long term can demographic transitions and poverty reduction be expected to ease this pressure.
3. Further enhancement of agricultural productivity is a key factor in substantially reducing the need for land and consequently the rate of biodiversity loss.
4. A concerted effort is essential if the rate of loss in the coming decades in the context of continuing human development trends is to be reduced. Optimal results can be obtained by a combination of options including: maximum enhancement of agriculture productivity, reducing climate mitigation with little implementation of bio-fuel, establishing wood plantations and sustainable meat production as well as a major increase in effective protected areas. Within the time limitation of this study this combination of

[2] These do not form part of this study

options could not be calculated. Although not part of this analysis, obviously local tailor-made measures will provide additional opportunities.

5. Trade liberalisation needs to be accompanied by carefully designed and controlled policy interventions to achieve poverty alleviation and to avoid unnecessary and persistent loss of biodiversity by land conversion in low-cost areas,.

Baseline

6. In this study a moderate business-as-usual scenario is used as baseline to evaluate the effectiveness of options. Key indirect drivers, global population and economic activity per capita, grow steadily by 50% and 200% until 2050, leading to a four times higher global economic output than at present.
7. Despite considerable efficiency-gains assumed in the baseline scenario, the need for food, fodder, energy, wood, infrastructure, agricultural land and production forest will unavoidably lead to a decrease in the global natural stocks in all ecosystems. Climate change, nitrogen deposition, fragmentation and unchecked human settlement will further expand their negative impact on biodiversity. As a result, global biodiversity is expected to decrease from about 70% to about 63% by 2050[3].
8. The Millennium Ecosystem Assessment (MA) scenarios assumed higher socio-economic growth rates and less improvement in agricultural productivity. Therefore, the applied baseline scenario is slightly more optimistic and results in less loss of biodiversity compared to the MA.
9. Changes in biodiversity are not equally distributed throughout the world and its biomes. The largest additional biodiversity losses are expected for Europe (11%), North America (9%), Sub-Saharan Africa (12%)and South and East Asia (9%). Dryland ecosystems - grasslands and savannah- are particularly vulnerable to changes over the next 50 years (inland waters and marine ecosystems are not considered). 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.

Options

10. Six policy options have been evaluated with respect to their potential for slowing biodiversity loss. The options were derived from current negotiations and discussions in various political arenas. It should be noted that the options are feasible but not 'easy' accomplished. Actual implementation of these policies requires strong international commitment and coordination:
    - Effective implementation of **full trade liberalisation in agriculture from 2015**, driven by free-trade considerations and development arguments following the current WTO Doha Round. Implementation leads to an additional biodiversity loss of 1.3% until 2050 due to a 6.5% global increase of land used for agriculture, concentrated in Latin America and Southern Africa. 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 US, Europe and Japan, resulting in disproportionately higher

[3] 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 annex 2.

[5] But note that other combinations of measures to reduce greenhouse gas emissions are also conceivable.

land requirements at the global level since current crop yields are much higher in these developed regions. The increase of 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 US, Canada, OECD Europe and Japan. This area potentially enables restoration of biodiversity, but only in the long term as initially the land previously used for agriculture will have 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 (option 1) in line with the proposals by the Millennium Project (UN Millennium Project, 2005). Assuming effective implementation of these additional direct investments, including higher productivity of 10%, this options 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 their own region, leading to a 10% increase of agricultural land (globally 3% extra) and an additional biodiversity loss of about 5.7%. Not all possible effects are taken into account. A hunger and poverty strategy requires heavy investments in infrastructure leading to further biodiversity losses. On the other hand, reducing extreme hunger and poverty can promote the demographical transition, break the poverty trap and decrease unintentional deterioration of natural capital (according to the Millennium Ecosystem Assessment).
- 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 costs of meat production. It is estimated that this results in a 10% increase in meat prices and subsequently in a decrease of the global meat consumption by about 5%. This lower consumption leads to a lower number of animals needed for food consumption and therefore to less agricultural area and nitrogen deposition. Consequently, the loss of 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, stabilizing CO_2-equivalent concentrations at a level of 450 ppmv in line with the option of keeping the global temperature increase below 2 ^{o}C requires 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[5]. In this scenario major energy consumption savings are achieved and 23% of the remaining global energy supply is produced from bio-fuels in 2050. This leads to an additional biodiversity loss of around 1% by 2050 as a result of the habitat loss for producing bio-fuels (about 10% of the global agricultural area). In the short term, 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%). Preliminary estimates show that after 2100 the initial biodiversity loss due to bio-fuel production may be exceeded by the biodiversity gains from avoided future climate change. Smart combinations of bio-fuel production with other land use options have not been explored.

- 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. In the short term, this leads to additional biodiversity loss through plantation establishment. As plantations gradually take over global production, the previously exploited semi-natural forest is left to restore. In the long run, this restoration counteracts the initial loss, and 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 restoration after 2050, the option will perform better.
  The role of deforestation in global biodiversity loss is not taken into account, since 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 for this target has been almost achieved. This option has not been further analysed here. **Effective conservation of 20% area of all ecological regions** will reduce the loss by 1%, the best result of the six considered options. 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 other 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 this will conserve relatively large and intact ecosystems that contain the majority of the species, amongst which also include 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 capable of quantifying 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.

11. 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. However, on the regional, national and local scales there will be biodiversity *and* economic gains because of safeguarding a variety of functions on which –eventually-humanity entirely depends (see the Millennium Ecosystem Assessment). Economic costs and biodiversity gains may be spread over time. Climate change policy will slightly 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 that of involved sectors.

Options in perspective

12. From the above it is evident that the options considered are too little or too late to meet the 2010-target. Some options like climate change mitigation and sustainable forest management show beneficial effects, but only after several decades. In the short term, these options exert increasing pressure on biodiversity. The options with immediate positive effects like protected areas or sustainable meat production are limited in scope. It is evident that economic growth takes place at the expense of further decline in biodiversity. The challenge remains to find realistic policy options that conserve biodiversity *and* help the extreme poor[6].
13. It follows from this preliminary assessment that there are three promising policy options to explore in order to make progress towards the 2010-target:
    - Search for ways to keep the long-term benefits of some options for safeguarding biodiversity, whilst reducing their short term pressures. For example, the climate change mitigation option considered in this study relies strongly on substitution of renewable bio-fuels for fossil fuels. Other mitigation options that may have less negative impact, or actually provide benefits for biodiversity conservation could be explored. With the assumptions made here, this might undermine reaching the climate target or at least lead to higher cost.
    - Make direct options 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.
    - Limit the trade-off between economic growth and biodiversity.
        - 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 focuses of the International Assessment of Agricultural Science and Technology for Development (IAASTD or Ag-assessment), currently under way. This enhancement should be implemented carefully, in order not to cause new undesired negative effects, like emissions of nutrients and pesticides and risks of land degradation.
        - Trade liberalisation 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.
        - Targeting the distribution of economic growth and investments on poor people. In the long term economic growth and poverty reduction may help

[6]. For example by 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).

biodiversity, as it is assumed to accelerate the demographic transition and adoption of more productive and sustainable land management practices.
- Solve 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.

2 Aims and limitations of the report

2.1 Aim

The secretariat of the CBD has assigned the Netherlands Environmental Assessment Agency (MNP) to explore candidate policy options which could contribute towards the achievement of the 2010-target at the global and regional levels as agreed upon 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 is executed by using the IMAGE-GLOBIO model which allows 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 are input for the Global Biodiversity Outlook 2 to support policy makers in determining cost-effective manners in achieving the 2010-target[9].
The study was executed in cooperation with UNEP-WCMC, UNEP-GRID Arendal and Agricultural Economics Research Institute (WUR-LEI). The assessment took place in the period 1 October to 15 December 2005.

2.2 Limitations

The reader should be aware this study is not meant to predict the future but to explore the major contributions of various currently debated policy options to the 2010-target on the global and regional scales.

The exploration of options in this report is not exhaustive, significant limitations include:

- This report aims at providing general quantitative insights on the efficacy of a limited number of major policy options, to support policy makers on major and minor opportunities, within the known limitations of this study.
- In the calculations of the rate of loss of biodiversity several pressures are not taken into account such as pollution, extensive grazing, fire, erosion and water extraction. The currently applied models do not yet include these factors. Possible policy options to reduce these pressures were therefore not considered. Concerned neither were the effects on inland waters and marine ecosystems, and possible extreme events resulting from climate change.
- Within the time constraints it was not possible to investigate optimal combinations of policy options and quantify their potential to reduce the rate of loss of biodiversity. Only

[9] The GLOBIO model is a model developed in cooperation with UNEP-WCMC and UNEP-GRID Arendal (REF).

poverty reduction has been calculated in combination with liberalisation of the agricultural market.

- The baseline scenario assumes high food production rates, compared to the four scenarios of the Millennium Ecosystem Assessment. In the MA scenarios, the total crop area increases by 8% to 23% over the same period to meet the human needs, resulting in a 1% higher biodiversity loss in the most favourable scenario.
- The results for year 2010 were interpolated from 2000 and 2030 as actual model outputs hardly differentiate at global and regional scales.
- The longer term benefits for biodiversity of reducing climate change and poverty reduction probably occur beyond the time horizon of this study (2050). This should be taken into account in the interpretation of the results.
- Annex 4 elaborates on the uncertainties and sensitivity of the model outputs.

3 Indicators, scales and models

This Chapter provides a brief description of the applied i) indicators, ii) temporal scales and spatial units, iii) baseline scenario and policy options and iv) of the model.

3.1 Indicators

In this study the status of biodiversity is expressed in terms of change in ecosystem extent and mean species abundance, respectively. The decrease in the abundance of species (and the associated increase in abundance of a few –often human-favoured- species) is a direct measure of biodiversity loss, also called the homogenization process (see Box 2). Cost indications are included, concerning direct and opportunity costs. Further, the effects of climate change, fragmentation and nitrogen deposition are assessed, as well as indications of the impact of alleviating extreme poverty with a focus on Sub-Saharan Africa.

In Box 1, the 2010-indicators are listed (according to CBD decision VII/30). The current model version generates quantitative parameters which are comparable to the indicators highlighted in bold.

Box 1. Headline indicators for assessing progress towards the 2010 biodiversity target [10]
Focal area: Reducing the rate of loss of the components of biodiversity, including: (i) biomes, habitats and ecosystems; (ii) species and populations; and (iii) genetic diversity
• **Trends in extent of selected biomes, ecosystems and habitats** • **Trends in abundance and distribution of selected species** Change in status of threatened species *Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socio-economic importance* Coverage of protected areas
Focal area: Maintaining ecosystem integrity, and the provision of goods and services provided by biodiversity in ecosystems, in support of human well-being
Marine Trophic Index • **Connectivity/fragmentation of ecosystems** Water quality in aquatic ecosystems
Focal area: Addressing the major threats to biodiversity, including those arising from invasive alien species, climate change, pollution, and habitat change
• **Nitrogen deposition** Trends in invasive alien species
Focal area: Promoting sustainable use of biodiversity
Area of forest, agricultural and aquaculture ecosystems under sustainable management Ecological footprint and related concepts
Focal area: Protecting traditional knowledge, innovations and practices
Status and trends of linguistic diversity and numbers of speakers of indigenous languages
Focal area: Ensuring the fair and equitable sharing of benefits arising out of the use of genetic resources
Indicator to be developed
Focal area: Mobilizing financial and technical resources, especially for developing countries, in particular, least developed countries and small island developing states among them, and countries with economies in transition, for implementing the Convention and the Strategic Plan**.**
• **Official development assistance provided in support of the Convention**

In addition the following indicators were derived:

- Climate change (temperature rise)
- Food production
- Poverty alleviation (focus on Sub-Saharan Africa)
- Cost estimation, where possible related to Gross Regional Product and aid funds

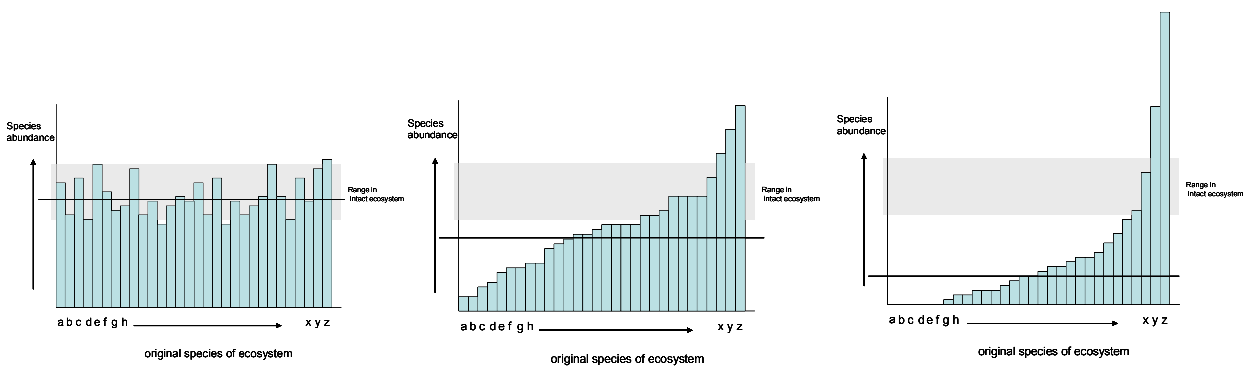
The current models does not yet allow for implementing the remainder.

Box 2: 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

[10] Focal areas and associated headline indicators are from decision VII/30 with refinement recommended in SBSTTA recommendation X/5. Box 1 lists only those headline indicators discussed in the Executive Summary, and the sequence of focal areas differs from decision VII/30. It should be noted that many headline indicators are relevant to several focal areas: for example the extent of selected biomes is an indicator of land use change, and therefore relevant to the focal area on addressing threats to biodiversity.

certain area (species richness) and their population sizes (species abundance). 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 in the world, also called “biomes” 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 the last century is the -unintentional- result of increasing human activities all over the world. The process of biodiversity loss is generally characterized by the decrease in abundance of many original species and the increase in abundance of a few other -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 of human activities, many different ecosystem types are becoming more and more alike, the so-called homogenisation process (Ten Brink, 2000; Pauly, 1998; Scholes, 2004; MEA, 2005). Decreasing populations are as well a signal of biodiversity loss as strongly expanding species, which may sometimes become even plagues in terms of invasions and infestations.



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 man-favoured species. Consequently the Convention on Biological Diversity (VII/30) has chosen for a limited set of indicators to use -amongst others- the “change in abundance of selected species” to track this degradation process. This indicator has the advantage that it expresses well the above mentioned homogenisation process, and can relatively easy be measured and modelled. Even for a relatively small area in e.g. tropical forest, an area may contain several million species. Thorough mapping and monitoring across larger areas is therefore simply not feasible or possible. However, luckily, there are numerous thorough peer-reviewed empiric studies available that quantitatively link changes in habitat, such as fragmentation, to biodiversity loss. By extensive reviews of the literature for specific habitat types and the extent of the pressures present, the potential loss in biodiversity compared to the undisturbed state has been modelled by projecting the impact of changes in different pressures over time (Alkemade *et al.*, in prep.). By comparing and analyzing also historic changes in habitats, including use of satellite imagery, records in changes can be projected out in time using different types of scenarios and assumptions.

For each biome, biodiversity loss has been expressed in *the mean abundance of the original species* compared to the natural or low-impacted state. This baseline is used here as a means of comparing between different model outputs, rather than as an absolute measure of biodiversity. If the indicator is 100% then the biodiversity is similar to the natural or low-affected state. If the indicator is 50% then the average abundance of the original species is 50% of the natural or low-affected state, and so on. To avoid masking, significant increased populations of original species are truncated at 100%, although they should have actually a negative score. Exotic or invasive species are not part of the indicator but their impact is by the decrease in the abundance of the original species they replace. The *mean abundance of the original species* at the global and regional levels is the sum of the underlying biomes values, in which each km2 of each biome is equally weighted (ten Brink, 2000; UNEP/CBD, 2003 and 2004).

3.2 Temporal and spatial scales

The effects of the options are explored at the global and regional levels for 2000, 2030 and 2050 and are compared with the trends in a moderate growth, business-as-usual scenario (baseline). The following geo-political regions and biomes are distinguished (Figure 1, Figure 2), the latter covering as much as possible the thematic areas and their sub-divisions of the Convention.

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 for model limitation reasons.

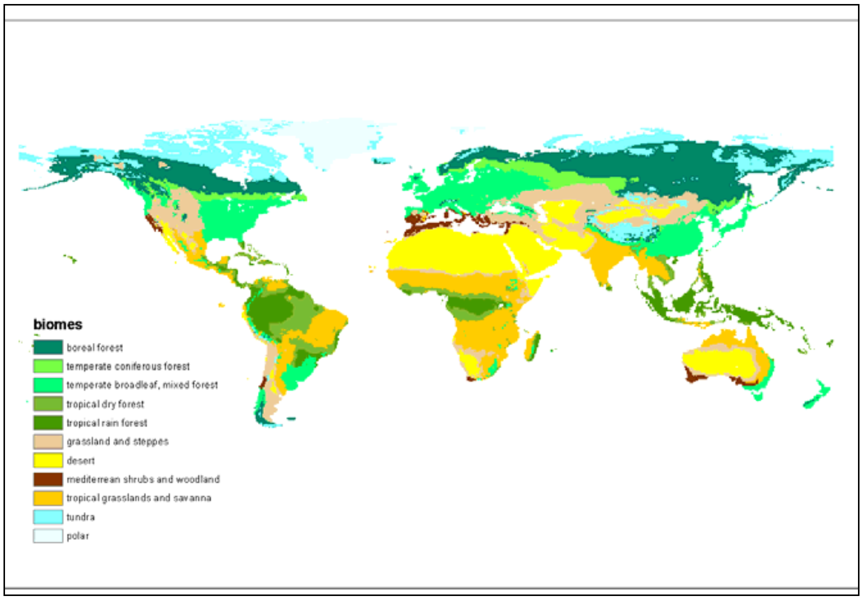


Figure 1: The biomes distinguished in the present IMAGE-GLOBIO model analysis .

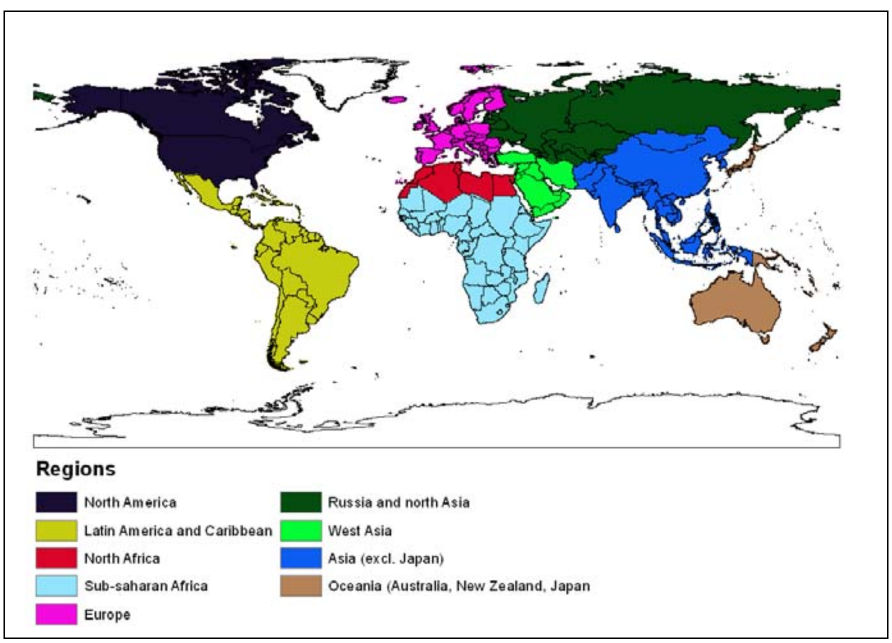


Figure 2: ***The regions considered. Greenland and Antarctica are not considered.***

3.3 Framework for analysis, indicators and main drivers

The framework used is similar to the conceptual framework used in the Millennium Ecosystem Assessment (MEA, 2003) and links indirect drivers like population, economic, technology and lifestyle drivers to direct drivers of change, such as land use change, climate change, energy use, the application of bio-fuels, fertiliser use and forestry. These drivers also involve landscape fragmentation and pollution, such as nitrogen-deposition. 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 3). These analyses also enable the assessments of trade offs and synergies between biodiversity and human well-being (including poverty).

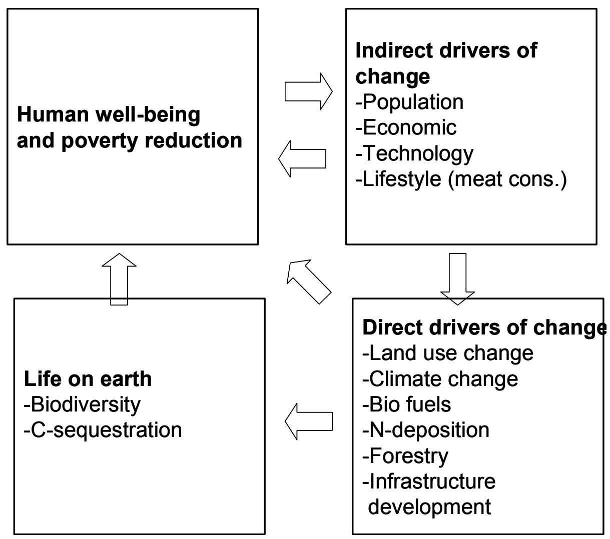


Figure 3: ***Framework for analysis of solution-oriented policy options using the GTAP-IMAGE-GLOBIO model (interpreted from MEA, 2005). Not all factors are reported in this study.***

3.4 The GTAP-IMAGE-GLOBIO model

The framework outlined in section 3.3 above is reflected in the analytical approach used in the study, consisting of a coupled suite of models driven by exogenous assumptions representing the indirect drivers of change in Figure 3. The IMAGE model (Alcamo, 1998; IMAGE team, 2001) then translates these exogenous drivers into the direct drivers of change, with the exception of infrastructure and settlement. The latter is estimated separately with the GLOBIO model as a function of (among others) spatially differentiated GDP development. From indirect drivers such as energy demand and supply and associated emissions of greenhouse gases and air pollutants, IMAGE calculates land-cover and land-use changes for agriculture and forestry practices. Agricultural demand, supply and trade are established in a linkage with the adjusted GTAP model (van Meijl *et al.*, 2005) and result in the production of crops and animal products per region. These demands are spatially allocated by the IMAGE model to calculate implications for land-cover and land-use per grid cell of 0.5x0.5°. Productivity assumptions are established between GTAP and IMAGE as the compounded result of bio-geophysical and economic factors. Resulting emissions lead to atmospheric concentration of greenhouse gases and associated temperature and precipitation patterns, as well as to nitrogen deposition. TIMER, the energy model of IMAGE (de Vries *et al.*, 2001) generates a demand for bio-energy for different end-use markets, taking potential land availability and productivity from IMAGE. The amount of bio-energy produced depends on energy demands, relative energy price developments and technological advancement.

Demand for regional forestry products is driven by population and industrial output, including traditional bio-energy (fuelwood and charcoal). This demand is met from several supply streams: most wood is from dedicated logging operations, and partially from deforestation activities arising from land conversion. Most of the converted forest is assumed to be burnt. This approach does not accommodate changes in wood production regions, thus limiting the possibility to analyze effects of shifting global production and trade.

The direct drivers from GTAP/IMAGE are used as input for the GLOBIO3 model The Global Biodiversity model framework (GLOBIO3) has been developed by UNEP-WCMC, UNEP-GRID Arendal and the Netherlands Environmental Assessment Agency (MNP, formerly part of RIVM). The GLOBIO3 project is a result of a merger between two different methods for modelling changes in biodiversity.

The IMAGE-NCI approach by UNEP-GRID and MNP focuses on energy use, land use change, forestry and climate change as pressure factors on biodiversity. The GLOBIO2 project by UNEP-GRID Arendal modelled the effect of human disturbance on biodiversity through the relationship between abundance of species and disturbance by roads.

In the GLOBIO3 model, the most important pressure factors with a direct influence on biodiversity have been combined. They are: (1) climate change, (2) land use change, (3) nitrogen deposition, (4) land use intensity and (5) change in infrastructure. (Alkemade *et al.*, in prep.)

The GLOBIO 3 model uses general dose-response relationships between the pressure factors and the relative mean species abundance of original species. The quantification of these relationships is based on a review of scientific literature on the effects of environmental change on the local species diversity and abundance. General relationships were compiled by combining the relative changes found in each study.

The relationship for land use is based on about 130 peer reviewed studies. The relationship for N-deposition is based on 50 studies (Bobbink 2004) on experimental addition of nitrogen in natural systems and the effects on species richness and species diversity. This relation was also used in the Millenium Ecosystem Assessment (MEA, 2005). Bobbink found that only studies for a limited number of ecosystems are available.

For the effects of infrastructure and settlement we used the GLOBIO 2 model (UNEP, 2002). The relationship is based upon a review of 309 papers, comprising information on 204 different species. For climate change we derived global dose response relationships from modelling studies on the projected shift of species and biome distributions (Bakkenes *et al.*, 2002, Thomas *et al.*, 2004 and Leemans and Eickhout *et al.*, 2003). For the effect of fragmentation we used the relationship of the patch size in the Global Land cover map (Barthelome, 2004) and the minimal area requirement for over 200 species (Verboom *et al.*, in press).

The NCI is calculated for each grid cell, by multiplying the separate effects of the different pressures on the relative fraction of original species.

4 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. On this baseline, a number of separate “policy options” are superimposed. 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, like WTO, CBD, IPCC and FAO and will affect one or more of the indirect or direct drivers. Implementation of options is feasible in principle, but asks for 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 of 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 is a more than 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 two: 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 exceeds 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 in 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 shifting towards more animal products in the diet at higher income levels implies a strong increase in agricultural output. Following and extending 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 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 small 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 forums, and aim at reducing biodiversity loss (at least partly) or 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, concerning promoting sustainable use, addressing threats to biodiversity, provisioning of adequate resources, and protecting components of biodiversity.

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

1. **Liberalisation of the agricultural market;** this 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 most poor regions; This option is calculated in combination with liberalisation of the agricultural marked.
3. **Limiting climate change**; this includes more stringent application of measures aiming to comply with the ultimate UNFCCC goal, including an increase of bio-fuels in order to mitigate climate change;
4. **Sustainable meat production**; standards on meat production will reduce health effects and nitrogen deposition, will increase meat production costs and reduce meat consumption;
5. **Sustainable forest management**; this will mainly affect the way of producing wood products, by increased wood plantations.
6. **Protected areas**; for protected areas two options have been used: extension of the protected areas network to a coverage of at least: 1) 10% and 2) 20% of each biome. The newly protected areas have been allocated, in order 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. This makes a selection indispensable. The options were selected based on: i) the possibilities of the IMAGE/GLOBIO model, ii) its potential to significantly reduce the rate of loss of biodiversity, iii) their coverage of the major causes of biodiversity loss according to the CBD, iv) current political discussions or targets in the international forums, v) its 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.

5 Future biodiversity

5.1 Planet Earth

5.1.1 Results for planet Earth

<u>Baseline development:</u>

- In the last 300 years, our planet's biodiversity has decreased to 70%. Initially, extensive use such as (i) hunting and collecting and (ii) conversion into extensive agriculture were the main factors. In the last century, (iii) infrastructure, human settlement, intensification of agriculture and forestry, pollution and fragmentation have added to the decline[12].
- Up to 2050 a further decline in biodiversity from about 70% to 63% is projected.
- The most affected regions are Europe, North America, Sub-Saharan Africa and South and East Asia.
- Dry lands -grasslands and savannah- show the largest deterioration, followed by tropical forests and tundra's.
- 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 within the time frame up to 2050 for the climate change option and for poverty alleviation.
- 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

[12] The so called "first, second and third strike"

changes can be expected to play a role as well[13], as they will delay the necessary changes until after 2010.

Costs

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

Trade 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 industrialized countries. This increase in official development assistance will slightly mitigate the positive effects of liberalisation in industrialized countries. However, this shift in investment will boost economic growth in Sub-Saharan Africa. GDP per capita is projected to be 25% above baseline levels in 2030.

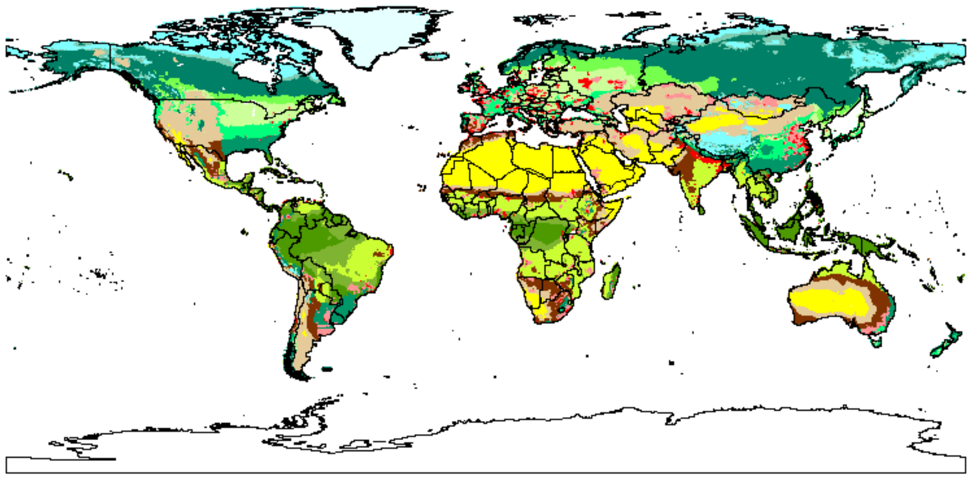
Climate change policy will require dramatic changes in the energy system. This is a costly option, However, costs can be limited by involving all regions (a global coalition) and using efficient and flexible mechanisms (e.g. emissions trading). Abatement costs for the world as a whole are in the order 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. The meat and forestry sectors are only small parts of the national economies after all (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/y (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/y. (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).

[13] These are not part of this study

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

5.1.2 Figures Earth



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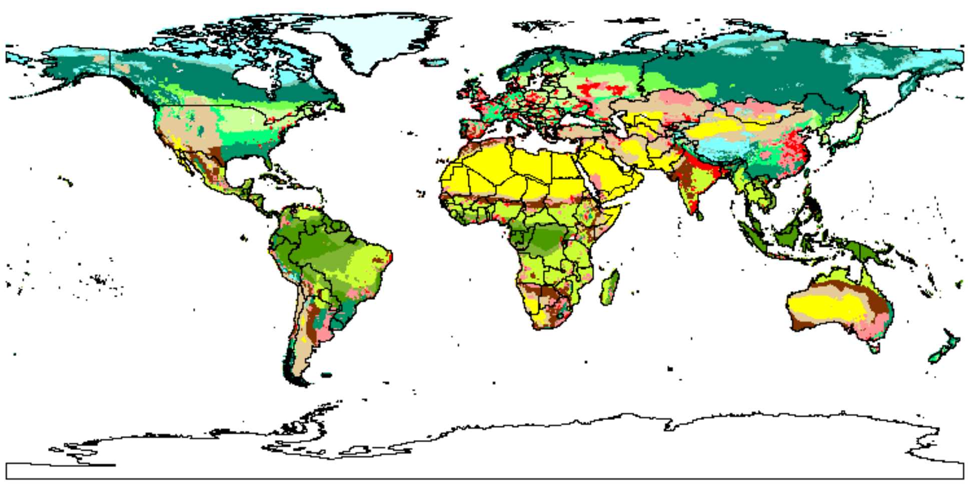
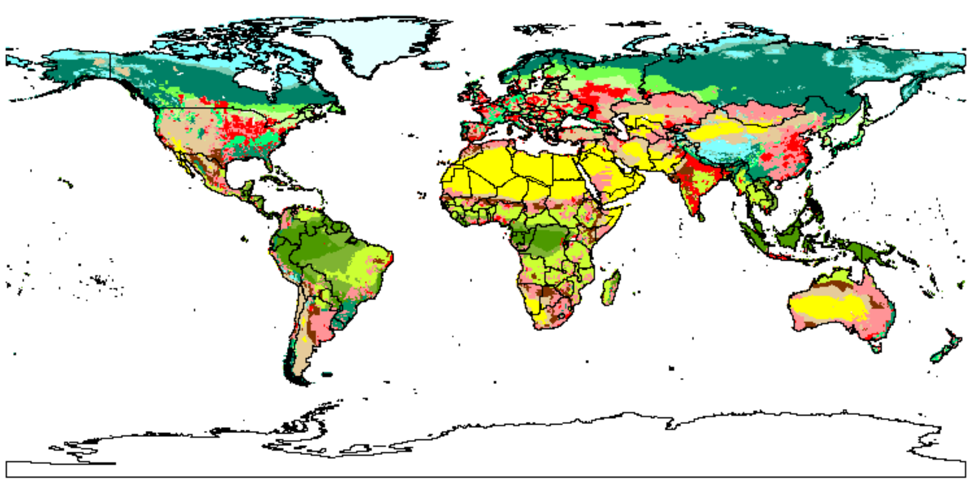


1800



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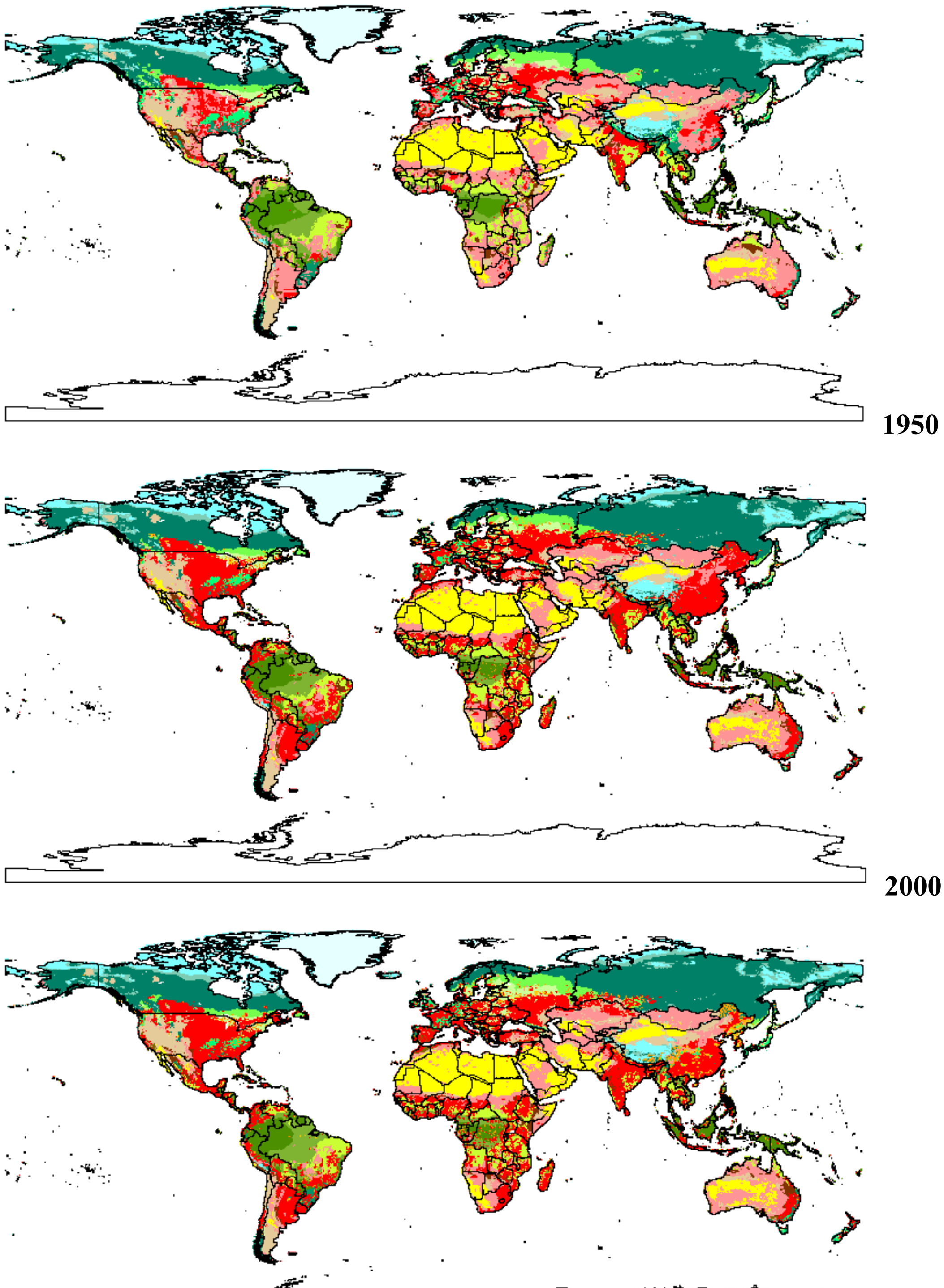


Figure 4: Land use changes since 1700-2050 (Klein Goldewijk, 2001; IMAGE-team, 2001)

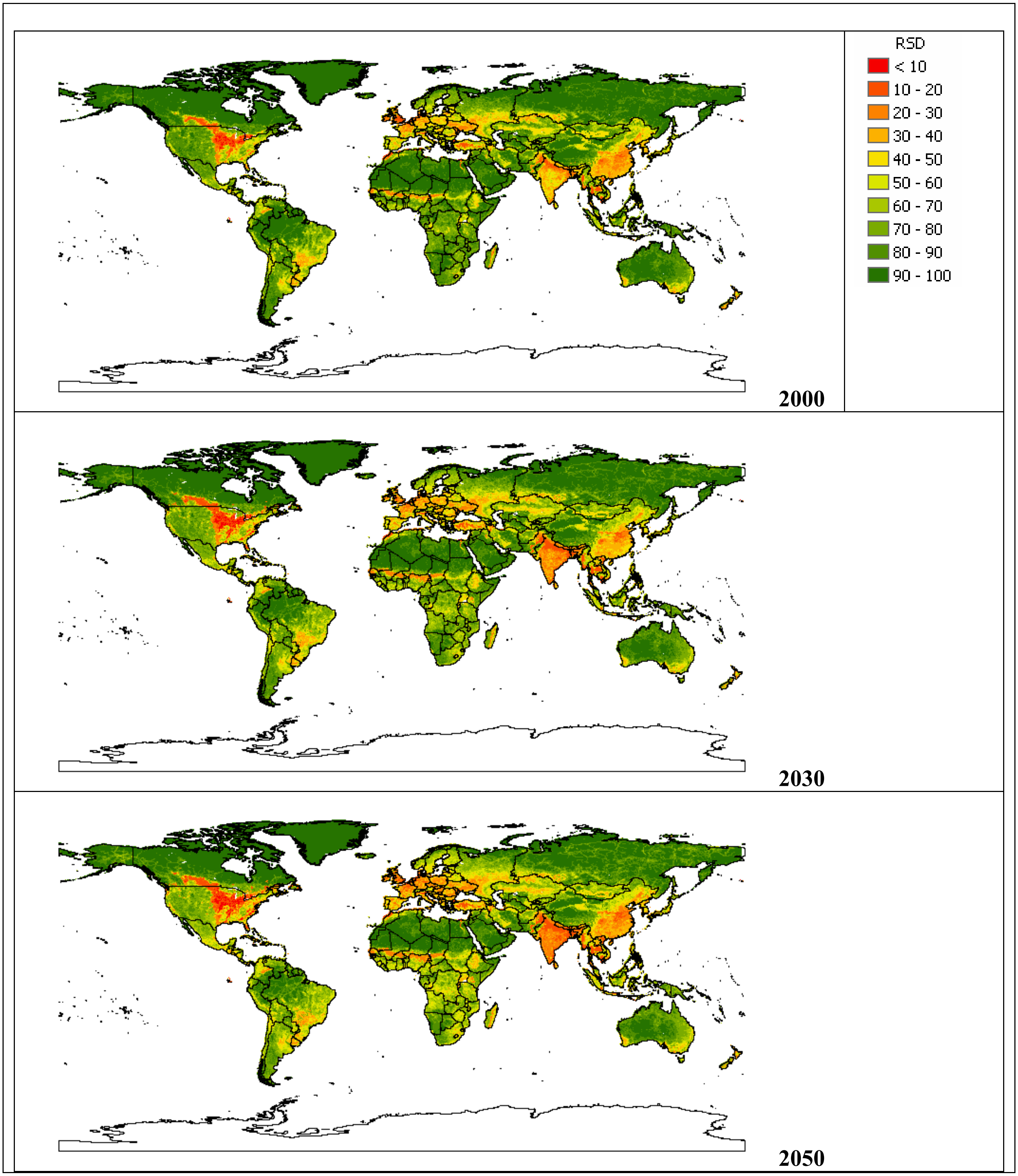
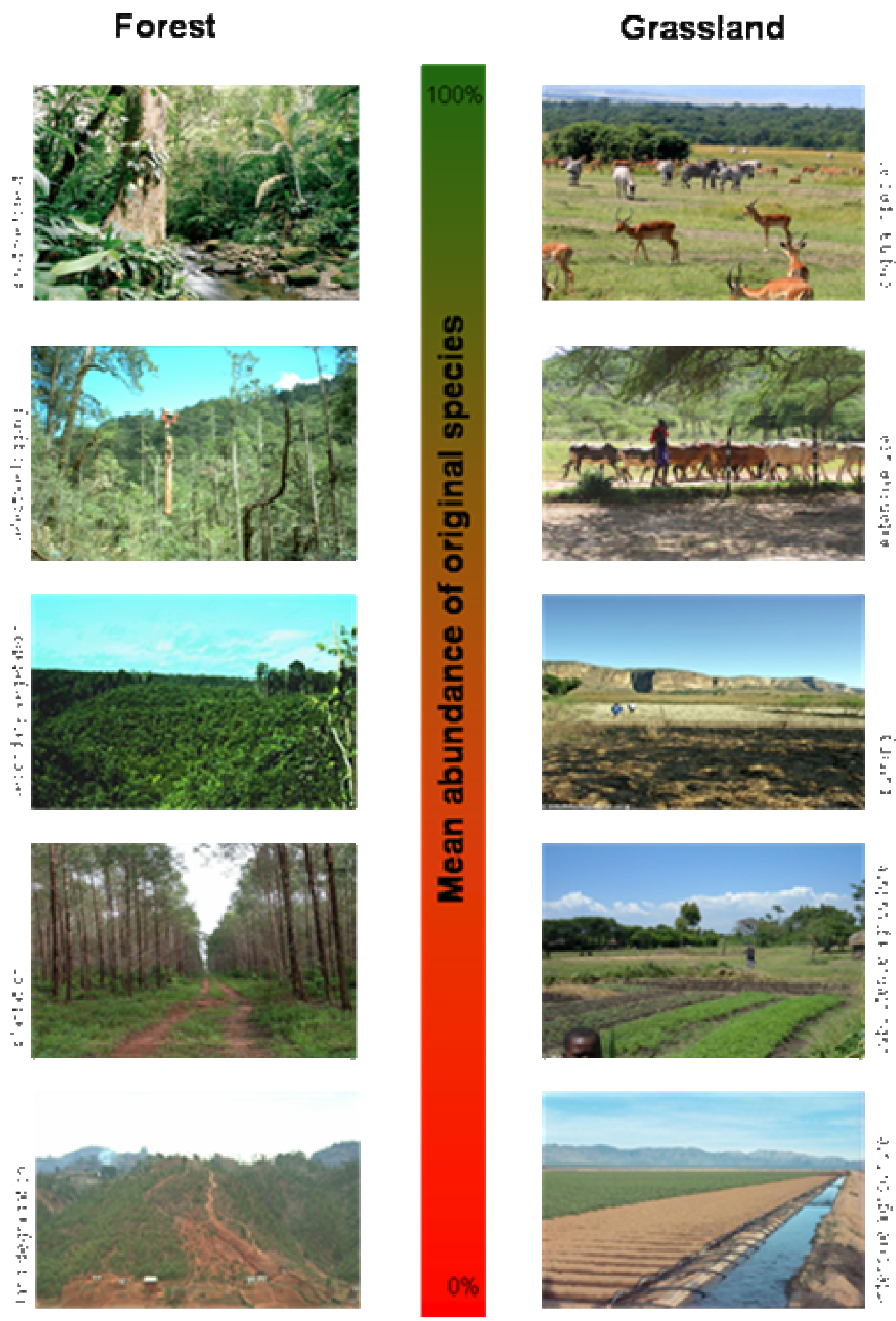
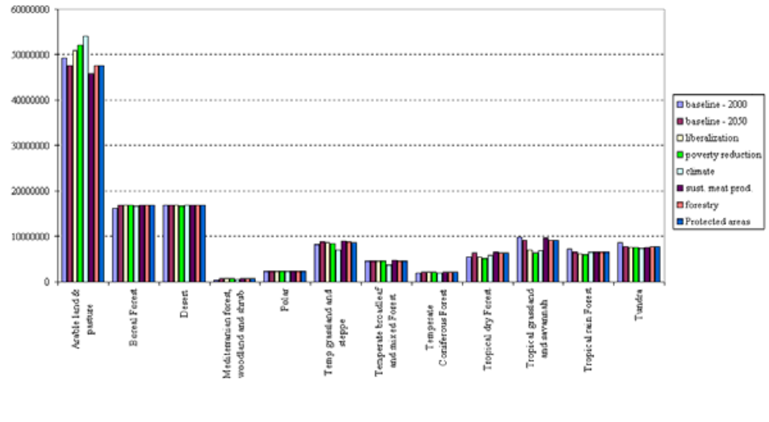


Figure 5: Global Maps on remaining species diversity (RSD) in the scenario period 2000-2050 (see Box 2 en 3 for further explanation)

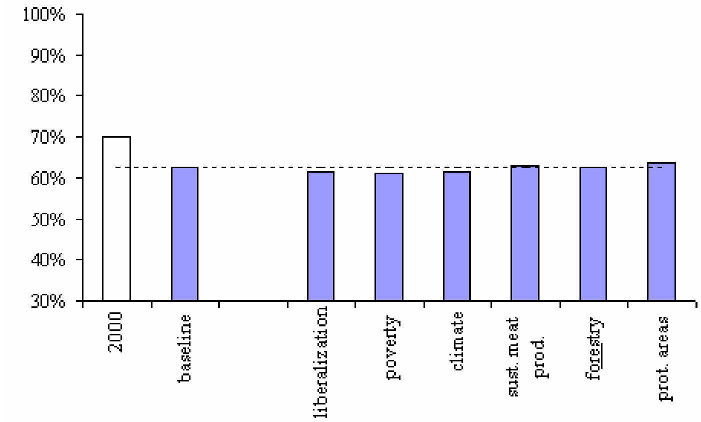
Box 3: Legend

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 2).

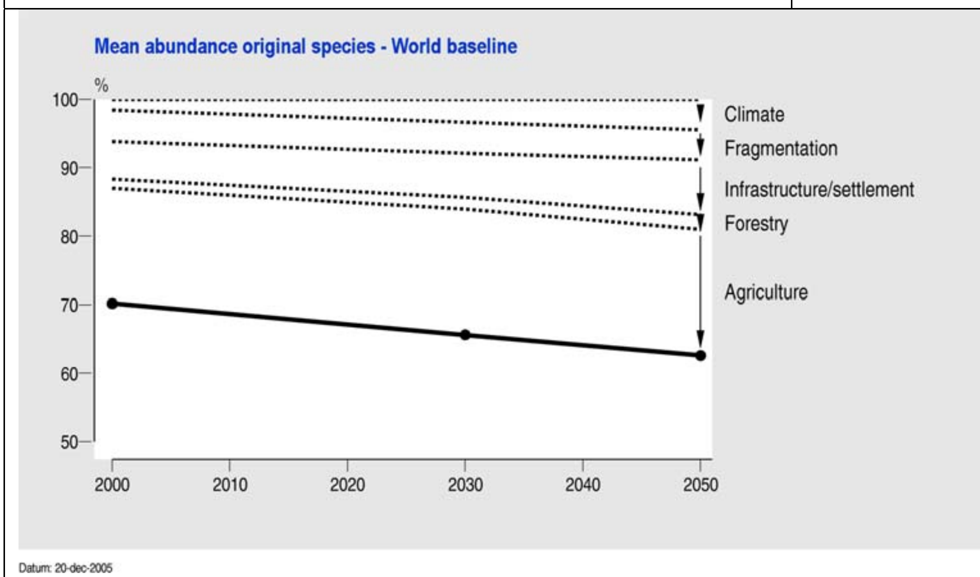




Trends per biome



Effect per option



Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 6: Global development and option effects per biome, global effects per option, and biodiversity trend (including shares of pressure factors), all for the baseline scenario.

Table 1: Summary of indicators for global baseline development until 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[15]	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%).

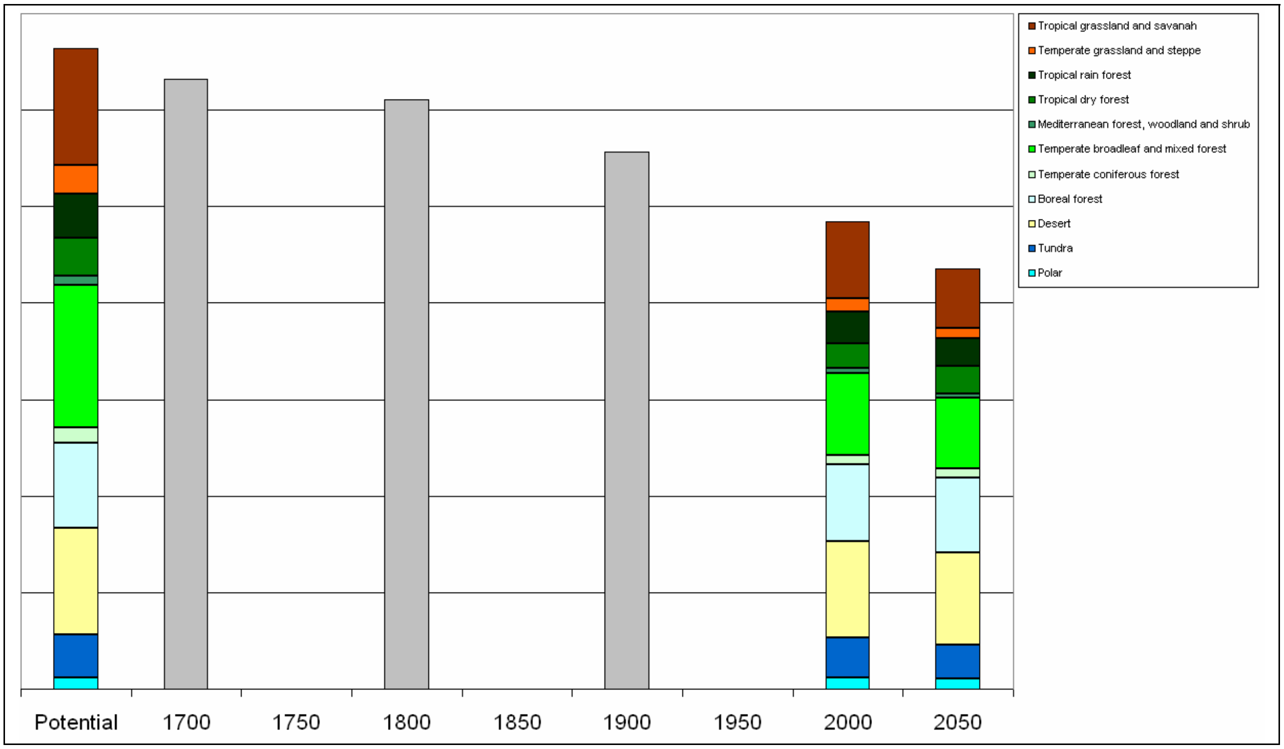


Figure 7: Trends in biodiversity from 1700 – 2050[16]

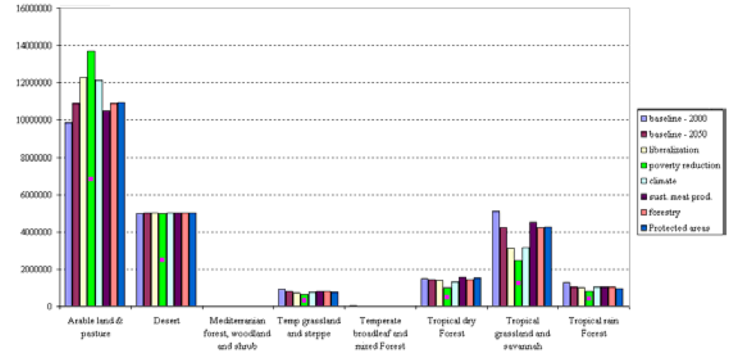
Table 2: Overview of baseline trends in biodiversity, and additional (-) or avoided (+) loss per option

Region	Biodiversity 2000	Baseline in 2050	Baseline loss	Liberali-sation	Poverty reduction	Climate Change	Sustainable Meat. Prod.	Sustainable Forestry	Protected Areas 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%							

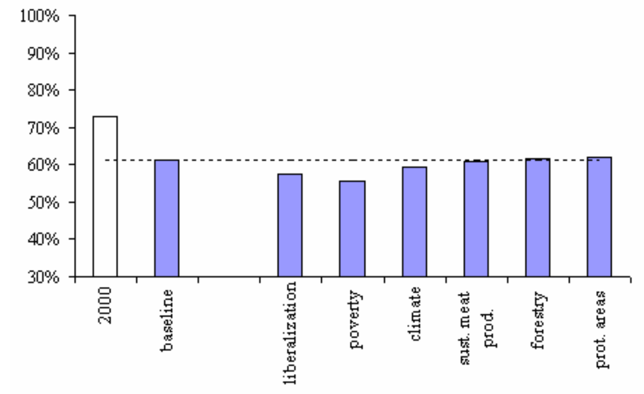
[16] In terms of mean abundance of the original species.

5.2 Sub- Saharan Africa

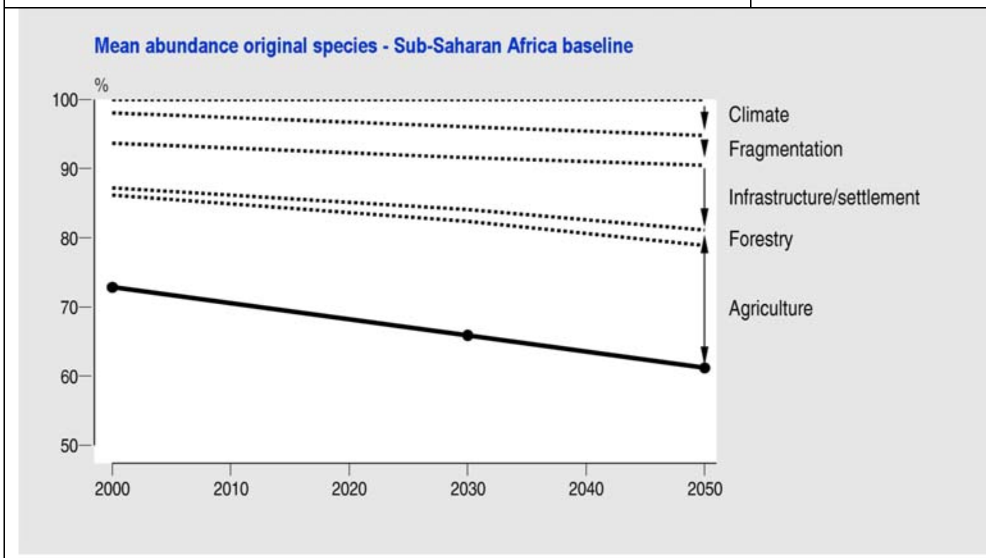
5.2.1 *Figures Africa*



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 8: Sub Saharan African development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 3: Summary of indicators for Sub Saharan African regional baseline development until 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	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%).

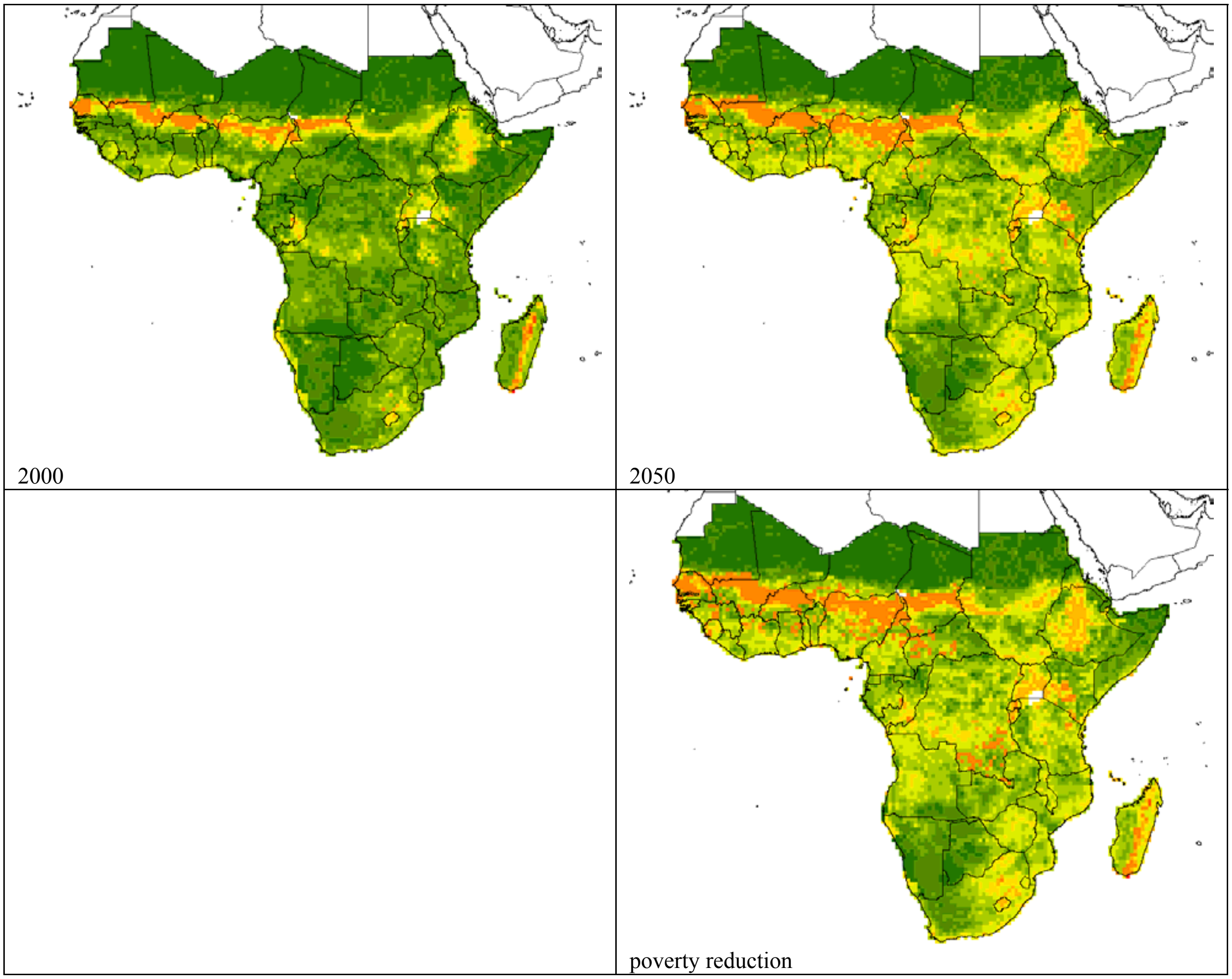


Figure 9: Spatial distribution of biodiversity for Sub Saharan Africa, in the baseline development (2000-2050), and change in biodiversity due to poverty reduction

5.2.2 Results for Sub- Saharan Africa

Baseline development:

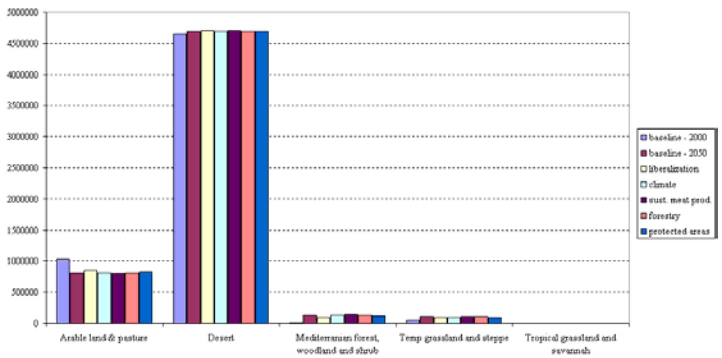
- In Sub-Saharan Africa, the biodiversity decreases in the scenario period from 73% in 2000 to 61% in 2050.
- This region is the only one where agricultural development plays a significant role in further biodiversity loss. The doubling of the population in this region, and the absence of strong increases in agricultural productivity drive the agricultural expansion.
- The change in land use can be seen as shifts in biomes. Conversion of mainly tropical grasslands and savannahs 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

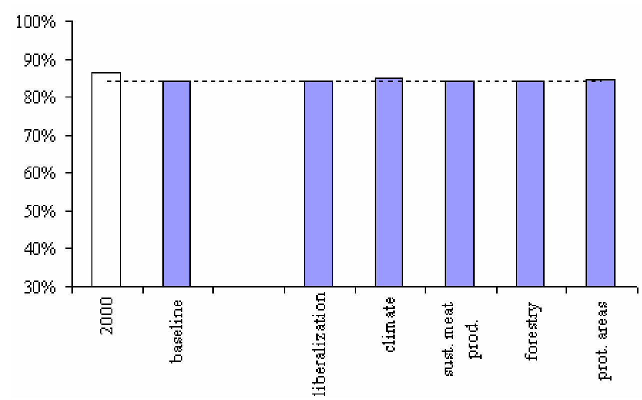
- Both liberalisation and poverty reduction lead similarly to a significant further reduction of the remaining biodiversity (-3.7% and -5.7%, respectively). Increased agricultural production is the main driving force in both options, leading to even more conversion than in the baseline. Not surprisingly, 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 savannahs.
- 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%).

5.3 North Africa

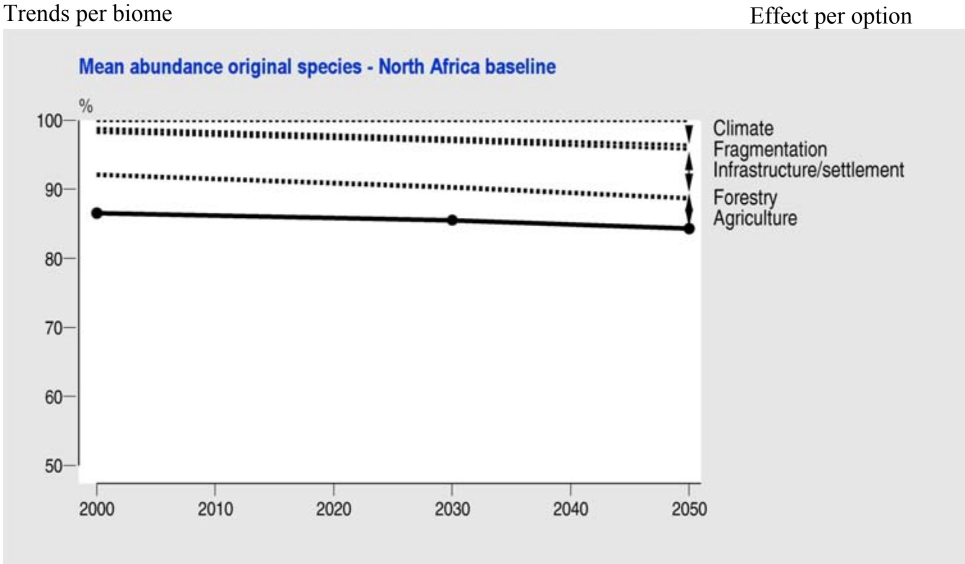
5.3.1 *Figures North Africa*



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 10: North African development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 4: Summary of indicators for North African regional baseline development until 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%).

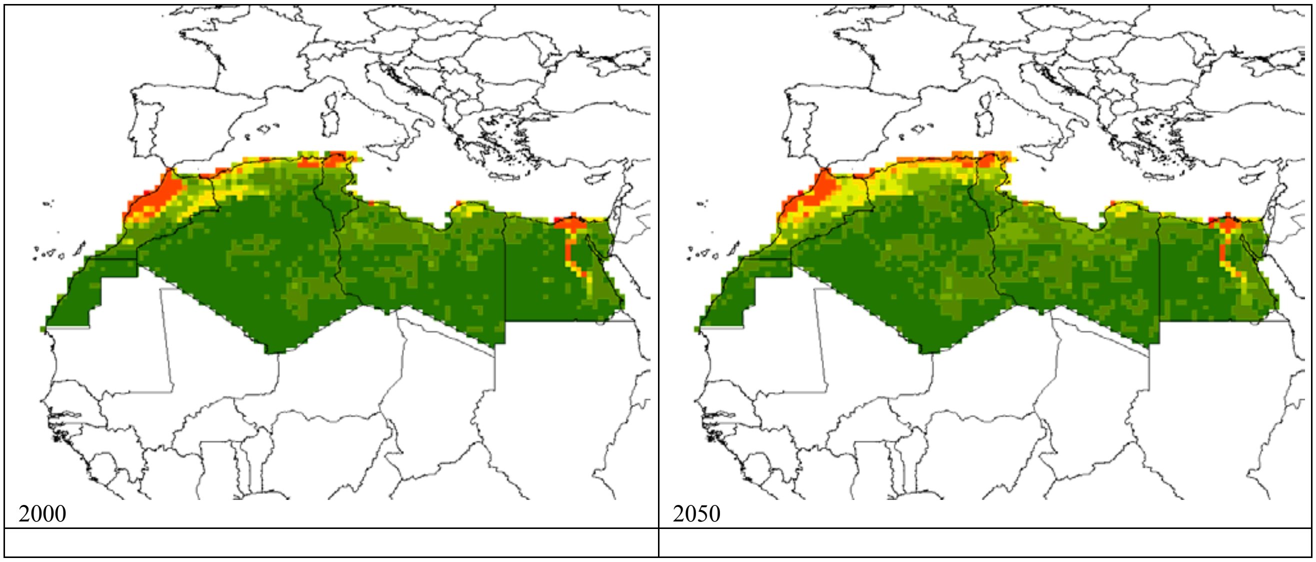


Figure 11: Spatial distribution of biodiversity for North Africa, in the baseline development (2000-2050)

5.3.2 Results for North Africa

Baseline development

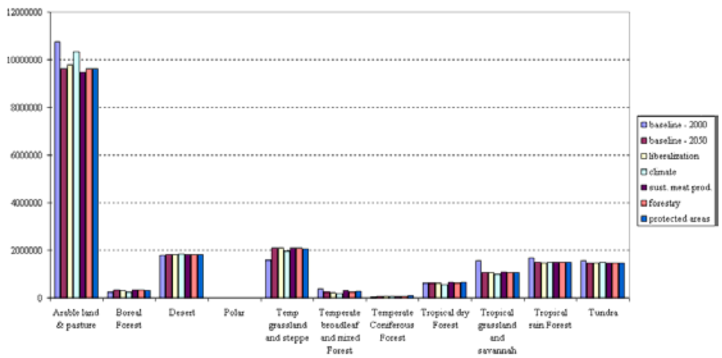
- In the North African region, the biodiversity is reduced from 87% to 84% between 2000 and 2050.
- The most important cause of this further loss is the effect of climate change on the natural biomes. Through temperature increase and increased drought, arable land is lost and replaced by other biomes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

Biodiversity effects of options

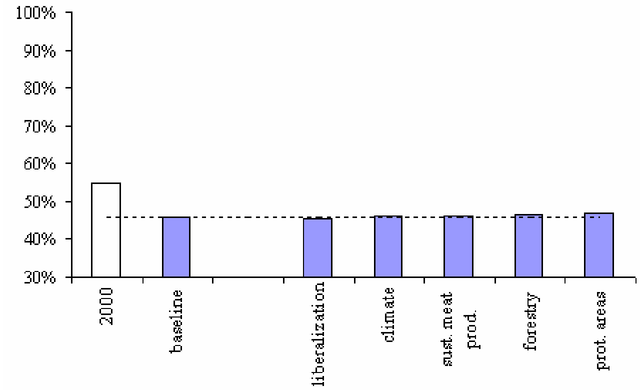
- Most options have very small effects. The region is characterized by a dominance of the desert biome that is either inaccessible or unsuitable for human exploitation. The area is therefore not very susceptible to options that affect land-use changes, such as biofuel production or increased agricultural activities through market 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.

5.4 South and East Asia

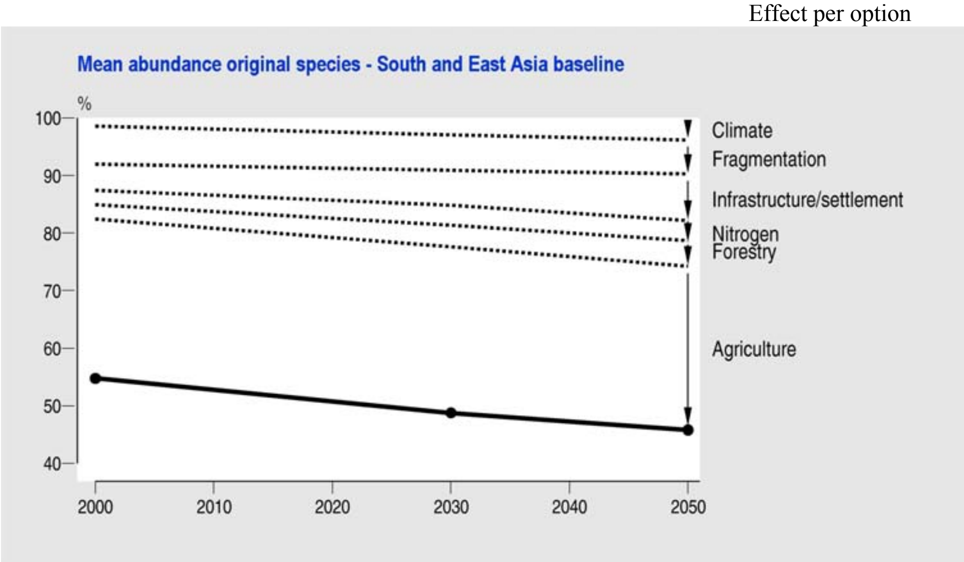
5.4.1 Figures South and East Asia



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 12: South and East Asian development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 5: Summary of indicators for South and East Asian regional baseline development until 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%).

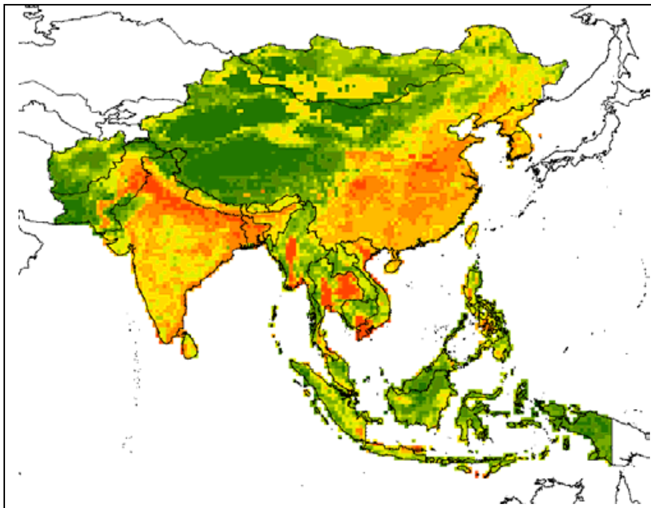
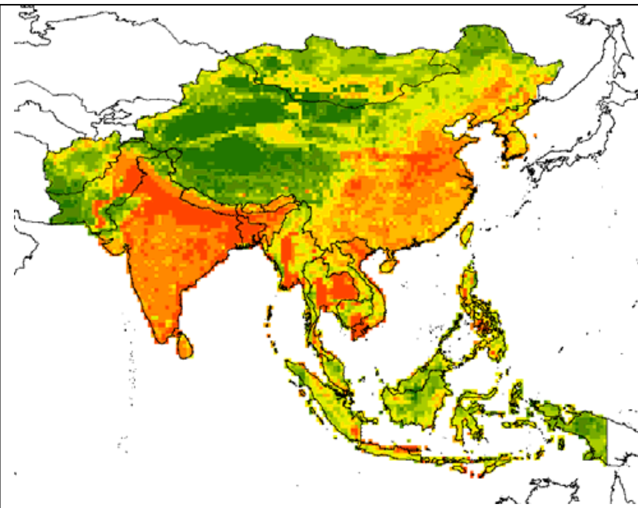
 2000	 2050
	Option effects not visible

Figure 13: Spatial distribution of biodiversity for South and East Asia, in the baseline development (2000-2050)

5.4.2 Results for South and East Asia

Baseline development

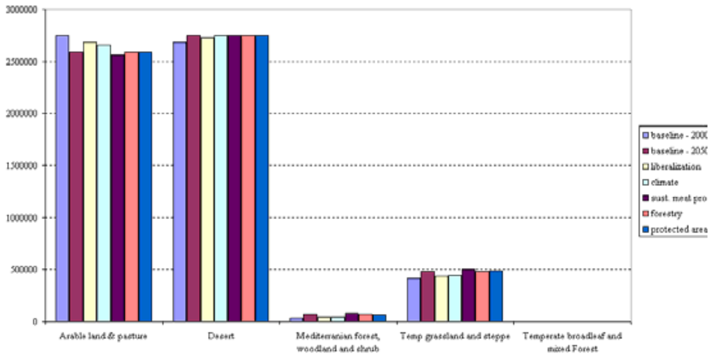
- In the region of South and East Asia, the biodiversity decreases from 55% in 2000 to 46% in 2050.
- This region is by far the largest under consideration. The considerable economic development in the past and the pressure from the large population, have had very strong effects in the past. This has resulted in a relatively low mean 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 much 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, so there is 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 taking place after 2000. The required production area rises sharply near 2050, because of lower productivity (result 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 amount 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.

Biodiversity effects of options

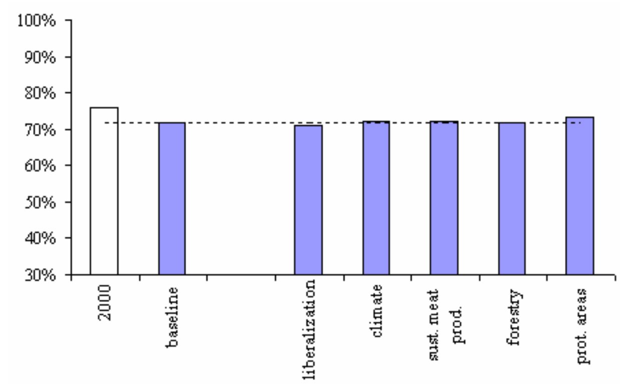
- In the forestry option, Asia is able to effectively produce wood from large areas of plantation forest, thereby substantially reducing the yearly cut forest area. Exploitation of semi-natural forests is gradually declining, and forests can restore to their original biodiversity levels. The effect will be become stronger in time, as semi-natural forests take a long time to recover from former forestry activities. The biodiversity increase is +0.8% by 2050.
- In China, agricultural productivity increase causes land to be taken out of production. In the climate mitigation option, this area can effectively be used for bio-fuel production. This partly counteracts the biodiversity gain from the removing climate change measures, and the net result is still positive (+0.4%).
- Increasing the area of protected areas leads to a 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, where room for production is made available through increased production efficiency.

5.5 West Asia

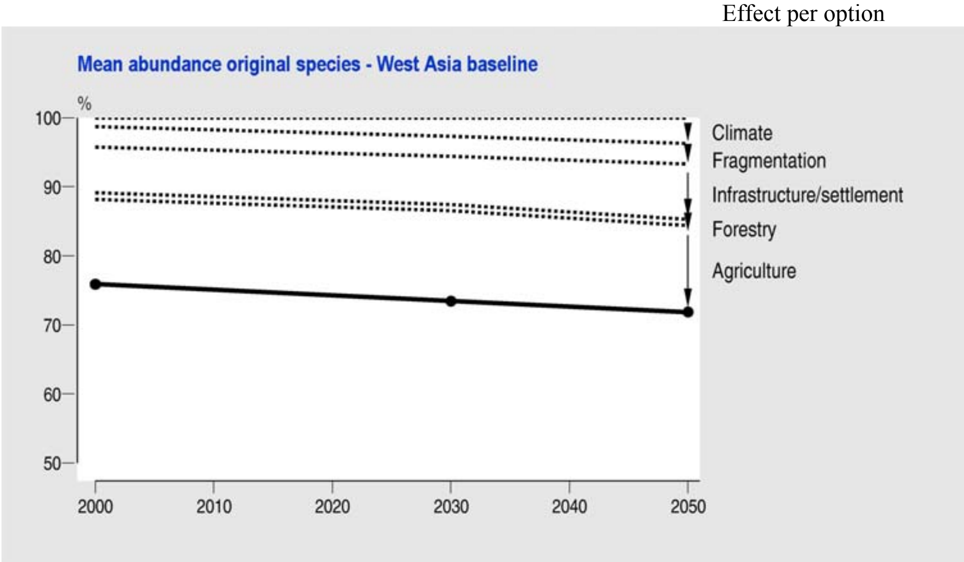
5.5.1 Figures West Asia



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 14: West Asian development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 6: Summary of indicators for West Asian regional baseline development until 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%).

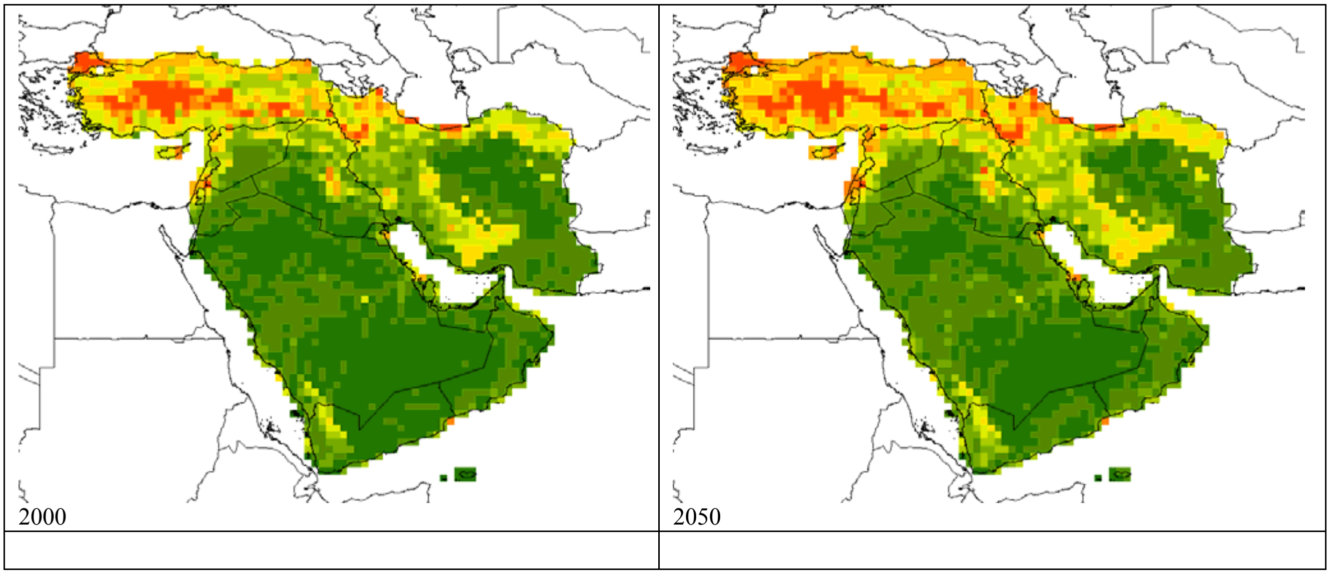


Figure 15: Spatial distribution of biodiversity for South and East Asia, in the baseline development (2000-2050)

5.5.2 Results for West Asia

Baseline development:

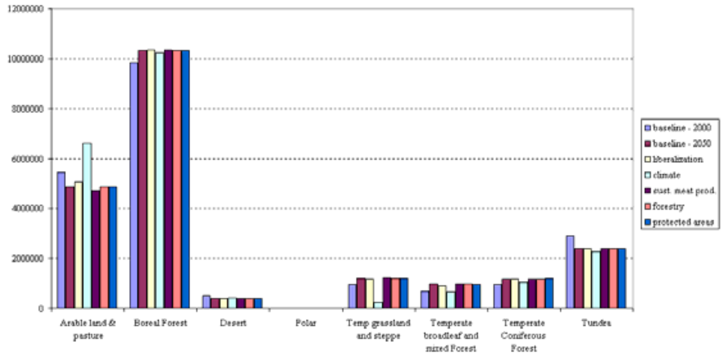
- In the West Asian region, biodiversity declines from 76% in 2000 to 72% in 2050.
- The relatively slow biodiversity decline, in comparison with other regions, is caused by the dominance of the desert biome that cannot easily be exploited and developed for human use. As a result, the indirect drivers 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

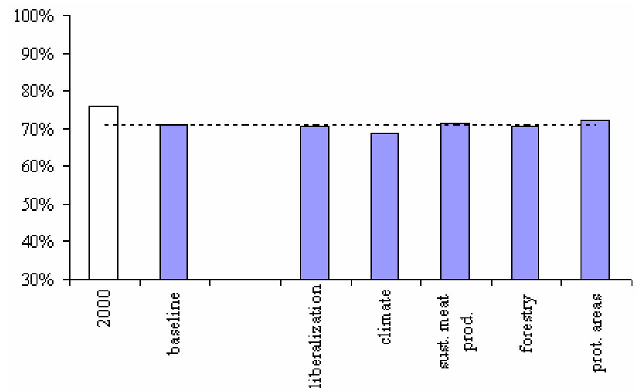
- Liberalisation of the agricultural market has a further biodiversity reducing effect (-0,7%). Arable land is expanded at the expense of temperate grassland and species rich Mediterranean shrub and woodland.
- Increasing the area of protected areas leads to higher biodiversity (+1.6%).
- Reduction of 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.

5.6 Russia and North Asia

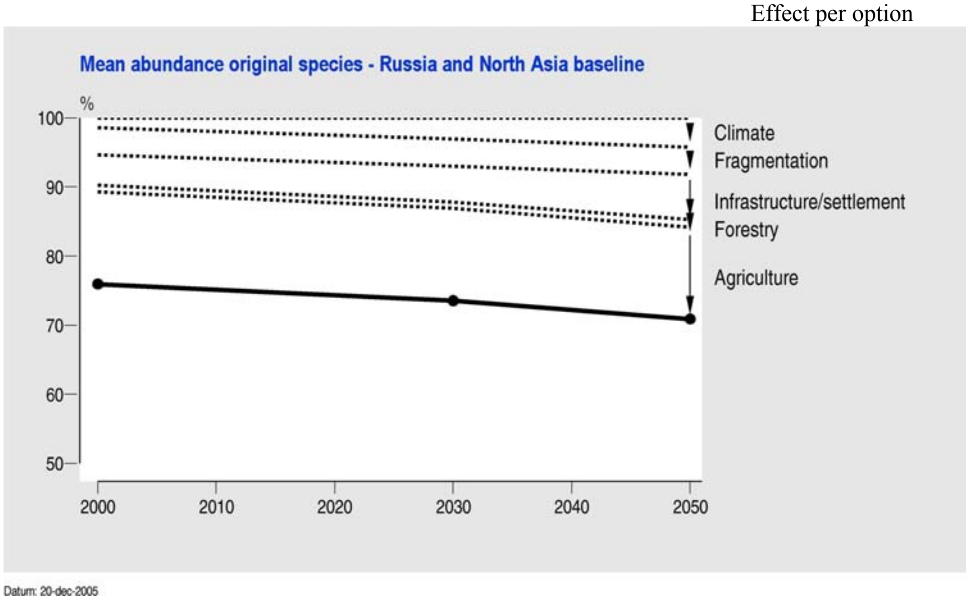
5.6.1 Figures Russia and North Asia



Trends per biome



Effect per option



Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 16: Russian and North Asian development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 7: Summary of indicators for Russian and North Asian regional baseline development until 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%).

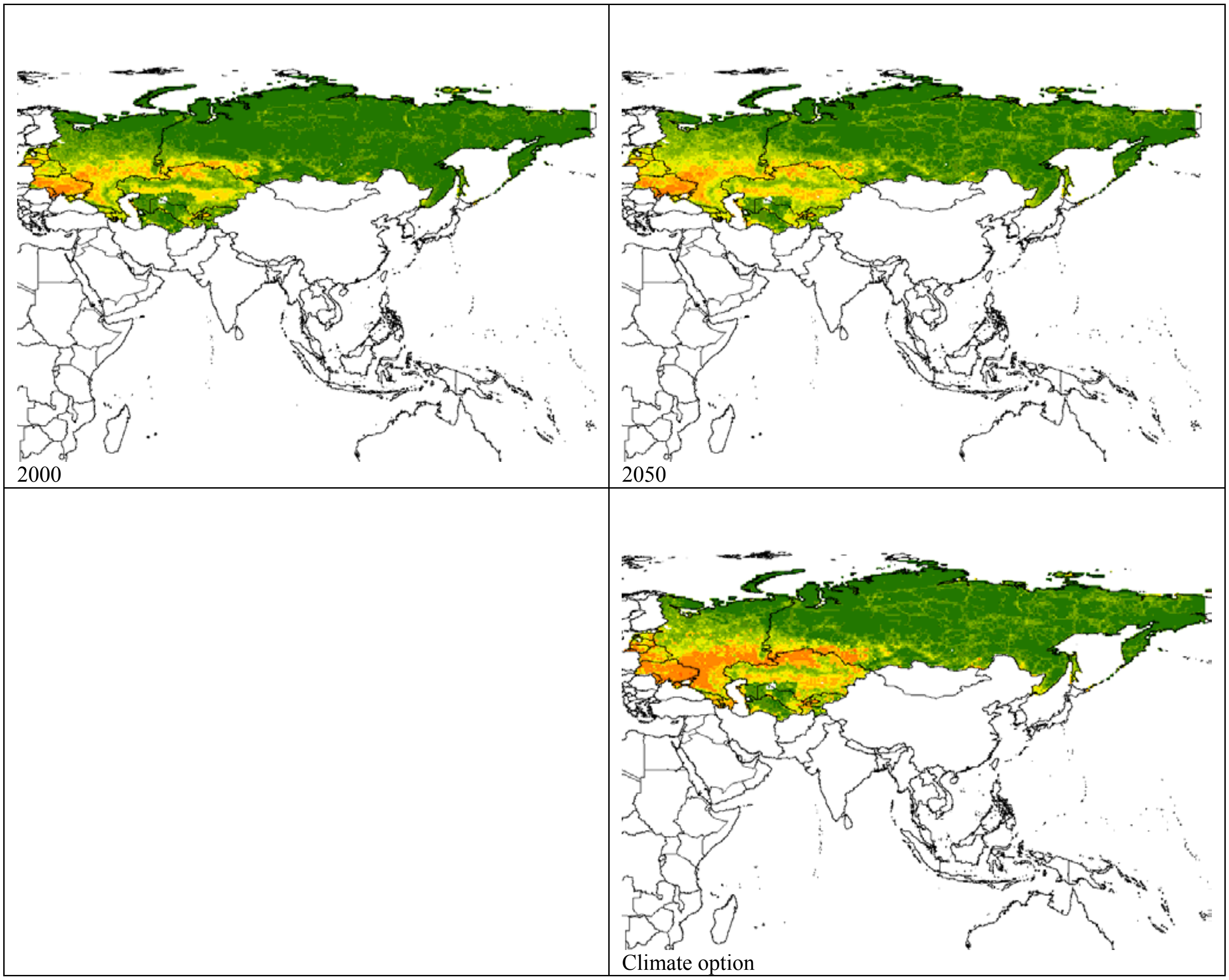


Figure 17: Spatial distribution of biodiversity for Russia and North Asia, in the baseline development (2000-2050), and change in biodiversity due to the climate change mitigation option

5.6.2 Results in Russia and North Asia

Baseline development

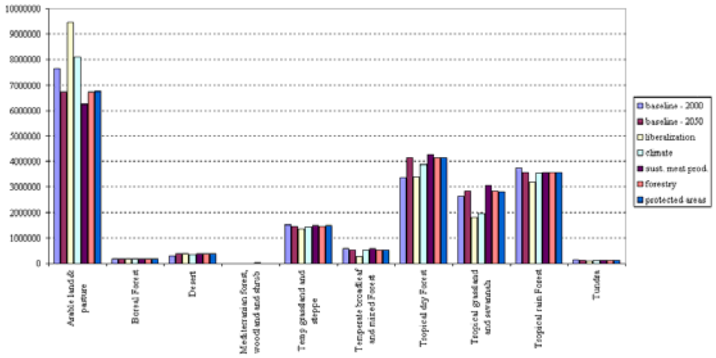
- In Russia and North Asia, the biodiversity declines from 76% in 2000 to 71% in 2050.
- The most important cause of the further loss is the climate change effect, affecting the vast areas of boreal forests and the tundra's.
- The infrastructural development is a further factor contributing to the biodiversity 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 it also produces for Europe and China. This increased trading will put additional pressure on the remaining vast boreal forest biome.

Biodiversity effects of options

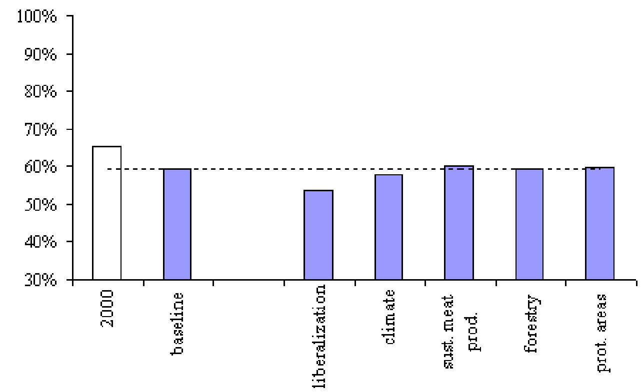
- The option with the largest effect for Russia and North Asia is reduction of climate change, leading to a further biodiversity loss of -2%. The region becomes an important area for bio-fuel production. Developments in the baseline have led to large amounts of abandoned agricultural land that can be 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.

5.7 Latin America & Caribbean

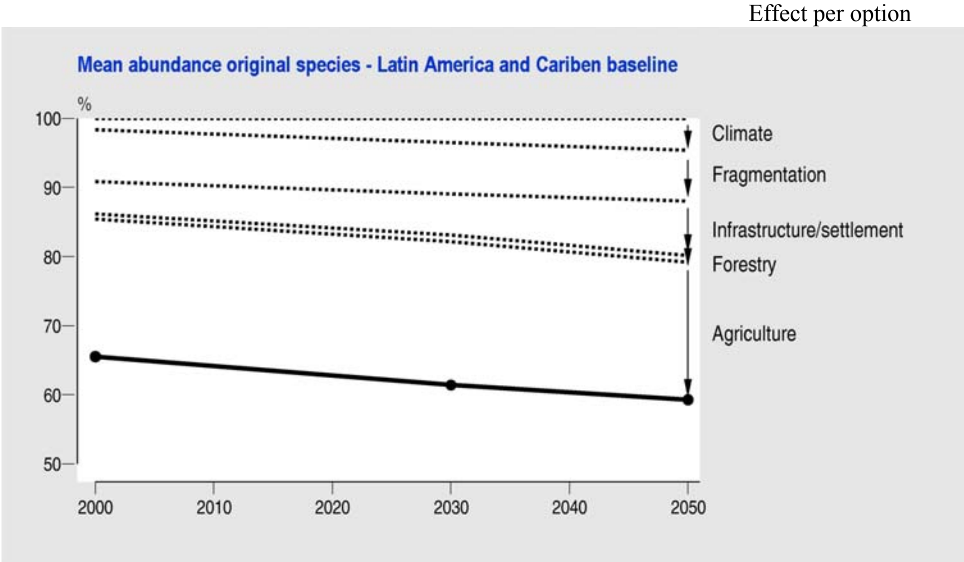
5.7.1 *Figures Latin America & Caribbean*



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 18: Latin American and Caribbean development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 8: Summary of indicators for Latin American and Caribbean regional baseline development until 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%).

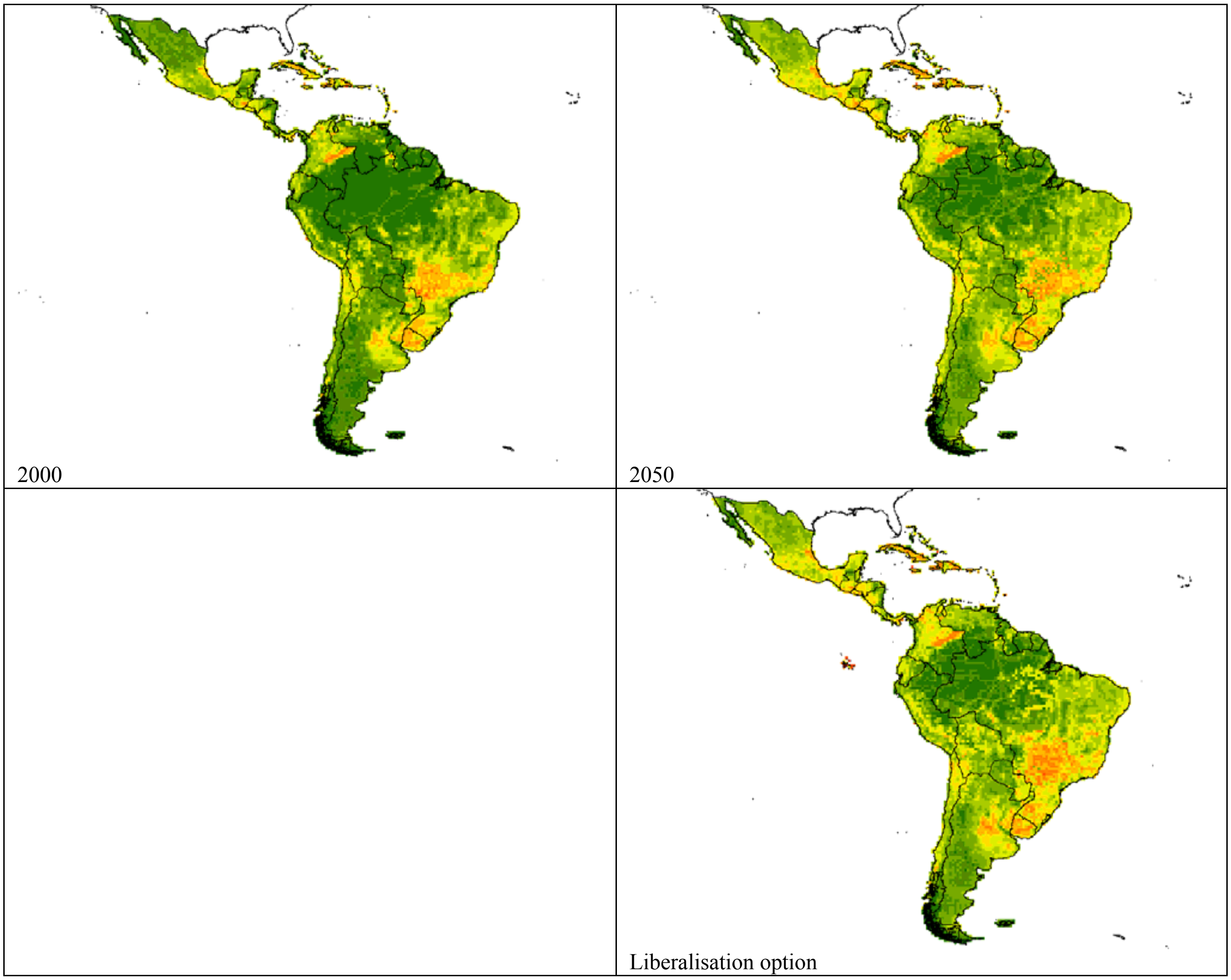


Figure 19: Spatial distribution of biodiversity for Latin America and the Caribbean, in the baseline development (2000-2050), and change in biodiversity due to liberalisation

5.7.2 Results for Latin America & the Caribbean

Baseline development:

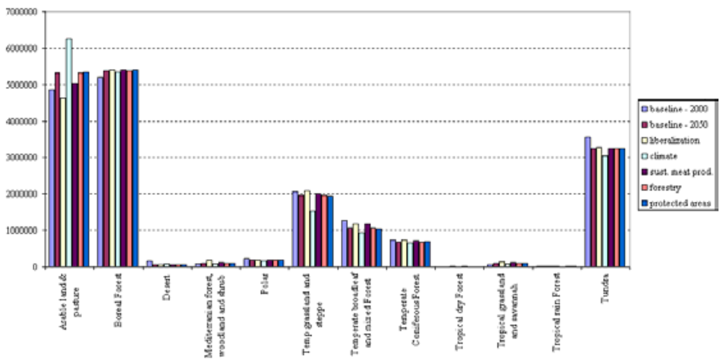
- In Latin America, the biodiversity declines from 66% in 2000 to 59% in 2050.
- The significant loss observed until 2000 was mainly due to habitat loss (land conversion for agriculture and forestry).
- The main factors contributing to the further biodiversity loss are infrastructural development, fragmentation and the effects of climate change. Together these factors account for a 7% loss.
- 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 the biodiversity restores only slowly. 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 amount of semi-natural forest. Furthermore, 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

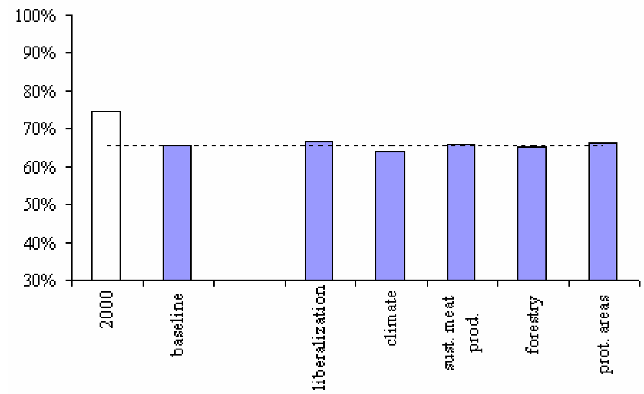
- Liberalisation of the agricultural market has by far the strongest effect in Latin America, further reducing the biodiversity (-5.4%). Liberalisation induces a boost in "south-south-trade" in agricultural products, driven by low production costs and ample supply of productive land. This holds strongly for Latin America, where agriculture experiences strong expansion and the area for food crops, grass and fodder has consequently grown by 40% in 2050 compared to the baseline. The loss of habitat associated with the land conversion mainly affects tropical dry and rain forest (inducing deforestation), and grassland and savannah areas. The reduction of dry forest area in 2050 is about as big as the gain expected in the baseline between 2000 and 2050.
- The climate mitigation option shows a net negative effect on biodiversity (-1.6%), as this region becomes an important producer of biofuel. The production of biofuel leads to further land-use change, mostly in tropical grasslands and savannah, which is the preferred location for bio-energy production. On the short term, the effect of additional agricultural land-use is larger than the positive effect from reduced climate change. By 2050 the net effect is still negative, but this can change as time proceeds.
- There is a noticeable effect of producing more sustainable meat (+0.7%), as meat production is an important activity in the region. In terms of biomes, 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.

5.8 North America

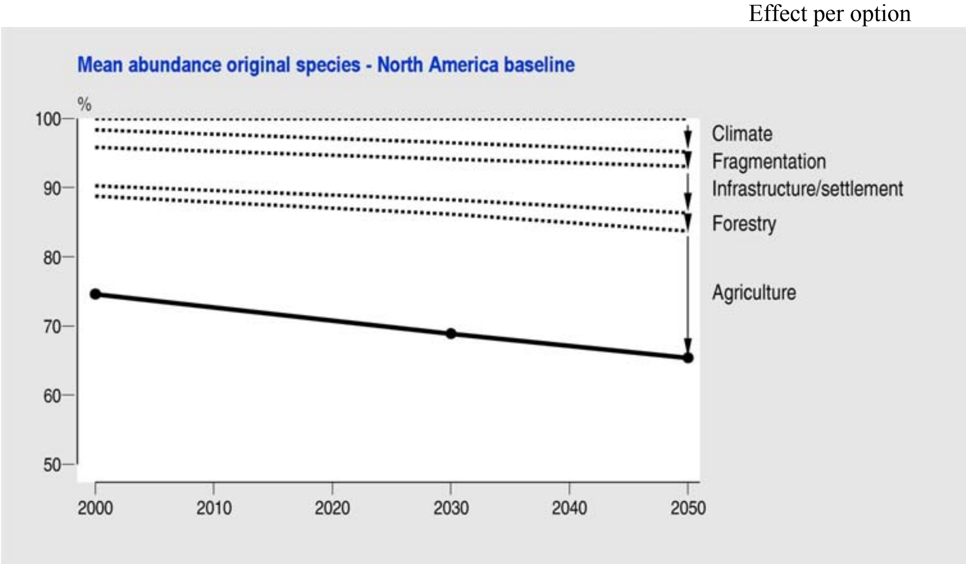
5.8.1 Figures North America



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 20: North American development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors) per biome

Table 9: Summary of indicators for North American regional baseline development until 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%).

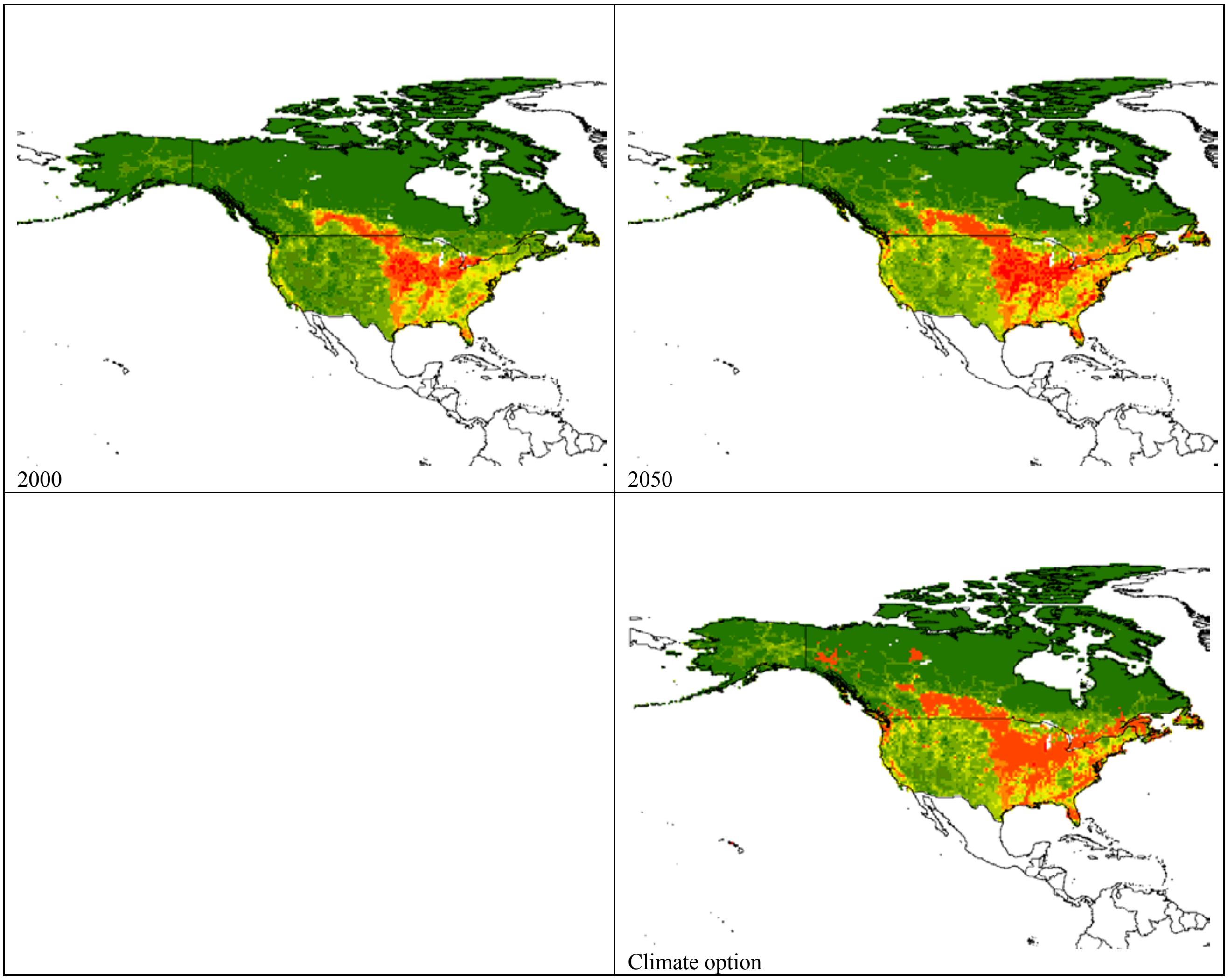


Figure 21: Spatial distribution of biodiversity for North America, in the baseline development (2000-2050), and change in biodiversity due to climate change mitigation

5.8.2 Results for North America

Baseline development:

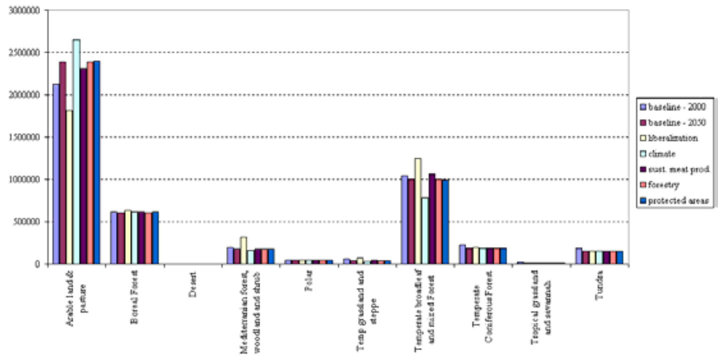
- In North America, there is a further decrease in biodiversity from 75% in 2000 to 65% in 2050.
- This decrease is mainly due to climate change, affecting a range of boreal to temperate biomes.
- Further, there is an increase in agricultural occupied land. The agricultural sector remains a strong player 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

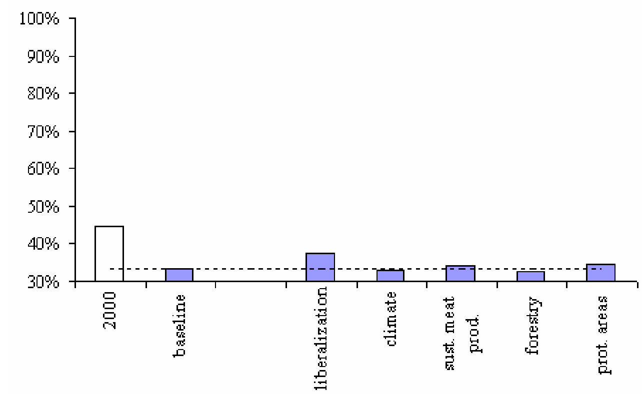
- Liberalisation has a distinct positive effect on biodiversity in North America (+1.4%). The increase in agricultural land use of the baseline is now reversed, as the opening up of global markets induces a shift of agricultural production to other regions like Latin America and Sub-Saharan Africa. Lifting of trade regulations allow 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 utilized. The associated loss of natural biomes, mainly temperate grasslands and tundra's, is only partly compensated by the reduced climate impact.
- The increased price of meat associated with more sustainable meat production practices does have a noticeable positive effect on biodiversity (+0.7%). Meat production decreases, lowering the demand for grass and fodder (not just in the region but also abroad). 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 further biodiversity loss (-0.3%). The productivity of plantations in this region is not very different from production in semi-natural forests. Establishing plantations (mainly in the USA) therefore leads to additional habitat loss that is in 2050 not yet counteracted by biodiversity gains in slowly restoring semi-natural forests.

5.9 Europe

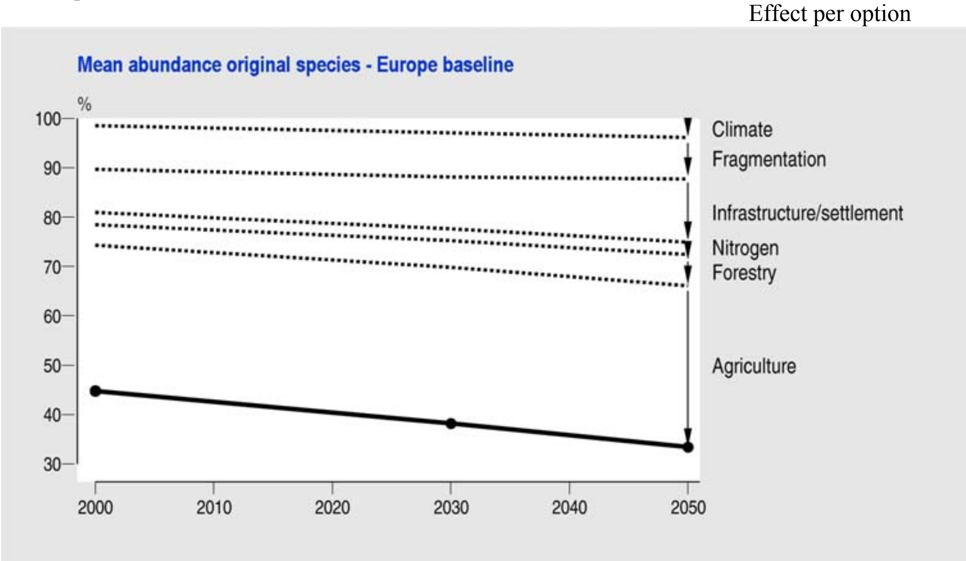
5.9.1 *Figures Europe*



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 22: European development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 10: Summary of indicators for European regional baseline development until 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%)

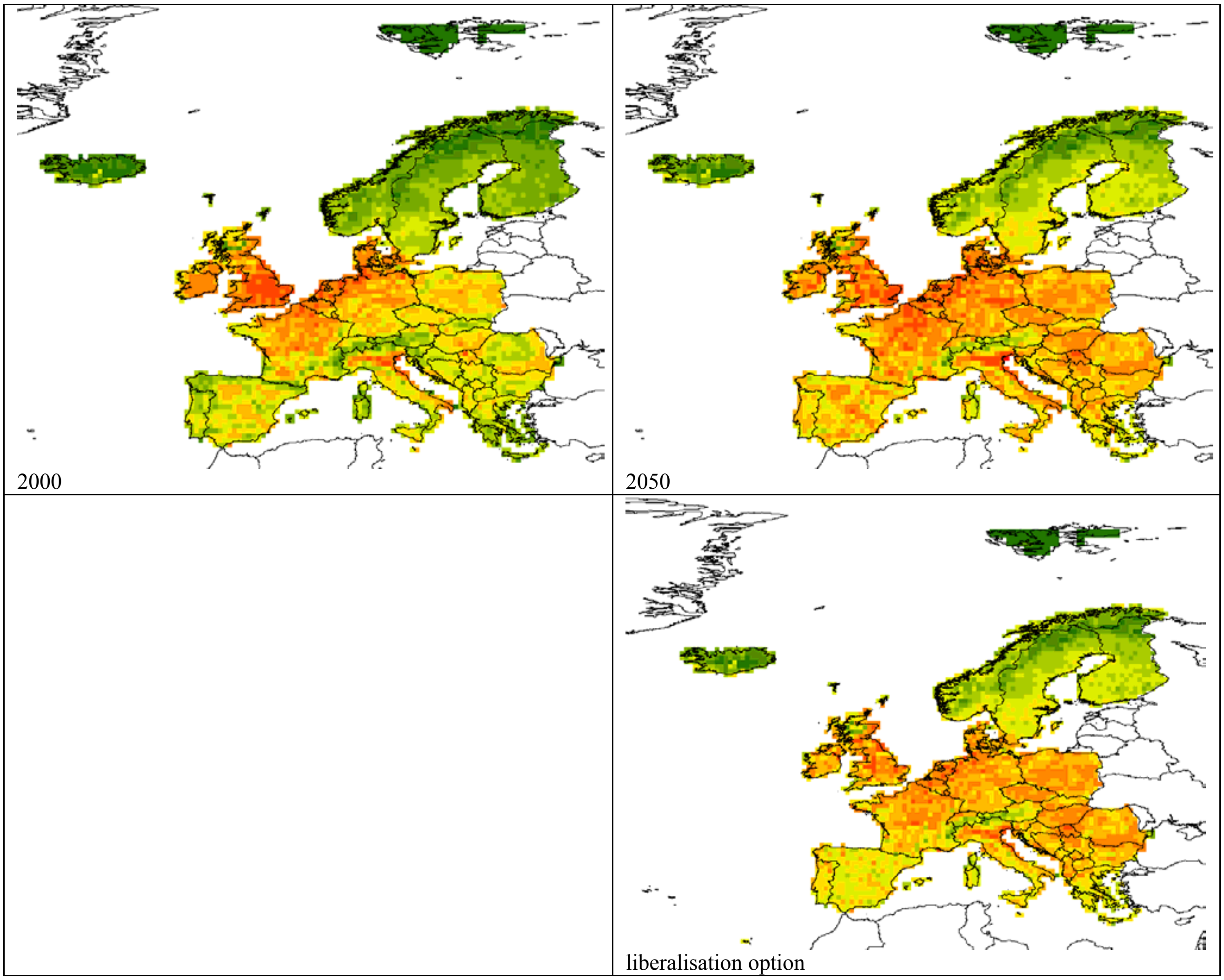


Figure 23: Spatial distribution of biodiversity for Europe, in the baseline development (2000-2050), and change in biodiversity due to liberalisation of the agricultural market

5.9.2 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, like 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.
- Several of the distinguished pressure factors contribute to this further biodiversity loss: climate change, infrastructural development and settlement, forestry. The latter indicates that European agriculture maintains its position in expanding world markets under continued agricultural policy and trade rules and regulations.

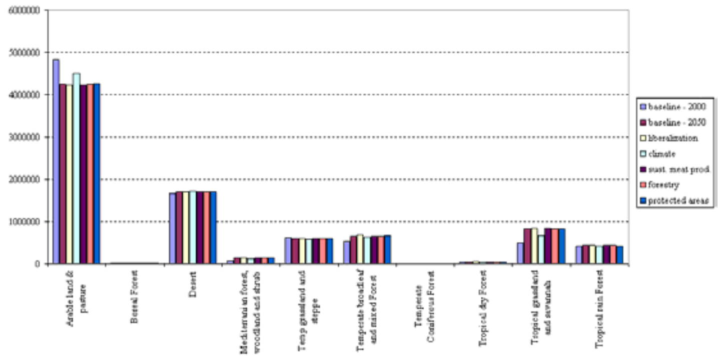
Effects of options

- Liberalisation has the largest positive effect on biodiversity in Europe (+4.2%). Lifting of 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%.

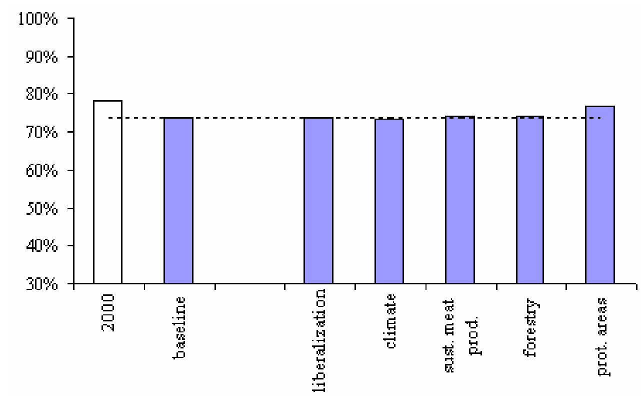
  The abandoned land is slowly returning to a more natural state, with higher biodiversity value; however this process is still not completed by 2050. Mediterranean forests, woodland and shrub and temperate forest areas show the biggest improvement.
- Relatively modest volumes of bio-fuel production, relative 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.

5.10 Oceania incl. Japan

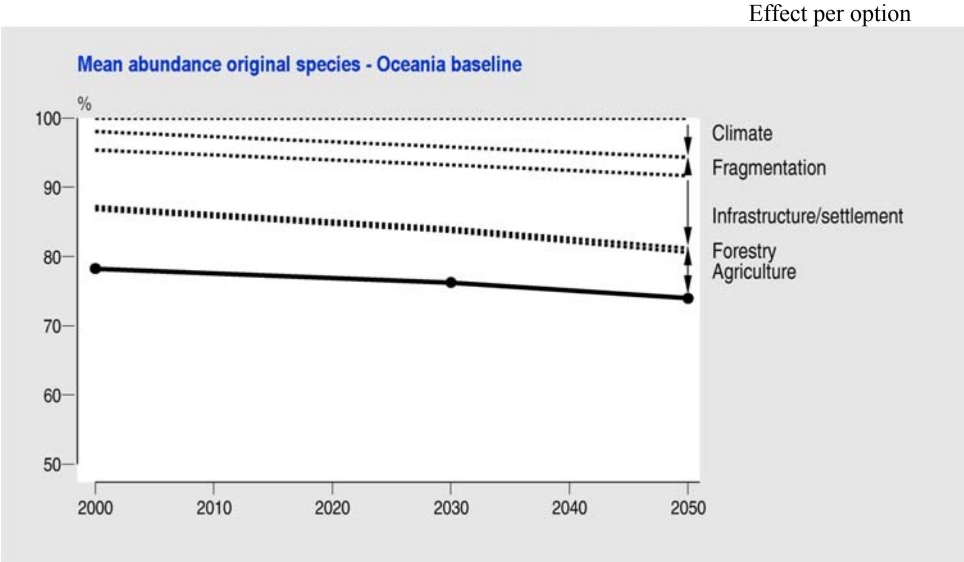
5.10.1 *Figures Oceania*



Trends per biome



Effect per option



Datum: 20-dec-2005

Baseline scenario, Trends in mean species abundance, incl. share per pressure

Figure 24: Oceanian (including Japan) development and option effects per biome, regional effects per option and biodiversity trend for the baseline scenario (including shares of pressure factors)

Table 11: Summary of indicators for Oceanian (including Japan) regional baseline development until 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%).

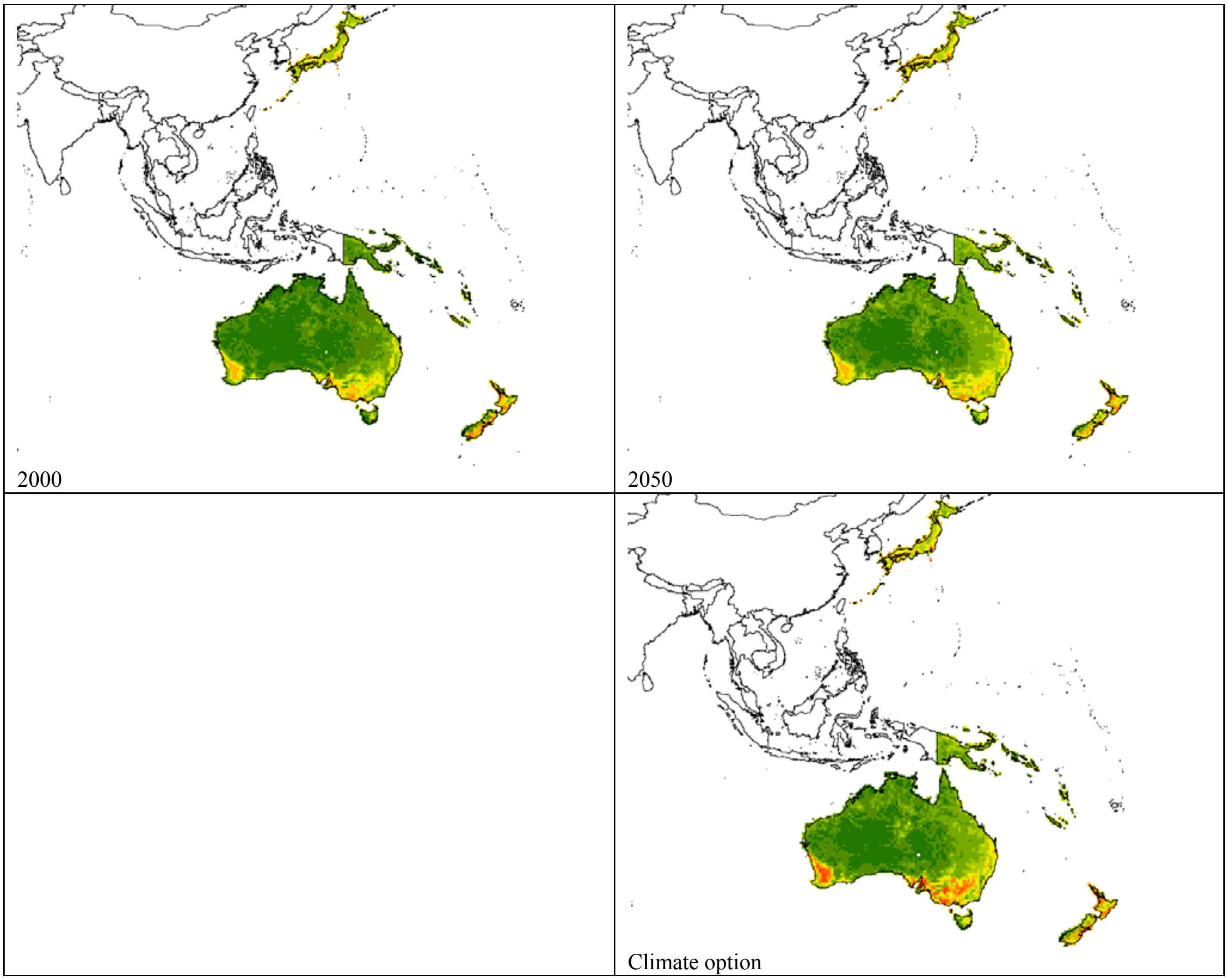


Figure 25: Spatial distribution of biodiversity for Oceania (including Japan), in the baseline development (2000-2050), and change in biodiversity due to climate change mitigation

5.10.2 Results for Oceania and Japan

Baseline development

- In Oceania and Japan, the biodiversity decrease 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 disappearing amount of arable land shows up as restored natural forest and savannah biomes.

Biodiversity effects of options

- Increasing the area 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 in this region. The Oceanic region does not employ import barriers at the moment, like 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 similar small effect.

Annex 1: 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 fertilizer, 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 (UN Millennium Project. 2005).

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 stylized 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[17].
- 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

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

more developed, better educated and healthier population will have lower fertility rates, leading to lower population growth, one of the driving forces behind biodiversity losses. This demographic transition is assumed not to take place within the scenario period.

3. Limiting climate change

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

Description of the policy option
As confirmed by a multitude of publications , assessed by the IPCC (EEA, 2004;IPCC, 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 recognized 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 the use of substantial amounts of land. 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, 2003). 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, 2030). 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. For the GBO2 study, the plantation establishment is maximized 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 standardize. 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 US (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-CBD, 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). 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

Contract CBD 2010-options GBO2.pdf

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).

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***: status of biological diversity and the a biotic 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.

Scenarios are applied to explore possible futures in which particular factors are considered as autonomous, and not to be influenced by the policy makers of concern. On a scenario policy options can be added.

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: Uncertainties and sensitivity

There are numerous sources of uncertainty that influence the outcome of the present analysis, ranging from data imprecision, model uncertainties (dose-response relations), to scenario assumptions (future ignorance). These cannot be dealt with completely here.
In this section, only the most important uncertainties and assumptions that affect the baseline and options are addressed, and qualitative expert judgments on their biodiversity effects are given. A more formal and full 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 finding
In general, the baseline presents an *optimistic* view on the future biodiversity decline, as considerable productivity improvements restrict the additional required production area for the growing world population. The area for the required agricultural crops are up to 20% lower than in the often used IPCC scenarios, and up to 28% lower than the MA scenarios (see figure below).

Thus, the baseline contains important technological improvements that reduce the biodiversity loss rates in the future. It is important to keep this in mind when judging the potential effects of options.

Most of the options are designed in an extreme way that overestimates the effects on biodiversity. Negative consequences are probably overestimated in the options on liberalisation, poverty reduction and sustainable meat production. The positive effects of increasing the protected areas are also overestimated.

Chances are that climate sensitivity turns out to be higher. So more measures (including bio energy production) will be necessary that will negatively affect the future biodiversity. The biodiversity saving potential of the forestry option is underestimated, but the global influence of forestry is generally low.

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 crop area in the baseline is relatively low in comparison with other often used IPCC scenarios (up to 20%). 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.

Liberalisation option sensitivity
As mentioned before, the liberalisation option is rather extreme in assuming that all barriers and des-incentives for free trade of agricultural products are simultaneously abolished. In reality, such agreements are introduced with delays, exemptions and special conditions leading to more gradual and partial shifts. As more time elapses, differences in wages and land rents that drive

the observed shift from North to South, tend to decrease. Thus, the effects will never materialize to the full extent reported here. Moreover, the WTO rules allow for interventions in unfettered trade under certain conditions, including environmental impacts and regulations.

Altogether, this means that the negative effects of liberalisation along more smoothened trajectories are probably smaller and 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, due to increased investments. Agricultural productivity and labor 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. 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 assumed to be negligible within the scenario horizon.

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 degrees 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 degrees, 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 smaller.

Changes in local climate are subject to even larger uncertainty 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 even differ in sign between the various models (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. In order to meet the ambitious target, large shares of the estimated potentials are 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 could 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 currently running 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 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 not known is whether these will causes an under- over overestimation of meat consumption.

A 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, but this has been taken into account in the baseline and option sufficiently. 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 get established on areas occupied by (semi-)natural forests (deforestation), and not on abandoned land or land in agricultural use (reforestation and afforestation). This practice is in not according to the sustainability criterion ("FSC-principle 10"). Taking the available "free" land into account (by introducing 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 at which burning forest biomes takes place in conversions processes is unknown, and it will differ strongly between regions. The assumption is that forests are burnt in the conversion process, what 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 reduce the considerable CO_2-emissions from burning, thereby reducing the biodiversity loss.

Each region produces the regional demanded wood. There are no global trade shifts. This assumption is plausible as the production goods (the forest and processing industries) are not easily translocated. But in practice shifts will occur where regions border. For instance harvesting is 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 by slower investment in plantation establishment.

Altogether, we have mostly taken conservative assumptions. Taking the mentioned 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 present land-uses, while no further conversion takes place. This means that enforcement of the reservation status is assumed to be complete.

In the 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 restore 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 ecoregions.

Altogether, this means that designating protected areas in the baseline and 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 12: 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 mentioned uncertain or neglected 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 removing reduction	No change	On the long run +/++
Limiting climate change	Climate sensitivity	+ / --	+ / --
	Costs of alternative measures	+ / -	+ / -
	Biodiversity response to change	??	??
Sustainable meat production	Costs of sustainable production overestimated	No change	-
	Elasticity 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	+ ?	+ ?

References

Alcamo, J., Leemans, R. and Kreileman, E. 1998. Global change scenarios of the 21st century. Results from the IMAGE 2.1 model. Pergamon & Elseviers Science, London.

Alkemade, R., Bakkenes, M., Bobbink, R., Miles, L., Nellemann, C., Simons, H., Tekelenburg, T. in prep. Global biodiversity assessment framework (GLOBIO 3). MNP report.

Azar, C., Lindgren, K., Larson, E. & Möllersten, K. in press. Carbon capture and storage from fossil fuels and biomass - Costs and potential role in stabilizing the atmosphere. *Climatic Change*.

Bakkenes, M., Alkemade, J.R.M., Ihle, F., Leemans, R. and Latour, J.B. 2002. Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050. *Global Change Biology* 8, 390-407.

Balmford, A., Gaston, K.J., Blyth, S., James, A. & Kapos, V. 2003. Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. *PNAS* 100(3):1046-1050.

Balmford, A. & Whitten, T. 2003. Who should pay for tropical conservation and how should the costs be met? *Oryx* 37(2): 238-250.

Bartholome, E., Belward, A., Beuchle, R., Eva, H., Fritz, S., Hartley, A., Mayaux, P. & Stibig, H.-J. 2004. Global Land Cover for the year 2000. European Commission, Joint Research Centre. Database.

Berndes, G., Hoogwijk, M., & van den Broek, R. 2004. The contribution of biomass in the future global energy system: a review of 17 studies. *Biomass and Bioenergy* 25(1): 1–28.

Birdlife International. 2005. Important Bird Areas (IBAs). http://www.birdlife.org/action/science/sites/index.html. Accessed 14 October 2005.

Blom, A. 2004. An estimate of the costs of an effective system of protected areas in the Niger Delta - Congo Basin Forest Region. *Biodiversity and Conservation* 13(14): 2661-2004.

Bobbink, R. 2004. Plant species richness and the exceedance of empirical nitrogen critical loads: an inventory. Utrecht University, Utrecht.

ten Brink, B.J.E. 2000. Biodiversity indicators for the OECD Environmental outlook and Strategy, a feasibility study. RIVM report 402001014, in co-operation with WCMC, Cambridge/Bilthoven.

Brown, C. 2000. The Global outlook for future wood supply from forest plantations. Working Paper No. GFPOS/WP/03. Food and Agriculture Organization of the United Nations, Rome, 141 pp.

Bruner, A.G., Gullison, R.E. & Balmford, A. 2004. Financial Costs and Shortfalls of Managing and Expanding Protected-Area Systems in Developing Countries. *BioScience* 54(12), 1119-1126.

Dixon, J., Gulliver, A. & Gibbon D. 2001. Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. FAO and World Bank, Rome and Washington D.C.

FAO, 2004. Trends and current status of the contribution of the forestry sector to national economies. Working paper: FSFM/ACC/07.

James, A., Gaston, K. & Balmford, A. 1999. Balancing the Earth's accounts. *Nature* 401: 323-324.

James, A., Gaston, K. & Balmford, A. 2001. Can we afford to conserve biodiversity? *BioScience* 51(1): 43-52.

Maturana, J. 2005. Economic costs and benefits of allocating forest land for industrial tree plantation development in Indonesia. CIFOR Working Paper, No. 30. Center for International Forestry Research (CIFOR) .

EEA. 2004. Impacts of Europe's changing climate. An indicator-based assessment. European Environment Agency, EEA Report No 2 /2004, Copenhagen.

den Elzen, M., Lucas, P., van Vuuren, D. 2005. Abatement costs of post-Kyoto climate regimes. *Energy policy* 33, 2138-2151.

Enters, Thomas & Durst, P.B. 2004. What does it take? The role of incentives in forest plantation development in Asia and the Pacific. FAO RAP Publication 2004/27.

FAO. 2003. World Agriculture: towards 2015/2030. A FAO perspective. FAO, Rome.

Francois, J., Van Meijl, H. & van Tongeren, F. 2005. Trade liberalisation and developing countries under the Doha round. *Economic Policy*, in press.

Hertel, T., Anderson, K., Hoekman, B., Francois, J.F., & Martin, W. 1999. Agriculture and nonagricultural liberalisation in the millennium round, paper presented at the Agriculture and New Trade Agenda, October 1-2, 1999, Geneva, Switzerland.

IEA,.2004. World Energy Outlook 2004. International Energy Agency, Paris, 2004.

IMAGE-team. 2001. The IMAGE 2.2 implementation of the SRES scenarios. A comprehensive analysis of emissions, climate change and impacts in the 21st century. National Institute for Public Health and the Environment, Bilthoven, report nr. 481508018.

IPCC. 2001a. Climate change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessement Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2001.

IPCC. 2001b. Climate Change 2001: Mitigation. Contribution of Working Group III to the Third Assessement Report of the Intergovernmental Panel on Climate Change Cambridge University Press, 2001.

IUCN,. 2004. The Durban Action Plan. http://www.iucn.org/themes/wcpa/wpc2003/english/outputs/durban/daplan.htm#outcome3. Revised March 2004. Accessed 14 October 2005.

Klein Goldewijk, K. 2001. Estimating global land use change over the past 300 years: the HYDE database, *Global Biogeochemical Cycles* 15(2): 417- 433. (http://www.mnp.nl/hyde).

Leemans, R. & Eickhout, B. 2003. Analysing changes in ecosystems for different levels of climate change. OECD workshop on benefits of climate policy: improving information for policy makers.

Leemans, R. & Eickhout, B. 2004. Another reason for concern: regional and global impacts on ecosystems for different levels of climate change. *Global Environmental Change* 14, 219 – 228.

Myers, R.A. & Worm, B. 2003. Rapid worldwide depletion of predatory fish communities. *Nature* 423, 280-283.

van Meijl, H., van Rheenen, T., Tabeau A. & Eickhout, B. 2005. The impact of different policy environments on agricultural land use in Europe. *Agriculture, Ecosystems and Environment*, in press.

Metz, B. & van Vuuren, D.P. 2006. How, and at what costs, can low-level stabilisation be achieved? –An overview. in: Avoiding Dangerous Climate Change, Cambridge University Press, Cambridge.

Millennium Ecosystem Assessment. 2003. Ecosystems and Human Well-being: A framework for Assessment. World Resources Institute, Washington DC.

Millennium Ecosystem Assessment. 2005a. Living beyond our means. Natural Assets and Human Well-being. Statement of the Board. World Resources Institute, Washington DC.

Millennium Ecosystem Assessment. 2005b. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington DC.

Millennium Ecosystem Assessment. 2005c. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Millennium Project. 2004. Interim report of task force 1 on poverty and economic development.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human well-being: Synthesis. Island press, Washington DC.

Nakicenovic, N. & Riahi, K. 2003. Model runs with MESSAGE in the context of the further development of the Kyoto protocol. International Institute for Aplied Systems Analysis.

OECD. 2003. Agriculture, Trade and the Environment, The Pig Sector. OECD, vol. 2003, no. 21, pp. 1 - 186

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P. & Kassem, K.R. 2002. Terrestrial Ecoregions of the World: A New Map of Life on Earth. *BioScience* 51(11): 933-938.

Orme, C.D.L., Davies, R.G., Burgess, M., Eigenbrod, F., Pickup, N., Olson, V.A., Webster, A,J., Ding, T., Rasmussen, P.C., Ridgely, R.S., Stattersfield, A.J., Bennett, P.M., Blackburn, T.M., Gaston, K.J., Owens, I.P.F. 2005. Global hotspots of species richness are not congruent with endemism or threat. *Nature* 436 (7053): 1016-1019.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. & Torres, F.C., Jr. 1998. Fishing down marine food webs. *Science* 279, 860-863.

Pearce, D. 2005. Economists and Biodiversity Conservation: What can we contribute? Plenary session European Association of Environmental and Resource Economists. Bremen, Germany, June 2005

Petersen A.C., Janssen P.H.M., van der Sluijs J.P., Risbey J.S., Ravetz J.R. 2003. RIVM/MNP guidance for uncertainty assessment and communication. Mini-checklist & quickscan questionnaire. Netherlands Environmental Assessment Agency, National Institute for Public Health and the Environment RIVM, Bilthoven.

Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., da Fonseca, G.A.B., Gaston, K.J., Hoffmann, M., Long, J.S., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J., Yan, X. 2004. Effectiveness of the global protected area network in representing species diversity. *Nature* 428 (6983): 640-643.

Sachs, J.D. 2005. Can extreme poverty be eliminated? *Scientific American* 293 (3): 56-65.

Stattersfield, A.J., Crosby, M.J., Long, A.J., Wege, D.C. 1998. Endemic bird areas of the world. Birdlife International, Cambridge, UK.

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., Siqueira, M.F.d., Graigner, A., Hannah, L., Hughes, L., Huntley, B., Jaarsveld, A.S.v., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Philips, O.L. and Williams, S.E. 2004. Extinction risk from climate change. *Nature* 427, 145-148.

UN Milennium Project. 2005. Investing in development: A practical plan to achieve the Millennium Develepment Goals. New York.

UNEP. 2002. Global Environment Outlook 3. London, Sterling, VA; Earthscan Publications Ltd.

UNEP/CBD. 2002. Report of the sixth meeting of the conference of the parties to the Convention on Biological Diversity. Decision VI/22: Forest Biological Diversity. UNEP/CBD/COP/6/20. Montreal.

UNEP/CBD. 2003. An exploration on biological indicators relevant to the 2010 target. Convention on Biological Diversity. UNEP/CBD/SBSTTA/9/INF/26. Montreal.

UNEP/CBD. 2004a. Decision VII/28: Protected Areas (Articles 8 (a) to (e)). UNEP/CBD/COP/7/21. Montreal.

UNEP/CBD. 2004b. Decision VII/30: Strategic plan: future evaluation of progress. UNEP/CBD/COP/7/21. Montreal.

UNEP/CBD. 2004c. Indicators for assessing progress towards, and communicating, the 2010 target at the global level. UNEP/CBD/SBSTTA/10/9. Montreal. Montreal.

UNEP-WCMC. http://www.unep-wcmc.org/resources/PDFs/10_all.pdf

UNFF. 2005, United Nations Forum on Forests, Report of the fifth session (14 May 2004 and 16 to 27 May 2005), Economic and Social Council, Official Records, 2005 Supplement No. 22, New York.

Verboom, J., R. Foppen, P. Chardon, P. Opdam, & P. Luttikhuizen. 2001. Introducing the key patch appoach for habitat networks with persistent populations: an example for marshland birds. *Biological Conservation* 100: 89-101.

Verboom, J., Alkemade, R., Klijn, J., Metzger, M. & Reijnen, R. in press. Combining biodiversity modeling with political and economic development scenarios for 25 EU countries. *Ecological Economics*, in press.

De Vries, H. J. M., van Vuuren, D.P., den Elzen, M.G.J. & Janssen, M.A. 2001. The Targets Image Energy model regional (TIMER) - Technical documentation.. MNP Netherlands Environmental Assessment Agency, Bilthoven, the Netherlands. www.mnp.nl/en

van Vuuren, D.P., den Elzen, M. Lucas, P., Eickhout, B. Strengers, B., van Ruijven, B., Wonink, S. & van Houdt, R. in prep. Stabilizing greenhouse gas concentrations: an assessment of different strategies and costs using an integrated assessment framework.

World Bank. 2003. Global Economic Prospects 2004. The World Bank, Washington DC.

WTO. 2001. WTO Agriculture Agreement. November 2001 at the Doha Ministerial Conference.