Netherlands Environmental Assessment Agency

MNP Report 555050002/2007

International review of the GLOBIO model version 3

R. Leemans, K.J. Gaston, A.S. van Jaarsveld, J. Dixon,
J. Harrison, M.E. Cheatle

Contact:
R. Alkemade
Natuur, Landschap en Biodiversiteit
Rob.Alkemade@mnp.nl

Netherlands Environmental Assessment Agency (MNP), P.O. Box 303, 3720 AH Bilthoven, the Netherlands;
Tel: +31-30-274 274 5; Fax: +31-30-274 4479; www.mnp.nl/en

Rapport in het kort

Internationale evaluatie van het GLOBIO model versie 3

In april 2005 heeft een internationale reviewcommissie de wetenschappelijke deugdelijkheid en beleidsrelevantie geëvalueerd van het GLOBIO3 model. De bouw van dit model is onderdeel van het project Internationale Biodiversiteit. Vier leden van de commissie, wetenschappers met grote ervaring in biologisch onderzoek, evalueerden het model vanuit een wetenschappelijk perspectief, terwijl twee leden, werkzaam bij UNEP, het model evalueerden vanuit een gebruikers perspectief. Hun conclusies zijn van belang om het modelleerwerk wetenschappelijk verantwoord te houden en gericht op de belangrijkste politieke vraagstukken.

De reviewcommissie concludeert dat het GLOBIO3 project geschikt is om een belangrijke rol te spelen in het geven van informatie over de huidige en toekomstige toestand van de biodiversiteit in regionale en mondiale verkenningen. Echter, de wetenschappelijke verankering en acceptatie moeten worden verbeterd en de dialoog met beleidmakers dient te worden geïntensiveerd.

Hoewel dit rapport in de eerste plaats als toets en leidraad voor het Internationale Biodiversiteit project dient, kan het ook worden gebruikt als een onafhankelijk oordeel over de deugdelijkheid van het model voor potentiële gebruikers.

Leden van de reviewcommissie waren: prof. Rik Leemans van Wageningen Universiteit, prof. Kevin Gaston van de University of Sheffield, prof. Albert van Jaarsveld van de University of Stellenbosch, John Dixon van CIMMYT, voorheen van FAO, Jerry Harrison van UNEP-WMCM, en Marion Cheatle van UNEP-DEWA.

Trefwoorden: GLOBIO3 model, internationaal, evaluatie, biodiversiteit, goederen en diensten, armoede

Abstract

International review of the GLOBIO model version 3

In April 2005, a review committee gathered to assess the scientifically validity and policy-relevance of the GLOBIO3 model as part of the International Biodiversity project. Four members of the committee are scientists with a great experience in biological research assessing the GLOBIO3 model from a scientific perspective, while two members are working at UNEP assessing the model from a user's perspective. Their judgment and recommendations are presented in this report. The conclusions are important in order to keep the modelling work scientifically sound as well as focussed on the major political key questions in the international arena.

The review committee concluded the GLOBIO3 project is well suited to play in important role in providing information on understanding ongoing trends and depicting future trends in regional and global assessments. However, the scientific imbedding and acceptance has to improve, while, simultaneously, the dialogue with policy makers needs to be strengthened.

This report serves primarily as guidance for the International Biodiversity project but can also serve as an independent review on the validity of the model for any potential end user.

Members of the committee were prof. Rik Leemans from Wageningen University, prof. Kevin Gaston from University of Sheffield, prof. Albert van Jaarsveld from University of Stellenbosch, John Dixon from CIMMYT, formerly from FAO, Jerry Harrison from UNEP-WMCM, and Marion Cheatle from UNEP-DEWA.

Keywords: GLOBIO3, model, international, review, biodiversity, goods, services, poverty

Foreword

In April 2005, a review committee gathered in Enkhuizen, the Netherlands, to assess the scientific validity and policy-relevance of the GLOBIO3 model as part of the International Biodiversity project. The committee consisted of Professor Rik Leemans, (Wageningen University), Professor Kevin Gaston (University of Sheffield), Professor Albert van Jaarsveld (University of Stellenbosch), and John Dixon from CIMMYT (formerly from FAO), all assessing from a scientific perspective, while Jerry Harrison from UNEP-WMCM and Marion Cheatle from UNEP-DEWA contributed in assessing from a user's perspective. Lenny van Bussel from Wageningen University took notes.

It is the ambition of the project to apply the GLOBIO model in formal global and regional assessments, therefore it was considered necessary -amongst others by the clients and co-funders of the project, the Ministries of Housing, Spatial Planning and Environment (VROM), Agriculture, Nature and Food quality (LNV) and Foreign Affairs (BZ)- to have an independent scientific and potential users review of the model, data and modelling strategy from the two perspectives.

The committee members are scientists with a lot of experience in biological research, modelling and assessments. Their judgment and recommendations are presented in this report. It was my pleasure to have been able to attend and participate in the discussions. I think the constructive mood of the review session is clearly visible in the report at hand. My gratitude goes to the committee for helping us to improve and thus be even more useful in gaining insight and producing relevant assessments.

The Netherlands Environmental Assessment Agency (MNP) was responsible for the actual publishing of this report. The Review Committee takes full responsibility for the contents.

Leon Braat

Netherlands Environmental Assessment Agency (MNP)
Head Team Nature, Landscape and Biodiversity

Contents

Summary

In April 2005, the review committee of the GLOBIO3 project gathered to discuss the structure, progress and possible policy-relevant applications of the project. The committee was impressed by the amount of work that was accomplished and supported the methodological choices made. However, modelling global biodiversity patterns and developing scenarios for changes in biodiversity in order to monitor progress towards policy targets (e.g. the World Summit on Sustainable Development (WSSD) target to reduce the decline in biodiversity by 2010) is extremely ambitious and not very likely to be achieved in a very detailed manner. Biodiversity involves many aspects (from genes to landscapes) and changes in biodiversity are driven by many, often indirect and remote factors. The selected approach of modelling species abundances and extent by using a series of indicators provides an adequate proxy or surrogate for the complexity of biodiversity. Also the GLOBIO3 contributions to the indicators discussions of the Conference of the Parties (CoPs) of the Convention on Biological Diversity (CBD) are very valuable and constructive.

The Millennium Ecosystems Assessment (MA) has made a first comprehensive attempt to determine the causes and extent of changes in biodiversity. The MA concludes that changes in important components of biodiversity were more rapid over the last 50 years than at any time in human history. Scenarios indicate that these rates will continue or accelerate in the future. The MA also attempted to link changes in biodiversity to poverty through ecosystem services. Establishing direct relationships proved extremely difficult.

Although the GLOBIO3 team has been involved in the MA, their tools were not yet available to direct the analyses. The MA scenarios were based on highly qualitative narrative scenarios based on some global models that do not deal properly with biodiversity, such as MNP's IMAGE model. This shows that there is ample need for approaches such as GLOBIO.

Having said this, the committee believes that the GLOBIO3 project is necessary, extremely timely and focused on realistic scientific goals and urgent user's needs. This could create competition with other groups and approaches.

The committee's advice is therefore:

1. Document and publish the model, indicators and approaches employed immediately and thoroughly in the scientific peer-reviewed literature. To achieve this, a clear publication strategy is required.
2. Develop a theoretical conceptual framework to better motivate the selected generalizations, parameterization and data. This will help to reduce confusion in terminology and, additionally allows for a more targeted and more effective use of the sparse data. Finally, a proper theoretical framework is essential to effectively communicate choices and results.
3. The validation of GLOBIO3 can be improved by making better use of available data bases on species richness, abundance patterns and pressures.

4. GLOBIO3 should make the next step in regional and global biodiversity-change scenarios. Mapping threats, for example, could be an important aspect.
5. The necessary link with biodiversity and poverty is still very weak in GLOBIO. The proposed approach provides the potential to quantify such links on the basis of existing empirical evidence for established relationships but here also a clear conceptual framework is lacking. The committee suggests improving the link by broadening the poverty accent to human well-being, which is easier to address in general terms, and by using obvious intermediates, such as ecosystem service and land-use change patterns.
6. Developing a dialogue between the GLOBIO3 project team and the user-community helps to keep track of changing user needs with respect to poverty and human well-being and other sustainability issues.
7. The majority of expertise in the team emphasizes the modelling of (species) biodiversity. The focus on poverty is led by one scholar but supported through some external collaboration. The committee recommends that the integration within the team can be strengthened by linking to other research groups within MNP (e.g. Prof. Dr. de Vries, IMAGE) or through collaborations with other institutes and universities. Additionally, the policy support activities seemed a little ad-hoc and should be improved and focused.

In conclusion, the GLOBIO3 project is well suited to play in important role in providing information on understanding ongoing trends and depicting future trends in regional and global assessments. Additionally, it can help to develop and test consistent indicator frameworks to be accepted and applied in international conventions. GLOBIO3 thus has the potential to play a major role in this respect. But, this means that the scientific imbedding and acceptance has to improve, while, simultaneously, the dialogue with policy makers needs to be strengthened.

1 Introduction

The Netherlands Environmental Assessment Agency (MNP) has developed several integrated environmental assessments for the Netherlands [e.g. 1, 2-5], for Europe [e.g. 6] and the world [e.g. 7, 8]. These assessments require the use of appropriate data from various sources, adequate indicators to depict trends and models to project plausible futures.

One of the emerging fields in all such assessments is biodiversity. Biodiversity has been defined in many different ways [9-14]. Over the last decade several studies tried to develop biodiversity scenarios [15-19] but most of them neglected realistic causal factors or only caricatured the expected changes. The GLOBIO (version 2) assessment developed by UNEP-GRID Arendal [20] tried to assess changes in biodiversity using a pressure indicator: road density. RIVM at that time already had more elaborate statistical species models [21] and advanced socio-economic and environmental models such as the IMAGE –Natural Capital Index combination [23] applied in GEO 1 and 3, and in some scenarios [22]. It was decided to combine the efforts of MNP, UNEP-GRID Arendal and UNEP-WCMC, and create a more comprehensive global biodiversity model, GLOBIO, to assess and project changes in biodiversity. Such a model should be applied for coarser regional and global assessments and support policy development within the framework of the Convention on Biological Diversity.

The project was funded by the Dutch Ministries of External Affairs (Development Agency DGIS), Agriculture, Nature Conservation and Food Security (LNV), and Housing, Physical Planning and Environmental Protection (VROM). These funding agencies requested two major needs. First, the model and its results should be useful for the global assessments directed towards nature conservation and sustainable use (functions) of UNEP, such as GEO and the MA. Second, as the Dutch development policy strongly focuses on poverty reduction, the relationship between poverty and biodiversity should be explicitly explored.

The Global biodiversity assessment [12] was the first global attempt to determine the causes and extent of changes in biodiversity. It failed because its scope was too scientific, neglecting the needs of the relevant international UN Conventions, such as the CBD. In 2001, the Millennium Ecosystems Assessment [MA, 8] was launched and used a series of different tools to assess past trends, current conditions and futures. The MA concluded that changes in important components of biodiversity were more rapid over the last 50 years than at any other time in human history. Scenarios indicated that these rates will likely continue or accelerate into the future. The MA also attempted to link changes in biodiversity to poverty through ecosystem services. Establishing direct relationships proved extremely difficult.

The review-committee and the GLOBIO-team looking at the team leader and photographer Ben ten Brink during the excursion in the Oostvaardersplassen. (From left to right: Christian Nellemann, Tonnie Tekelenburg, Albert van Jaarsveld, John Dixon, Rik Leemans, Leon Braat, Lera Miles, Kevin Gaston and Rob Alkemade.)

When the MA started, it was envisioned that the GLOBIO3 and MNP's IMAGE project would provide the necessary instruments to develop the scenarios. However, it proved difficult to develop, test and validate the global applications which were based on drivers of change and scenarios. In the end the MA scenarios were primarily based on qualitative narrative approaches to determine changes in biodiversity, ecosystems, ecosystem services and human well-being. These changes were illustrated by applying some highly aggregate model runs [8]. The situation with respect to biodiversity modelling is structurally different from climate change modelling within IPCC, in which a series of different global and regional models can be used [23]. Most of these models provide robust results, although most models solely focus on energy related emissions and climate change, and not on deforestation or agricultural, hydrological or ecological impacts. This clearly shows that there are still many opportunities and needs for a solid and widely accepted modelling framework to model changes in biodiversity as a function of societal and environmental change.

This report results from a two-day meeting with the GLOBIO3 project team (MNP-RIVM in cooperation with UNEP-WCMC, UNEP-GRID Arendal and other regional partners) and an international review committee (for a participants list see Appendix 1). Since 2002, the project team has been building a global biodiversity model (i.e. GLOBIO3) to be used in international assessments. GLOBIO3 should be part of a coherent set of policy-support instruments consisting of:

- Indicators that qualitatively describe and quantitatively calculate the status of biodiversity, its provision of ecosystems' goods & services and the resulting consequences for poverty.

- Monitoring data that are used to establish past trends and the current state of biodiversity, ecosystems' goods & services and poverty conditions.
- Models that determine of the plausible future pathways given particular socio-economic developments (including policies) and that quantify relationships between biodiversity, ecosystems' goods & services and poverty.

As a whole GLOBIO3 must provide a model-based, indicator and scenario system to evaluate environmental policies under changing socio-economic and environmental conditions, which alter the pressures on biodiversity and limit its conservations and sustainable use. The review committee was asked to evaluate the progress of the project, the underlying assumptions and data, the theoretical foundation of the model parameterizations and its possible applications. The program of the meeting is summarized in Appendix 2. The review was conducted by evaluating several background papers (Appendix 3) and several presentations on topics that the committee concluded to be important and that were to be discussed in more detail.

The project team provided the review committee with a list of specific questions (Appendix 4). These questions were judged to be relevant, although sometimes too general or detailed. They were therefore not addressed individually, but incorporated in the general discussions. The chair (Leemans) tried to balance to discussions of the different topics and summarized the different conclusions.

2 Report on the discussions

Ir. F. Langeweg (Deputy Director MNP) opened the meeting. He stressed that the GLOBIO3 project should bridge scientific understanding with policy needs. In doing so, special emphasis should be given to robust findings and uncertainties. Leemans reiterated this and stressed once more that an international modelling approach should also be scientifically accepted and documented in the scientific literature. This is, for example, one of the criteria for using the resulting insights in international assessments, such as IPCC and MA. In this respect it is a pity that the very innovative Natural Capital index [24, 25], although developed and discussed under the CBD[1], is only published in RIVM reports. Others [e.g. 13, e.g. 26] have now taken the scientific credits for this type of approach.

Drs. Ben ten Brink subsequently introduced the GLOBIO3 project, its aims and achievements in supporting international biodiversity and developmental policies. He also repeated the aim of the review: assess the scientific credibility and authority and its policy applicability. Suggestions for the further development into GLOBIO4 were also welcomed. Due to the DGIS funding, especially recommendations on how to improve the linkages between biodiversity and poverty were required. The properties of this link were discussed shortly. One of the obvious links seemed to be that continued poverty reduced the effectiveness of nature conservation efforts, but there were few indications of other direct relationships [see also 14].

Dr. Rob Alkemade and his colleagues then presented the modelling of biodiversity loss. He introduced the statistical distribution models that were developed and published for climate change applications [21, 27, 28] and added the pressure (i.e. stressors that reduce biodiversity) based approaches. In a straightforward multiplicative approach all these pressures were combined to determine their effect on biodiversity. These pressures include, for example, climate change, N-deposition, land-use change (agriculture, forestry, urban), infrastructure and human settlement, fragmentation and agricultural intensification. This resulted in changes in species abundance and extent, the two components of the integrative Natural Capital Index (NCI). Discussion of the approach focused on the appropriateness of the multiplicative approach, whether one should determine changes in trends (c.f. the biodiversity target, agreed at the WSSD to reduce the decline in biodiversity by 2010 [29]) or conditions, what is the most appropriate scale to apply this approach (local, regional, continental or global), and the different aspects of biodiversity (e.g. abundances, richness, evenness, complementarity and hotspots). Also the interactions between populations should somehow be addressed (The reduction of a population of one species, could result in the increase of another). Although this is not always easy, a clear distinction should be made between original species, introduced species, migrating species (e.g. due to climate change) and alien species. All these different possibilities and requirements blurred the model

[1] UNEP/CBD/SBSTTA/3/9 and UNEP/CBD/SBSTTA/3/inf.13

objectives and purpose. It is recommended that the purpose of the model should be more clearly established, so that the expectations of the model's applications can become more realistic and focused. It would therefore be valuable to improve the profile of user needs through direct user consultation and /or continuous user dialogue. MNP has some relevant experience in doing this [e.g. 30, 31-33].

Dr. Tonnie Tekelenburg presented the relationship between poverty and changes in biodiversity. He stressed the preliminary nature of the available analysis but already demonstrated some insights. The review committee welcomed the attempt to relate changes in biodiversity to poverty, but the main focus of the discussion was on the appropriateness of solely focusing on poverty and less on other socio-economic and developmental issues. For example, the millennium development goals were mentioned as another useful link. The approach and discussion is reported below.

At the end of the meeting, the committee discussed the general findings and recommendations and reached considerable consensus, which is presented here.

2.1 Specific topics that were discussed

2.1.1 Data

The accuracy of model results depends critically on the underlying data. This is especially the case with GLOBIO3 because of the relatively simple model structure with "clear and transparent relationships" between inputs (pressure factors) and output data (biodiversity). Also, with the NCI already reduced to 70 percent of original, and diminishing fast, these is a need to marshal the best possible data for these estimates. It is recognized that some of the data inputs are derived from existing validated models, for example IMAGE-2, but the focus of the discussion was on the raw data of the direct drivers on biodiversity.

Ideally, the rapid spread of farming systems and situations in which biodiversity is affected by human activity should be reflected in the underlying databases which drive the model. The background papers indicate, and the team confirmed, that the search for data on the impact on biodiversity has been limited to published literature. It was agreed that this has produced insufficient observations for many ecosystems and regions to provide robust estimates of the relative impacts on wild biodiversity. This is particularly the case in developing countries, and even some non-European OECD countries, where the paucity of monitoring systems and research leads to very few observations on poverty-human activity-biodiversity loss interactions. Moreover, the existing and current estimates are limited to species richness and we have very little information on other aspects of biodiversity.

The situation is particularly critical with regards to agriculture, because it has such a powerful effect on biodiversity and the functioning of GLOBIO3. The framing of agriculture impacts in the global farming systems of [34] may be useful to understand and differentiate the impact pathways, and to improve the estimates of impacts on biodiversity.

Further search for underlying data on the human activity-biodiversity relationship is recommended, with particular emphasis on agriculture and, within agriculture, on poverty hotspots. It is proposed that this should be conducted in the context of the global farming systems. Two steps are recommended: initially, intensify the search in the published literature, throwing the net broader to include journals such as Agro forestry, Agricultural Systems and Human Ecology. However, these published sources are likely to be inadequate, so it is recommended to search for unpublished (grey) literature and reports too, looking to major national universities and national sustainable development committees as well as the regular biodiversity contacts. Through triangulation, the goal should be to arrive at robust estimates and for each disaggregated farming system (approximately double the number of land uses recognized in the present tables).

2.1.2 Modelling assumptions

Key assumptions of the GLOBIO3 model are that (i) changes in local original species richness in response to a pressure factor equate to changes in the mean abundance (i.e. the number of individuals or any other quantitative measure, such as biomass) of the original species at a regional scale, and (ii) the relationship between change in local species richness and change in mean abundance is a constant, such that a given level of change in local species richness results in a given level of change in mean abundance irrespective of the prevailing land use et cetera.

These assumptions are, however, untested, and raise important concerns:

1. If the local assemblage is a small sample of the regional one, then the relationship between change in local species richness and regional mean abundance could be weak or non-existent. An important assumption here is the area over which the regional assemblage is being assessed, and hence at which changes in mean abundance are being predicted. In the main, this seems to be the 1km x 1km resolution of the land use data employed in GLOBIO, although it is the 0.5^{o} x 0.5^{o} cell for climate change (a difference that itself calls for careful consideration). There is thus a considerable difference in the spatial scale at which most responses to pressure factors have been determined and that to which the results are being extrapolated.
2. If there is a relationship between change in local species richness and regional mean abundance, this will be influenced by three things, the ratio of the local to regional abundance of species, the shape of the regional species-abundance distribution (including the overall numbers of individuals and species, as well as the pattern of division of individuals amongst species) and the spatial distribution of individuals across the region (random, aggregated et cetera). Spatial variation in any or all of these could mean that a given change in local species richness equates to a different change in regional mean species abundance in different regions, and that the relationship between the two does not have a slope of one (i.e. mapped changes in local species richness can not be interpreted as similar changes in regional mean abundance).

Several approaches are available to determine how robust the assumptions of the GLOBIO3 model with regard to the relationship between changes in local species richness and changes in regional abundance are:

1. Use studies of local changes in species richness in response to a pressure factor to determine whether there is a general relationship locally between changes in species richness and changes in mean abundance, and the form of this relationship. If this relationship is weak, or has a slope that differs from one, then it is unlikely that changes in local species richness predicts changes in regional mean abundance (note, the converse is not necessarily true – if the local relationship is of an appropriate form it does not categorically mean that the local-regional relationship is so).
2. Use existing data sets on local and regional occurrences and abundances of species assemblages to explore empirical relationships between local changes in species richness and regional changes in mean species abundance.
3. Use analytical and simulation studies to explore the influence on the relationship between changes in local species richness and changes in regional mean abundance of the ratio between local and regional abundance (i.e. how large a sample local assemblages are of regional ones), and regional differences in the size and species-abundance distribution of regional assemblages.

An additional assumption of the model is that any loss of species is necessarily bad or of conservation concern. This is not always the case as a species which is widely distributed and has significant numbers may very well show local declines in numbers without this being of global or regional concern. This is why the model should attempt to demonstrate why a local decline in species is of broader scale conservation concern. This means that local observations have to be placed into a regional context. There is a whole range of methodologies available for this type of landscape complementarity assessment [44].

2.1.3 Assessment of the biodiversity-poverty relationship

The GLOBIO3 team aims to develop a module, which will enable it to relate the state and change in biodiversity to the occurrence of poverty at various spatial scales. Therefore a conceptual framework for this relationship is being developed. The relationships in this framework will be quantified and based on empirical evidence.

A preliminary study shows that biodiversity is related to the occurrence of poverty but that a direct one to one relationship does not necessarily exist. All configurations are possible: both high and low biodiversity occurs with high and low levels of poverty. The analysis further shows that the dominant socio-economic and ecological factors in the relationship include population density and growth, lack of ecosystem management, institutional failure, market structure and demand, perverse fiscal incentives (taxes/subsidies), infrastructure and access to natural resources and social services.

Three approaches are proposed by the GLOBIO3 team to establish this relationship:

1. A **probabilistic approach** parameterized through a multi-variate analysis on the major drivers. This approach should result in a "likelihood of poverty" measure.
2. A **mechanism approach** which assumes that the biodiversity-poverty relationship can be described in a small number of standard configurations from the above factors. This approach resembles the syndrome approach [35, 36]. A preliminary analysis indicated that typical combinations of factors/drivers can be grouped into three mechanisms that are correlated with biodiversity loss and poverty:
   - Poverty (livelihood)-driven change
   - Capital driven change
   - Policy driven change

   These mechanisms may operate in isolation, but in most cases there are strong linkages. The mechanisms may be further specified and sub-divided based on case studies.
3. A **causal modelling approach** which relates the drivers in a deterministic and dynamic model is proposed. Major drivers are placed in this framework including how they relate to one another (Figure 1). This approach requires much more insights into the underlying processes, and in which the provision of ecosystem goods and services form an essential intermediate step.

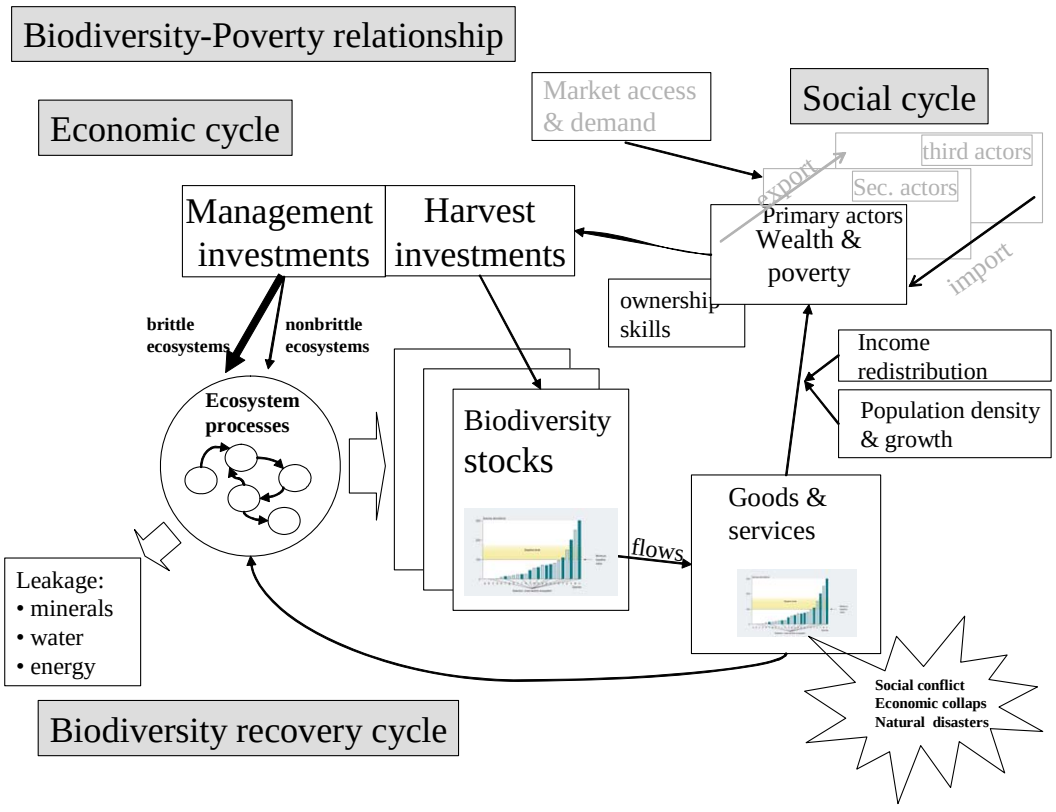

Figure 1: A preliminary, schematic picture of the major drivers and their relationships as derived from the initial analysis.

The review committee strongly welcomed the empirical approach but was simultaneously highly critical on the too strong focus on simply poverty. Significant and general relationships are probably too difficult to establish. A broader emphasis on the use of ecosystem services and human well-being was recommended. This will broaden the

applications and would incorporate sustainability issues and broader scenarios for socio-economic and environmental change. The Millennium Ecosystem Assessment, for example, showed that the Millennium development Goals, one of which was aimed at reducing poverty, could not be reach without a stronger integration with other development (e.g. health, education and gender) and environmental (e.g. climate change, desertification and biodiversity) issues. Additionally, stimulating collaboration with (international) organizations and institutions that deal with poverty, development and related issues could further strengthen the empirical and theoretical basis of the study.

2.2 Additional topics

During the presentations and discussions many specific points were made. Most of them are summarized in the list below.

- Define concepts clearly and provide a project glossary, which will improve the dissemination and acceptance of the model and their results. Presently many concepts are confusing and represent explicit GLOBIO3 jargon. This should be avoided.
- An additional value of a species approach is its use in setting priorities in the selection of protecting areas at the regional and continental or biome level and in modelling the Red List indicators in order to project future threats.
- The policy relevance of GLOBIO3 lies not only in the extinction of a species but also in assessing vulnerable species. Both are relevant for the different applications. Possibilities would include focusing on rare and endangered species from the red lists or the European habitat directive [see for example 37]. Habitat modelling can be used to complement the species and pressure approaches. Another way to deal with this aspect is to improve the definition of threats and explicitly model and map them within GLOBIO3.
- The pressure maps are highly aggregated and could provide too much spatial detail. What are the limitations of such maps and the employed spatial approaches? The quality of the underlying data and assumptions should be assessed and the data poor areas should be identified or at least flagged in the results.
- Although some of the approaches are taken from the literature, it is not clear how well the GLOBIO3 approach is grounded in scientific theory. Why, for example, are species-area curves as employed by the IMAGE-2 group for the MA scenarios not used?
- Synergies between different policies (e.g. policies on conservation, land use and poverty reduction) are important to identify. However, this has to be placed in a specific regional socio-economic and environmental context. There are no silver bullets for developing ideal policies [see, for example, 8]. One possible way to depict different contexts is to develop environmental Kutznet curves for specific regions [e.g. 38]. Or use of broader concepts such as ecosystem services and human well-being relationships.
- A further search for underlying data on the human activity-biodiversity relationship is recommended, with particular emphasis on agriculture and, within agriculture, on poverty hotspots.

- Options for research (limited by the capacity of the GLOBIO3 team):
    - Elaboration more on the underlying mechanisms of biodiversity threats and decline.
    - Proper management of economy and institutions can be included in GLOBIO3. This requires the inclusion of expertise on economics and political science through collaboration with other research institutes.
    - Improve the incorporation of the (role of) local decision maker, who is responsible for conservation. Actor oriented modelling approaches [39] could help to include such role into the GLOBIO3 models.
    - Develop local and regional case studies each with a specific context to show the validity of GLOBIO3. Biodiversity hotspots [40], for example could be selected as case studies.
    - Poverty does not only have a rural dimension but also an urban one. Is such a distinction relevant for biodiversity issues? This aspect directly relates to the determinants of poverty. Processes, like corruption, seem important and can be included as well. Play with different ideas!
    - It is recommended that a series of comprehensive world maps with biodiversity threats and loss or, more general, human vulnerability maps [e.g. 41, 42, 43] should be pursued. This also requires an advanced visualization system with overlays of different maps and the derivation of spatial statistics. UNEP-WCMC has a lot of experience and can surely help.
- Show these funding agencies and other stakeholders that there is excellent access to the scientific world with the right connections to local experts, to innovative modelling approaches (e.g. actor oriented, more probabilistic predictive approaches, risk assessments and vulnerability assessments). GLOBIO3 can also act as a mediator to get all the right information together and harvest the added value. Links with the GLOBIO3 model should then be made explicit.

3 Conclusions and recommendations

The committee concludes that the GLOBIO3 project is necessary, extremely timely and focuses on realistic scientific goals and urgent user's needs. To increase the value of the project's results, however, some additional steps will have to be carried out. These steps are listed below in the committee's recommendations:

1. **Document and publish the model, indicators and approaches immediately and thoroughly in the scientific peer-reviewed literature.** This will increase the scientific credibility and authority and will increase the acceptance by the policy community. To achieve proper documentation, a clear publication strategy is required.
2. **Develop a theoretical conceptual framework to motivate and explain the selected generalizations, model parameterizations and data sets used.** This will reduce the apparent confusion in terminology, allows for a more targeted and thus more effective use of the sparse data and could provide recommendations on prioritizing new data gathering exercises (possibly performed by other organizations). Additionally, an accepted theoretical framework will assist in defining the weighting factors among the various driving forces in the pressure-based models more clearly and placing the analysis into a regional or global conservation context. Finally, such a framework is essential for effective communication, and for conveying results and uncertainties.
3. **Improve the validation of the different models and assess the quality of the underlying data sets.** The validation of GLOBIO3 can be improved by making better use of available datasets on species richness, abundance and pressures.
4. **Illustrate and explain ongoing global and regional trends with GLOBIO3 and develop consistent and plausible future scenarios.** Mapping threats, for example, could be an important aspect. The GLOBIO3 project is adequately placed to make the next step (following the MA scenarios) in regional and global biodiversity-change scenarios. This will strongly improve regional and global assessments.
5. The necessary linkage between biodiversity and poverty still requires a lot of work in GLOBIO. The proposed approach provides potential to quantify such a link on the basis of existing empirical evidence for such relationship. **The committee suggests, however, developing an appropriate consistent conceptual framework that explicitly highlights the link between poverty and biodiversity. This could be achieved by broadening poverty towards human well-being. This will allow addressing changes and impacts in more generic terms by using some obvious intermediates,** such as ecosystem services and land-use changes. Such a more-encompassing focus will further facilitate the application of GLOBIO3 towards the Millennium Development Goals and sustainable use. It further helps to align the envisaged outputs to more global-change oriented integrated assessment models that are essential for comprehensive scenario development.
6. **Developing a GLOBIO3 user-community dialogue could also help to keep track of the changing user needs.** An effective user dialogue system will help to improve the

dissemination of results and understanding and help to increase the relevance of, for example, the incorporation of poverty and human well-being relationships.

7. The majority of expertise in the team strongly emphasizes the modelling of (species) biodiversity. The focus on poverty is led by one scholar but supported through some collaborations. **The committee recommends that the integration within the team is strengthened by linking to other research groups** within MNP (e.g. Prof. Dr. de Vries and the MNP IMAGE-team) or through collaborations with other institutes and universities. Additionally, the policy support activities seemed a little ad-hoc and should be strengthened and focused.

In conclusion, the GLOBIO3 project is well suited to play in important role in providing information for understanding ongoing trends and depicting future trends in regional and global assessments, such as EEA State of the Environment reports, UNEP's GEO, IPCC and the MA. Additionally, it can help to develop and test consistent indicator frameworks to be assessed and applied by the international conventions, such as CBD. GLOBIO3 therefore has the potential to play a major role in this regard. Short-term activities and products and longer-term accomplishments and goals have to be defined. To achieve this, a project strategy with clear research and application priorities, has to be developed and implemented. Central to this strategy is the improvement of the scientific imbedding and acceptance and the simultaneous strengthening of the dialogue with policy makers.

References

1. RIVM, 1998 LeefOmgevingsBalans. Voorzet voor vorm en inhoud, National Institute for Public Health and the Environment: Bilthoven. p. 139. RIVM report 408504001.
2. RIVM, 2001. Milieubalans 2001. Het Nederlandse milieu verklaard. Kluwer: Alphen aan de Rijn. pp. 167. RIVM report 251701053.
3. RIVM, Alterra, and LEI, 2001. Natuurbalans 2001. Kluwer: Alphen aan de Rijn. pp. 189. RIVM report 20010912.
4. RIVM, 2004. Milieubalans 2004. Het Nederlandse milieu verklaard. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu. pp. 199. RIVM report 251701057.
5. RIVM, 2005. Milieubalans 2005. Bilthoven: Milieu en Natuur Planbureau. pp. 156. RIVM report 251701066.
6. EEA ETC/ACC, UBA, and RIVM, 2004 Impacts of Europe's changing climate. An indicator-based assessment, European Environment Agency.
7. UNEP, 2002. Global Environment Outlook 3. London: Earthscan publications. pp. 446.
8. Reid, W.V., H.A. Mooney, A. Cropper, D. Capistrano, S.R. Carpenter, K. Chopra, P. Dasgupta, T. Dietz, A.K. Duraiappah, R. Hassan, R. Kasperson, R. Leemans, R.M. May, A.J. McMichael, P. Pingali, C. Samper, R. Scholes, R.T. Watson, A.H. Zakri, Z. Shidong, N.J. Ash, E. Bennett, P. Kumar, M.J. Lee, C. Raudsepp-Hearne, H. Simons, J. Thonell, and M.B. Zurek, 2005. Millennium Ecosystem Assessment Synthesis report. Washington DC: Island Press. pp. 160.
9. Gaston, K.J., ed. 1996. Biodiversity: A biology of numbers and difference. Blackwell Science: London. pp. 396.
10. Lovejoy, T.E. and L. Hannah, eds., 2005. Climate Change and Biodiversity. Yale University Press: New Haven. pp. 418.
11. Gaston, K.J., 1994. Biodiversity - measurement. Progress in Physical Geography 18: 565-574.
12. Heywood, V.H. and R.T. Watson, eds., 1995. Global biodiversity assessment. Cambridge University Press: Cambridge. pp. 1140.
13. Scholes, R.J. and R. Biggs, 2005. A biodiversity intactness index. Nature 434: 45-32.
14. Duraiappah, A., S. Naeem, T. Agardi, N. Ash, D. Cooper, S. Díaz, D.P. Faith, G. Mace, J.A. McNeilly, H.A. Mooney, A.A. Oteng-Yeboah, H.M. Pereira, S. Polasky, C. Prip, W.V. Reid, C. Samper, P.J. Schei, R. Scholes, F. Schutyser, and A. van Jaarsveld, 2005. Ecosystems and human well-being: Biodiversity synthesis. Washington DC: Island Press. pp. 81.
15. Sala, O.E., F.S. Chapin, III, J.J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sannwald, L.F. Huenneke, R.B. Jackson, A. Kinzig, R. Leemans, D. Lodge, H.A. Mooney, M. Oesterheld, L.N. Poff, M.T. Sykes, B.H. Walker, M. Walker, and D. Wall, 2000. Global biodiversity scenarios for the year 2100. Science 287: 1770-1774.

16. Chapin, F.S., III, O.E. Sala, and E. Huber-Sannwald, 2001. Global biodiversity in a changing environment: Scenario for the 21st century. New York: Springer Verlag. pp. 372.
17. Leemans, R. and P.N. Halpin, 1992. Global change and biodiversity, in Biodiversity 1992: Status of the Earth's Living Resources, B. Groombridge, Editor Chapman and Hall: London. p. 254-255.
18. Leemans, R., 1999 Applying global change scenarios to assess changes in biodiversity, National Institute for Public Health and the Environment: Bilthoven. p. 65. RIVM report 481508012
19. Gitay, H., A. Suárez, R.T. Watson, O. Anisimov, F.S. Chapin, R.V. Cruz, M. Finlayson, W.G. Hohenstein, G. Insarov, Z. Kundzewicz, R. Leemans, C. Magadza, L. Nurse, I. Noble, J. Price, N.H. Ravindranath, T.L. Root, B. Scholes, A. Villamizar, and X. Rumei, 2002 Climate change and biodiversity, Intergovernmental Panel on Climate Change: Geneva. p. 77.
20. Nellemann, C., L. Kullerud, I. Vistness, B.C. Forbes, T. Foresman, E. Husby, G.P. Kofinas, B.P. Kaltenborn, J. Rounaud, M. Magomedova, R. Bobiwash, C. Lambrechts, P.J. Schei, S. Tveitdal, O. Gron, and T.S. Larsen, 2001 GLOBIO global methodology for mapping human impacts on the biosphere. The arctic 2050 scenario and global application, UNEP: Nairobi. p. 47.
21. Bakkenes, M., J.R.M. Alkemade, F. Ihle, R. Leemans, and J.B. Latour, 2002. Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050. Global Change Biology 8: 390-407.
22. 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. RIVM report 481508018
23. Nakícenovíc, N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler, T.Y. Jung, T. Kram, E. Emilio la Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Riahi, A. Roehrl, H.-H. Rogner, A. Sankovski, M.E. Schlesinger, P.R. Shukla, S. Smith, R.J. Swart, S. van Rooyen, N. Victor, and Z. Dadi, 2000. Special report on emissions scenarios. Cambridge: Cambridge University Press. pp. 599.
24. ten Brink, B.J.E., 2000. Biodiversity indicators for the OECD Environmental Outlook and Strategy: a feasibility study, National Institute for Public Health and the Environment: Bilthoven. p. 52. RIVM report 402010014
25. de Heer, M., V. Kapos, and B.J.E. ten Brink, 2005 Biodiversity trends and threaths in Europe. Development and test of a species trend indicator, UNEP World Conservation Monitoring Centre, Cambridge & Nethlands Environmental Assessment Ageny (RIVM-MNP): Bilthoven. p. 72.
26. de Groot, R., J. van der Perk, A. Chiesura, and A. van Vliet, 2003. Importance and threat as determining factors for criticality of natural capital. Ecological Economics 44: 187-204.

27. van Oene, H., F. Berendse, J.R.M. Alkemade, M. Bakkenes, F. Ihle, and C.G.J. de Kovel, 1999 Assessment of long-term effects of climate change on biodiversity and vulnerability of terrestrial ecosystems, Dutch national Research Programme on Global Air Pollution and Climate Change: Bilthoven. p. 168.
28. Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega Huerta, A.T. Peterson, O.L. Phillips, and S.E. Williams, 2004. Extinction risk from climate change. Nature 427: 145-148.
29. Balmford, A., L. Bennun, B. ten Brink, D. Cooper, I.M. Côte, P. Crane, A. Dobson, N. Dudley, I. Dutton, R.E. Green, R.D. Gregory, J. Harrison, E.T. Kennedy, C. Kremen, N. Leader-Williams, T.E. Lovejoy, G. Mace, R. May, P. Mayaux, P. Morling, J. Phillips, K. Redford, T.H. Ricketts, J.P. Rodriguez, M. Sanjayan, P.J. Schei, A.S. van Jaarsveld, and B.A. Walther, 2005. The Convention on Biological Diversity's 2010 Target. Science 307: 212-213.
30. van Daalen, C.E., W.A.H. Thissen, and M.M. Berk, 1998. The Delft process: Experiences with a dialogue between policy makers and global modellers, in Global change scenarios of the 21st century. Results from the IMAGE 2.1 model, J. Alcamo, R. Leemans, and G.J.J. Kreileman, Editors, Elseviers Science: London. p. 267-285.
31. Berk, M.M. and M. Janssen, 1998 The interactive scenario scanner (ISS): a tool to support the dialogue between science and policy on scenario development., National Institute for Public Health and the Environment: Bilthoven. p. 31. RIVM report 481508005
32. Berk, M.M., J.G. van Minnen, B. Metz, W. Moomaw, M. den Elzen, D. van Vuuren, and J. Gupta, 2001 Climate options for the long term (COOL) global dialogue: synthesis report, National Institute for Public Health and the Environment: Bilthoven. p. 57. RIVM report 490200003
33. Gupta, J., H. van Asselt, B. Amelung, M. Berk, H. Buiteveld, E. Dalenoord, L. Hein, M. Huynen, O. Kuik, R. Leemans, P. Martens, J. Mulder, A. Oost, M. Schaeffer, K. Verbeek, and M. van der Wegen, 2004 Re-evaluation of the Netherlands' Long-Term Climate Targets, Institute for Environmental Studies: Amsterdam. p. 146.
34. Dixon, J., A. Gulliver, and G. D., 2001 Farming systems and poverty. Improving farmers' livelihoods in a changing world, FAO and WorldBank: Rome and Washington. p. 420.
35. Petchel-Held, G., A. Block, M. Cassel-Gintz, J. Kropp, M. Lüdeke, O. Moldehauer, F. Reusswig, and H.J. Schellnhuber, 1999. Syndromes of global change: a qualitative modelling aproach to assist global environmental management. Environmental Modelling and Assessment 4: 295-314.
36. Schellnhuber, H.J., A. Block, M. Cassel-Gintz, J. Kropp, G. Lammel, W. Lass, R. Lienenkamp, C. Loose, M. Lüdeke, O. Moldehauer, G. Petchel-Held, M. Plöchl, and F. Reusswig, 1997. Syndromes of global change. GAIA 6: 19-34.

37. Thuiller, W., S. Lavorel, M.B. Araujo, M.T. Sykes, and I.C. Prentice, 2005. Climate change threats to plant diversity in Europe. Proceedings National Academy of Sciences 102: 8245-8250.
38. Stern, D.I., 2004. The rise and fall of the environmental Kuznets curve. World Development 32: 1419-1439.
39. Becu, N., P. Perez, A. Walker, O. Barreteau, and C. Le Page, 1999. Agent based simulation of a small catchment water management in northern Thailand: Description of the CATCHSCAPE model. Ecological Modelling 170: 319-331.
40. Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca, and J. Kent, 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858.
41. Metzger, M.J., R. Leemans, D. Schröter, W. Cramer, and ATEAM Consortium, 2005 The ATEAM vulnerability mapping tool, C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC): Wageningen.
42. Metzger, M.J., R. Leemans, and D. Schröter, 2005. A multidisciplinary multi-scale framework for assessing vulnerabilities to global change. International Journal of Applied Earth Observation and Geoinformation 7: 253-267.
43. Schröter, D., W. Cramer, R. Leemans, I.C. Prentice, M.B. Araujo, N.W. Arnell, A. Bondeau, H. Bugmann, T.R. Carter, C.A. Gracia, A.C. de la Vega-Leinert, M. Erhard, F. Ewert, M. Glendining, J.I. House, S. Kankaanpaa, R.J.T. Klein, S. Lavorel, M. Lindner, M.J. Metzger, J. Meyer, T.D. Mitchell, I. Reginster, M. Rounsevell, S. Sabate, S. Sitch, B. Smith, J. Smith, P. Smith, M.T. Sykes, K. Thonicke, W. Thuiller, G. Tuck, S. Zaehle, and B. Zierl, 2005. Ecosystem Service Supply and Vulnerability to Global Change in Europe. Science 310: 1333-1337.
44. Margules, C.R. and Pressey R.L. Systematic conservation planning. Nature 405: 243-253.

Appendix 1. Participants

Participants of the Advisory Group

Prof. Rik Leemans from Wageningen University in the Netherlands (Chair of the meeting)

Prof. Kevin Gaston from the University of Sheffield in the United Kingdom

Prof. Albert van Jaarsveld from the University of Stellenbosch in South Africa

John Dixon from CGIAR, CIMMYT in Mexico

Jerry Harrison from UNEP-WCMC in the United Kingdom (was unable to attend the meeting but provided *written* comments from a client's perspective)

Marion Cheatle from UNEP-DEWA (was unable to attend the meeting but provided *written* comments from a client's perspective).

Participants of the Project team:

Rob Alkemade

Lera Miles

Tonnie Tekelenburg

Michel Bakkenes

Ben ten Brink

Christian Nellemann

Participants of MNP

Fred Langeweg (deputy director MNP, opening of the review only)

Leon Braat (MNP, head of the team Nature Landscape and Biodiversity)

Appendix 2. Final agenda

1st Day 21 April 2005

9.00-9.15	Welcome of MNP-RIVM (Fred Langeweg, deputy director)
9.15-9.30	Introduction of the project, aims of the review (Ben ten Brink, project leader)
9.30-10.30	Main aspects of review, work planning & reporting & role project team members (Advisory group)
10.30-18.00	Review (presentations by Rob Alkemade & Tonnie Tekelenburg and discussions)
18.15- 20.00	Historical walk through Enkhuizen

2nd Day 22 April 2005

8.00-11.00	Excursion to the nature reserve “Oostvaardersplassen”
11.00-14.00	Review Continued
14.00-15.00	Preparation of conclusions and advice and appointments on final reporting
15.00-16.00	Reporting of the Advisory Group,
16.00	Closure of the review meeting

Appendix 3. Informative papers for the review committee

1. Introduction to the reports on the GLOBIO3 model
   B.J.E. ten Brink
2. Global biodiversity assessment framework (GLOBIO)
   J.R.M. Alkemade, M. Bakkenes, R. Bobbink, L. Miles, C. Nellemann, H. Simons and T. Tekelenburg
3. Climate impact on species diversity
   M. Bakkenes, J.R.M. Alkemade and B. Eickhout
4. Impacts of land use changes on species diversity: A global overview
   J.R.M. Alkemade, H. Simons, M. Bakkenes and M. Van Oorschot
5. Impacts of Intensification of agricultural production on species diversity
   T. Tekelenburg and J.R.M. Alkemade
6. Plant species richness and the exceedance of empirical nitrogen critical loads: an inventory
   R. Bobbink
7. Poverty-Biodiversity relationships, an investigation towards a poverty module for the GLOBIO3 model.
   T. Tekelenburg, J.J Kessler and B.J.E. ten Brink
8. Plans on species-based modelling in GLOBIO
   J.R.M. Alkemade

Appendix 4. Review questions

The aim of the review is to assess the scientific validity and policy relevance of the GLOBIO-3 model and to provide advice on directions for future work in the context of its function and target-audience. The following guiding questions were developed by the GLOBIO3 team and presented to the review committee.

Questions on the quality of the GLOBIO-3

Does the model cope with the set of requirements?

To be more specific from the scientific point of view (in order of relevance):

- Is the model design transparent, understandable and well founded?
- Do the indicators calculated with the model cover well the state-indicators chosen by the CBD: i) trends in abundance and distribution of selected species; and ii) trends in extent of selected biomes, ecosystems and habitats; and possibly others?
- Do the indicators calculated with the model express well the process of biodiversity loss, or are other indicators more adequate or useful to add?
- Are the pressure factors in the model prioritized well or are major factors lacking?
- Has the model additional value in comparison with existing models?
- Have existing knowledge, data and insights adequately been used in the model?
- Are the individual module algorithms valid as well as the entire model?
- Are uncertainties determined and addressed and to what extent do uncertainties limit its use?
- What might be interesting institutes or partners to cooperate with?

To be more specific from the policy making point of view:

- Is the model design transparent and understandable?
- Does the model (by e.g. assessments reports) provide a (potential) tool for making biodiversity policies more effective at the national, regional and global levels?
- How could the interaction with the policy- making process be more effective?

Questions on future work

Are the extension of the model with a species-based model and poverty relevant and most promising approaches?

To be more specific from the scientific point of view (in order of relevance):

- Is the intended species-based approach a feasible and useful addition to the current pressure-based model? Or are other model approaches more effective such as population dynamics and food web models?
- Could the species-based approach provide means for modelling the provision of biodiversity goods & services?
- Is the preliminary conceptual framework of the poverty-biodiversity relationship valid and a promising way of including poverty in the GLOBIO-4 model?

- What might be interesting institutes or partners to cooperate with?
- To be more specific from the policy making point of view:
- What should be improved first to make the model more policy relevant, more communicative or more accepted?
- Should the model be down scaled, spatially and/or temporally?