Research Proposal: Integrated landscape assessment, scenario analysis and valuation in Sub-Saharan Africa

Michiel van Dijk & Rene Verburg
Final version (17-12-12)

Dit onderzoek is uitgevoerd door LEI- Wageningen UR in opdracht van en gefinancierd door het Ministerie van Economische Zaken, in het kader van het Beleidsondersteunend onderzoekthema Ruimtelijke Regionale Versterking van Economie en Natuur (projectnummer BO-11-014-000).

Table of contents

1 Introduction

The Department of Nature and Biodiversity of the Ministry of Economic affairs is planning to organise an international conference on integrated landscape management in June 2014. To stimulate and trigger discussion on new policy options a background study is needed that illustrates the challenges of food security, economic development, ecosystem conservation, and climate change associated with multi-purpose landscape use. The Ministry requested that the study covers the following issues:

- *Scenario analysis.* To address future uncertainties in key socio-economic (e.g. GDP, population and technical change) drivers and climate change, and quantify policy impact a scenario study combined with model quantification is desired.
- *Landscape level assessment.* The landscape level provides the essential link between global and local drivers of land use change and is the nexus where the different challenges of food security, climate change, biodiversity and ecosystems come together. At the same, it allows for discussion of issues at regional (intra-country) level with policymakers.
- *Valuation of ecosystems and biodiversity.* In previous studies the MSA index was used to quantify the impact on biodiversity. Although useful, the Ministry would like to be able to 'price/value' biodiversity (taking into account the limitations of such an approach) to better communicate the trade-offs between socio-economic development and biodiversity. Hence, it goes more in the direction of a cost-benefit analysis.
- *Trade-offs and synergies.* The study must highlight and illustrate the trade-offs and synergies between the multiple purposed for which the landscape can be used, in particular also looking at food security.
- *African case study.* It is expected that competing claims for land will become more and more relevant in the African context as a consequence of economic development and increasing demand for natural resources.

This document presents a proposal for such a study including objectives and research questions, overview of previous studies, methodology, potential case study countries and possible research partners.

2 Aim

In the 'classical' view of sustainable development persistent trade-offs occur between economic development and biodiversity conservation in rural areas. A number of recent studies has taken a different approach by mapping the total range of ecosystem services a landscape may provide and how they relate to biodiversity (e.g. Polasky et al., 2008; Ruijs et al., 2013). Ecosystems and the goods and services they provide can have positive effects on food security issues and the (economic) development of rural areas, placing the role of nature and biodiversity into a new perspective. An important part of such an analysis is the valuation of ecosystem services to make them comparable and reveal changes over time and space. For this, the value of ecosystems has to be captured and the function and role they provide in the (local) economy. With such information, perhaps other decisions are taken regarding conservation -, economic-, and food policies. To provide relevant policy options, new type of analysis have to be undertaken.

Such analysis, however, also requires new methodologies and tools. The aim of this project proposal is to present a methodology to assess both economic and ecosystem demand and development for land under different future scenarios in Sub-Saharan Africa. Knowledge on the role of natural capital into economy can stimulate the development of new policies to strengthen biodiversity and economic development at the same time. Particular attention therefore needs to be devoted to the valuation of ecosystems.

In order to address this issue the following questions will be addressed:

- Which model frameworks have been used in previous studies and how can they be modified to address the specific requirements set for this study?
- How can ecosystems be valued and how can this approach be combined with integrated assessment models?

In addition, several criteria are presented that play a role in selecting the case study country as well as a list of potential African countries that fulfil these criteria.

3 State of current knowledge

3.1 Integrated modelling of land use change

LEI-WUR, in cooperation with other research institutes, has built up considerable experience with the assessment of land use change using a combination of scenarios and models (see Verburg et al., 2007). The following projects have been instrumental in developing and refining the methodology that is also proposed for this study (See below):

- *Eururalis.* Eururalis is a scenario study starting from four contrasting world visions. It takes into account the major forces driving land use change and provides a tool for exploring impacts of drivers and policies on sustainability at the global and local scale. Funders: the Dutch Ministry of Agriculture, Nature and Food quality (now part of the Ministry of Economic Affairs). Period: 2004-2010.[1]
- *Scenar 2020 I and II.* The Scenar 2020 study aims at identifying of future trends and driving forces that will be the framework for the European agricultural and rural economy on the horizon of 2020. It provides a systematic review of the primary variables that rural and agricultural policies have to take into account, including rural demographic patterns, agricultural technology, agricultural markets, and the natural and social constraints on land use that are likely to exist in 2020. Funders: European Commission. Period: 2006 and 2009.[2]
- *Global-to-local Vietnam.* The aim of the Global-to-local Vietnam project is to support Vietnam's implementation of programs and policies on, REDD+, climate smart agriculture, and rural development and employment by building a "knowledge infrastructure platform" that provides (1) the space that brings together policymakers, researchers, NGOs, donors and other stakeholders to define objectives for land use in Vietnam and (2) the infrastructure (i.e. the data, scenarios, models, and tools) to enable the development of optimized land policies. It applies the land use modelling framework developed in the Eururalis project to developing country context. Funders: Climate Development and Knowledge Network and the Dutch Ministry of Agriculture, Nature and Food quality (now part of the Ministry of Economic Affairs). Period: 2011-2012.[3]
- *VOLANTE.* VOLANTE provides an interdisciplinary scientific basis to inform land use and natural resource management policies and decision-making in Europe. VOLANTE is designing new methodologies and integrated models to analyse human environment interactions, feedbacks in land use systems, hotspots of land use transitions and identify critical thresholds in land system dynamics. VOLANTE unites researchers with experience and expertise in land use processes and modelling at multiple spatial and temporal scales from different scientific disciplines. Funders: EU FP7. Period 2010-2015: [4]
- *FoodSecure.* FoodSecure is an interdisciplinary research project to explore the future of global food and nutrition security. It aims to design effective and sustainable strategies for assessing and addressing the challenges of food and nutrition security and provide a set of analytical

[1] See http://www.eururalis.eu for more information [Accessed 13 September 2013].
[2] See http://ec.europa.eu/agriculture/publi/reports/scenar2020 and http://ec.europa.eu/agriculture/analysis/external/scenar2020ii [Accessed 17 September 2013].
[3] See http://cdkn.org/project/land-use-policy-optimisation-in-vietnam [Accessed 17 September 2013].
[4] See http://www.volante-project.eu for more information [Accessed 13 September 2013].

instruments to experiment, analyse, and coordinate the effects of short and long term policies related to achieving food security. Funders: EU FP7. Period: 2012-2017.

Through these projects, LEI-WUR has gained considerable experience in the assessment and modelling of long run (up to 2050) scenarios that analyse land use, food security and biodiversity change under different potential futures. Although most of the projects assess these complex issues at the global or (sub) continental level, recently (notably in Global-to-local Vietnam) the methodology has also been applied to the country level. In addition, as part of the FoodSecure project and in cooperation with the Dutch Environmental Assessment Agency (PBL), new scenarios are currently being developed (see below), which can also serve as a basis for the proposed study in this proposal.

3.2 Ecosystem goods and services

The milestone paper of Costanza et al. (1997) and the many follow ups, like the Millennium Ecosystem Assessment (Carpenter et al., 2005), was the first to put the discussion on ecosystem goods and services (often abbreviated to ESS) to the general public. Today it is commonly acknowledged that ecosystems can provide many different goods and services that can be aggregated into four different types (also see Annex for a detailed list of ecosystem services):

- Provisioning services, such as food, timber, water and fibre.
- Regulating services, examples of which are flood control, disease control, pollination and water purification.
- Cultural services, for instance, recreation and spiritual benefits.
- Supporting services, which include nutrient cycling, soil formation and photosynthesis.

These goods and services has formed the root for a better understanding of natural capital, because ESS represent a certain value for human welfare that can be capitalized. The Economics of Ecosystems and Biodiversity (TEEB) (Brink, 2011) is probably the most influencing approach to the valuing of ecosystems for human welfare. TEEB is a global initiative focused on drawing attention to the economic benefits of biodiversity including the growing cost of biodiversity loss and ecosystem degradation. One of its main goals is to capture the values of ecosystem services and biodiversity.

3.3 Valuation of ecosystems

Although the various goods and services ecosystems (and therefore nature) provide are well understood, valuing them is much more difficult. The main cause is that there are no market mechanisms for most of these public goods. For goods like timber, food and probably fibre market mechanisms do exist. For other goods and services market mechanisms have been established (like carbon sequestration) or shadow prices have been developed (e.g. some water functions like purification). Specially cultural services are notorious of having no clear market demand. To establish (economic) value to nature two different kinds of valuing techniques can therefore be applied. Those goods and services for which we can establish a kind of market (using real or shadow prices) are referred to as revealed preferences (RP) and we can assume these values are dynamic; the balance and equilibrium between supply and demand determines prices like for other commodities in neo-classical macro-economics. For cultural and many supporting services we are dependent upon indirect measures, called stated preferences (SP). Methods to derive prices are willingness to pay (WTP), Avoided Costs (AC), Hedonic Pricing (HP) and Travel Cost (TC) (e.g. de Groot et al., 2012).

These different methods to arrive at a certain price level thus run the risk of misinterpret value benefits of nature since the outcome of the methods can be very heterogeneous. Unlike RP, where prices can have a global value, SP can be very regional specific and dependent on relative income (e.g., purchasing power), cultural background and local diversification of ecosystem types. Moreover, values derived from SP can also be highly dynamic in time (Brander et al., 2012a; Brander, et al., 2012b), and changes in size, quality and rarity of ecosystems also have strong effects on the value people perceive. I.e., willingness to pay can therefore change a lot under different local (and social) conditions. Nonetheless, such valuing methods are often used in Social Cost Benefit Analysis (SCBA), under the condition that as long as each valuing method is consistently used to a particular function, service or good. This can be done, because in SCBA not the *absolute* value is relevant, but the changes in values driven by, for example, policy measures. Hence the *relative* value is of interest. In this proposal the value of nature will also be proceeded in a *relative way* by comparison of values *between* scenarios, rather than providing the absolute value of a given ecosystem.

Various papers (Barbier, 2007; Brock et al., 2011; van der Lely et al., 2013) have provided (norm) values of particular goods and services in different types of ecosystems, ranging from grasslands, temperate and tropical forests, coral reefs and wetlands. De Groot et al. (2012) have disaggregated these values for each type of service in each ecosystem in int. $/ha/year. Therefore, the aim of the described methodology is not to calculate or establish new values, but rather re-use those from literature as norm values for various goods and services of ecosystems.

3.4 Assessment of food security and the links with biodiversity and ecosystem services

Food security is defined as *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO, 1998). This definition consists of four key dimensions: availability (i.e. the supply of food determined by domestic food production, stock levels and net food trade), access (i.e. the resources of households and individuals to purchase food), utilization (i.e. nutritious and safe diets, and clean water) and stability (i.e. the temporal dimension of the other three dimensions).

By far most attention has been devoted to the modelling of the availability dimension of food security by using crop models or integrated assessment models (e.g. Alexandratos and Bruinsma, 2012; Nelson et al., 2010), looking at issues such as: changes in yields, impact of climate change and change in food production levels. The assessment of access and nutrition is a relatively new and underdeveloped area mainly because it requires data at the micro/household level, which are often not available. Regarding food access, a number of models present projections for the change in food prices and food trade, while only a few models are able to project changes in undernourishment and child malnutrition. Unfortunately, these latter two indicators are mostly using broad assumptions at the aggregate at regional level and do not directly measure poverty, one of the key determinants of food access and nutrition. In fact, the aim of the FoodSecure project , listen above, is to integrate household and poverty modelling with global and macro type integrated assessment frameworks to arrive at better projections for food and nutrition security. This project, however, has just started and results for a limited number of countries (e.g. Brazil and Ghana) will not be available before end of 2014.

Due to their complex and multi-faceted nature, the investigation of the relationship between food security on the one hand and ecosystem services and biodiversity on the other, is not easy. Apart from direct relationships between ecosystem services and food availability (i.e. the production of food), there are many indirect causal relationships. This is illustrated by Tekelenburg et al. (2009), who provide a framework which relates biodiversity with poverty, a key driver of food access and nutrition. For this reason, different combinations of trends in changes in food security and biodiversity are identified (e.g. win-lose, lose-win and win more-lose less) and the outcomes are not evident at forehand.

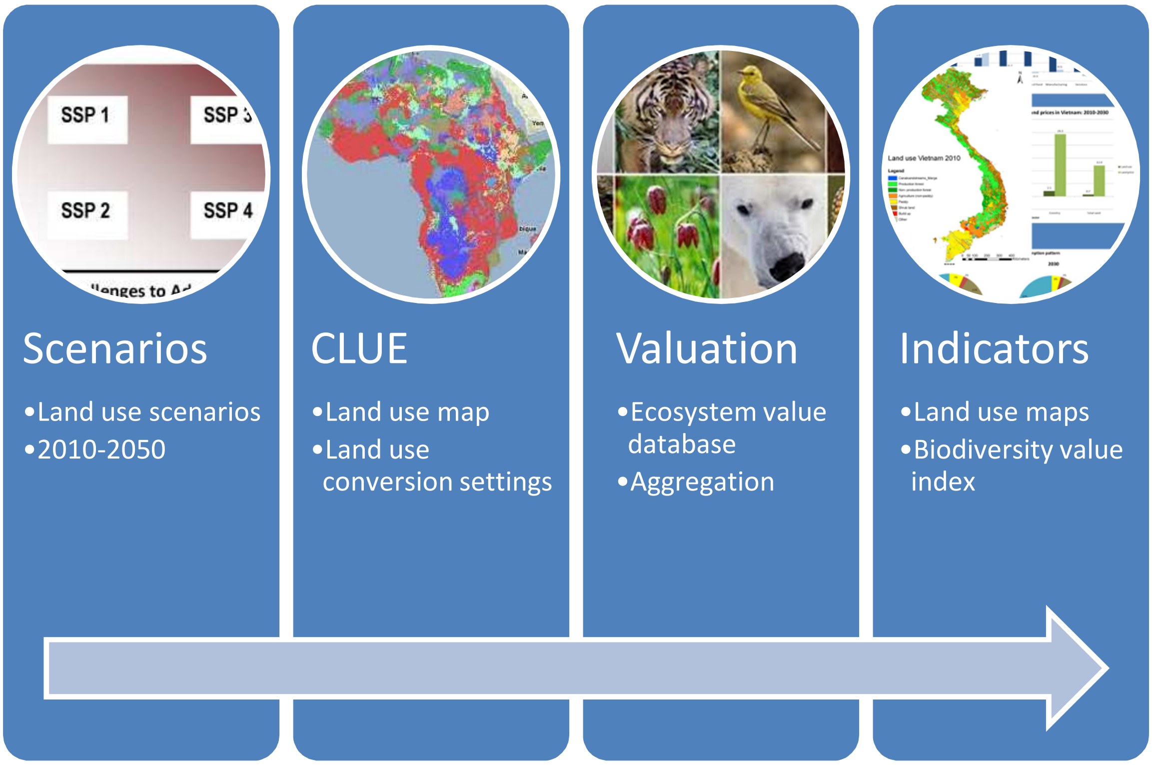
4 Proposed methodology

The methodology proposed for this project builds upon the studies that are summarised in the previous section. The core is the approach described in Verburg *et al.* (2007, 2006) and Van Meijl *et al.* (2006) and is composed of a set of global and national scenarios that are combined with a spatially explicit land use model to examine the impact of global developments such as population growth, economic development and climate change on land use change and biodiversity. This study presents the first application to a Sub-Saharan African country. To measure the impact of global and local drivers of land use change on biodiversity the framework is extended with a post-calculation to estimate the change in the value of biodiversity under different scenarios.

4.1 Modelling approach

Figure 1 depicts the four steps in the modelling framework. After the selection of the case study country, the first step in the modelling process is the design and selection of a set of plausible land use scenarios that take into account technological change, food and energy security, population growth and climate change up to 2050. The scenarios can be developed by using information on past trends of land use change (e.g. deforestation, urbanisation and change in agricultural land), consulting stakeholders, building on existing scenarios or a combining a number of these approaches.

Figure 1: Land use and ecosystems valuation modelling framework



In the second step, CLUE (Conversion of Land Use change and its Effects model, Verburg et al., 2002), is used to downscale the aggregate land use scenarios to the landscape (local) level for the period up to 2050. CLUE allocates future land-use change by combining spatial and non-spatial data on the bio-geophysical and human drivers of agricultural land use with current land use maps and incorporating assumptions on land use conversion and spatial policies. At the spatially disaggregated level, location characteristics such as the type of soil, slope, protected areas and proximity of infrastructure and populated areas, are important drivers of land use and land use change. By statistically linking GIS data on location characteristics with current land use, CLUE is able to identify the most suitable location for different types of land use classes.

In the third step of the modelling framework, the land use maps that are generated by CLUE are combines with data on the value of ecosystems to estimate the value maps for each of the scenarios (see below for details).

Finally, a number of indicators are presented that summarise the results of each scenario. Key output are a number of number of maps (one for each scenario with an expected resolution of 1x1 km depending on available land use maps) that depict land use change in the case study country from the start of the scenario up to 2050 and the corresponding change in the value of ecosystems. A more detailed description about the methodology to construct the indicator is presented in the next section.

The methodology as outlined is most suitable to produce land use and ecosystem valuation scenarios for one single country but can also easily be applied to a regional group of countries that share borders, such as the East African Community (Kenya, Tanzania, Uganda, Burundi and Rwanda). In principle, the approach can also be applied to lower spatial levels, such as a province or region within a country but this requires very detailed spatial information, which is often not available or of poor quality in most African countries.

4.2 Mapping and valuation of biodiversity

A simplified version of the proposed framework to derive at a valuation of ecosystems was used previously for the Nature Outlook of the Dutch Environmental Assessment Agency (PBL, 2012) and described in detail by Leneman et al. (2013). This work included the development of a database that included both costs and benefits of providing ecosystem services in different ecosystem types (forest, grassland, heathland and dunes). The framework of Leneman et al. (2013) was developed for the Dutch context, and did not include the impact of environmental pressure on ecosystem values. In the GLOBIO approach (Alkemade *et al.,* 2009), ecosystems are prone to various environmental pressures, affecting biodiversity. These pressures vary from climate change, habitat fragmentation to atmospheric deposition. Analogous to the GLOBIO approach, the different scenarios key to this project, therefore not only directly affect ecosystems due to land conversion and land use change, but also indirectly through these different pressures put on ecosystems. In addition, such pressures not only affect quality of ecosystems, but also the goods and services they provide. In ultimo, limited provision of the services also reduce their value. Currently however, there is no (fast) methodology that could capture all these effects, and studies that focus on such are only able to do that for a very limited number of services, usually only one for one type of ecosystem.

Schulp et al. (2012) have developed a new methodology for a fast mapping of ecosystem services, based on various GIS maps. This methodology can be applied in various regions (if spatial maps are available), but the method is not very specific. The mapping is confined to a limited number of services; food crop yield, wild food, carbon sequestration, soil erosion prevention, flood protection, pollination, air quality and tourism. Norm values of these services are also monetarized by de Groot *et al*. (2012).

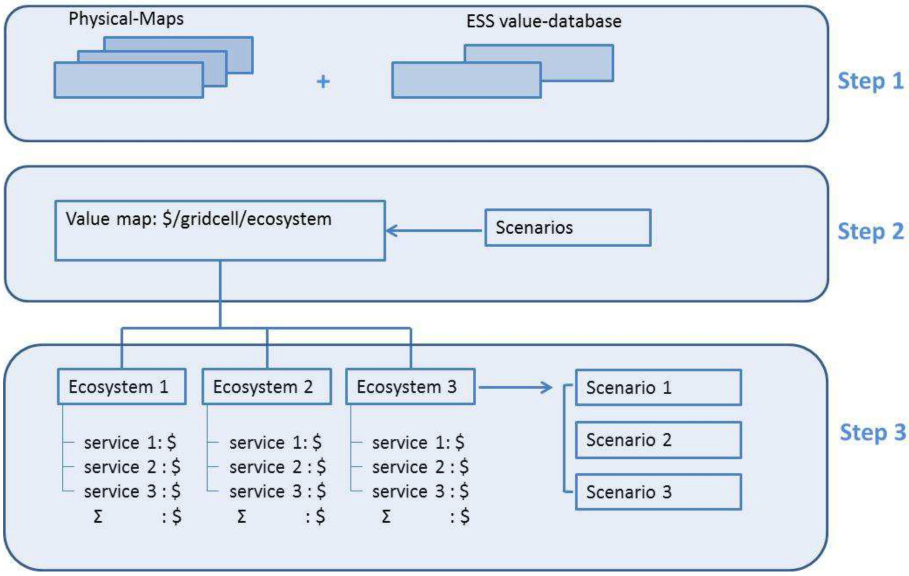
The current methodological framework therefore is an addition to the previously developed methods. The framework is depicted in figure 2. The framework constitutes of three essential steps:

Step 1: A number of physical maps are generated of the various land use types for the year 2050, including different natural ecosystems, soil type, climatic conditions, etc. In addition, a generic database will be designed, based on data from literature. This database contain values for ecosystems as well as for goods and services found in ecosystems. This database thus calculates ESS/ecosystem (in int. $/ha/yr).

Step 2. By combination of the physical maps and the ESS database (e.g., Schulp *et al*., 2012) value maps are generated. These value maps display the value of the different ecosystems (aggregation of all services) per unit grid or for a total area. It is possible however, to disaggregate this map for each ecosystem or each good and service separately. In addition the land use changes and conversions, as well as infrastructure are included in the scenarios. Land use, land conversion and infrastructure are directly connected to the value maps.

Step 3. For each scenario a final map is calculated, using the previous steps. For the final maps, values of different ecosystems are aggregated. Nonetheless, these values can also be disaggregated (to the various good and services). Likewise, all ecosystems present in a particular scenario are aggregated to one value; the total value of nature. These values are calculated for each scenario separately. Only differences in value are used in the further steps of this study.

Figure 2: methodological framework to estimate the economic value of nature



4.3 Evaluation of results

The main output of the analysis are value maps that indicates how the value of ecosystem services changes over time, in space and across scenarios. The maps will help to identify the areas with the highest ecosystems services value and therefore deserve particular policy attention. A comparison of maps across scenarios will reveal the impact of different futures on ecosystem values. In particular, it would be interesting to know to what extent rapid economic growth (for example because of trade policies) leads to change in ecosystems values and, if so, what are the areas that gain/loose the most. Also, similar to Braat en ten Brink (2008), it is possible to compare the change in value with projected GDP growth to put things into perspective.

Finally, by comparing changes in the value food production with changes in the value of other ecosystem services, insights can be derived on the trade-off between food security objectives and the provision of other ecosystem services under different futures. This, however, is only a partial assessment of food security that only takes the food availability dimension into account. As has been explained above, the state-of-the art modelling frameworks are not yet able to adequately analyse all dimensions of food security. For this reason, this project uses a more qualitative approach when analysing access and nutrition in relationship with ecosystem services. One possible option is to describe the potential channels through which the various ecosystem services affect food security in a region and identify policies that contribute to win-win outcomes.

The analysis offers a tool summarize and quantify the various ecosystem services of a country or area in a consistent manner and analyse their trade-offs. As such, it can be used as a starting point for the engagement with stakeholders, such as decision makers, smallholder farmers, NGOs and local entrepreneurs, to discuss landscape and ecosystem policy options.

5 Country selection

At forehand it was decided that the case-study would cover one or two countries in Africa. Given this criteria, other factors that play a role in selecting an interesting case-study country are:

- **Relevance:** To illustrate the trade off and synergies between different ecosystem services, the landscape pattern of the case-study country should be sufficiently diverse.
- **Data availability:** The analysis requires detailed assumptions on socio-economic drivers and spatially explicit data on a high number of variables.
- **Links with other projects and initiatives.** In order to better position the research, it would be an advantage to select a country that is already involved in a policy dialogue with the Netherlands (e.g. BUZA focus countries). From an efficiency perspective, it is recommended to select a country that is part of existing research projects.

On the basis of these criteria we propose the following countries as candidates for the case-study: Ghana, Ethiopia and Kenya.

6 Research partners

The research project will be undertaken in cooperation with the Dutch Environmental Assessment Agency (PBL). Several parts of the proposal have already been discussed with PBL and the relevant researchers in the organisation have confirmed their willingness to participate. In case detailed GIS knowledge and resources are required, ALTERRA-WUR will be approached for cooperation.

7 Budget

Tentative budget Euro 75,000 (based on comparable projects). A more detailed budget breakdown can be prepared when the details of the project (e.g. timeline, detailed description of work, number of scenarios, level of analysis) are known. As indicated above, it is possible to reduce the budget by cutting out the ‘global-to-local’ modelling part and limit the project to a land use change assessment of a single country. These options are up for discussion.

8 Products

- Research report
- Policy brief (summary of report including main findings and policy recommendations)
- Presentation (powerpoint) at conference

9 Annex: Potential indicators for determining (sustainable) use of ecosystem services

	Services comments and examples	Ecological process and/or component providing the service (or influencing its availability) = functions	State indicator (how much of the service is present)	Performance indicator (how much can be used/provided in sustainable way)
Provisioning				
1	Food	Presence of edible plants and animals	Total or average stock in kg/ha	Net Productivity (in kcal/ha/year or other unit)
2	Water	Presence of water reservoirs	Total amount of water (m3/ha)	Max sust. water-extraction (m3/ha/year)
3	Fiber & Fuel & other raw materials	Presence of species or abiotic components with potential use for timber<comma> fuel or raw material	Total biomass (kg/ha)	Net productivity (kg/ha/year)
4	Genetic Materials: genes for resistance to plant pathogens	Presence of species with (potentially) useful genetic material	Total "gene bank" value (e.g. number of species & sub-species)	Maximum sustainable harvest
5	Biochemical products and medicinal resources	Presence of species or abiotic components with potentially useful chemicals and/or medicinal use	Total amount of useful substances that can be extracted (kg/ha)	Maximum sustainable harvest (in unit mass/area/time)
6	Ornamental species and/or resources	Presence of species or abiotic resources with ornamental use	Total biomass (kg/ha)	Maximum sustainable harvest
Regulating				
7	Air quality regulation: (e.g. capturing dust particles)	Capacity of ecosystems to extract aerosols & chemicals from the atmosphere	Leaf area index NOx-fixation<comma> etc.	Amount of aerosols or chemicals "extracted"-effect on air quality
8	Climate Regulation	Influence of ecosystems on local and global climate through land-cover and biologically-mediated processes	Greenhouse gas-balance (esp. C-sequestration); Land cover characteristics etc.	Quantity of Greenhouse gases etc. fixed and/or emitted â†’ effect on climate parameters
9	Natural Hazard mitigation	Role of forests in dampening extreme events (e.g. protection against flood damage)	Water-storage (buffer) capacity in m3	Reduction of flood-danger and prevented damage to infrastructure
10	Water regulation	Role of forests in water infiltration and gradual release of water	Water retention capacity in soils etc. or at the surface	Quantity of water retention and influence of hydro-logical regime (e.g. irrigation)
11	Waste treatment	Role of biota and abiotic processes in removal or breakdown of organic matter xenic nutrients and compounds	Denitrification (kg N/ha/y); Immobilization in plants and soil	Max amount of chemicals that can be recycled or immobilized on a sustainable basis.
12	Erosion protection	Role of vegetation and biota in soil retention	Vegetation cover Root-matrix	Amount of soil retained or sediment captured
13	Soil formation and	Role of natural processes in	E.g. bio-turbation	Amount of topsoil

	regeneration	soil formation and regeneration		(re)generated per ha/year
14	Pollination	Abundance and effectiveness of pollinators	Number & impact of pollinating species	Dependence of crops on natural pollination
15	Biological Regulation	Control of pest populations through trophic relations	Number & impact of pest-control species	Reduction of human diseases<comma> live-stock pests<comma> etc.
Habitat or supporting				
16	Nursery habitat	Importance of ecosystems to provide breeding<comma> feeding or resting habitat for transient species	Number of transient species & individuals (esp. with commercial value)	Dependence of other ecosystems (or "economies" on nursery service
17	Genepool protection	Maintenance of a given ecological balance and evolutionary processes	Natural biodiversity (esp. endemic species); Habitat integrity (irt min. critical size)	"Ecological Value" (i.e. difference between actual and potential biodiversity value)
Cultural & amenity				
18	Aesthetic: appreciation of natural scenery (other than through deliberate recreational activities)	Aesthetic quality of the landscape based on e.g. structural diversity "greenness" tranquility	Number/area of landscape features with stated appreciation	Expressed aesthetic value e.g.: Number of houses bordering natural areas # users of "scenic routes"
19	Recreational: opportunities for tourism and recreational activities	Landscape-features Attractive wildlife	Number/area of landscape & wildlife features with stated recreational value	Maximum sustainable number of people & facilities Actual use
20	Inspiration for culture<comma> art and design	Landscape features or species with inspirational value to human arts etc.	Number/area of Landscape features or species with inspirational value	#books, paintings, etc. using ecosystems as inspiration
21	Cultural heritage and identity: sense of place and belonging	Culturally important landscape features or species	Number/area of culturally important landscape features or species	Number of people "using" forests for cultural heritage and identity
22	Spiritual & religious inspiration	Landscape features or species with spiritual & religious value	Presence of Landscape features or species with spiritual value	Number of people who attach spiritual or religious significance to ecosystems
23	Education & science opportunities for formal and informal education & training	Features with special educational and scientific value/interest	Presence of features with special educational and scientific value/interest	Number of classes visiting Number of scientific studies, etc.

10 References

Alexandratos, N., Bruinsma, J., 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper Rome, FAO.
Banse, M., van Meijl, H., Tabeau, A., Woltjer, G., Hellmann, F., Verburg, P.H., 2011. Impact of EU biofuel policies on world agricultural production and land use. Biomass Bioenergy 35, 2385–2390.
Barbier, E.B., 2007. Valuing ecosystem services as productive inputs. Econ. Policy 22, 177–229.
Braat, L.C., Brink, P. ten, 2008. The Cost of Policy Inaction: The case of not meeting the 2010 biodiversity target.
Brander, L.M., Bräuer, I., Gerdes, H., Ghermandi, A., Kuik, O., Markandya, A., Navrud, S., Nunes, P.A.L.D., Schaafsma, M., Vos, H., Wagtendonk, A., 2012. Using Meta-Analysis and GIS for Value Transfer and Scaling Up: Valuing Climate Change Induced Losses of European Wetlands. Environ. Resour. Econ. 52, 395–413.
Brander, L.M., J. Wagtendonk, A., S. Hussain, S., McVittie, A., Verburg, P.H., de Groot, R.S., van der Ploeg, S., 2012. Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. Ecosyst. Serv. 1, 62–69.
Brink, P. ten, 2011. The Economics of Ecosystems and Biodiversity in National and International Policy Making. Routledge.
Brock, A., Ferrer, M., Scholte, S., 2011. Economic Valuation of Medicinal Plants for Local and Global Use The Case of Bonaire.
Carpenter, S.R., Pingali, P.L., Bennett, E.M., Zurek, M. (Eds.), 2005. Ecosystems and human well-being: Scenarios, Volume 2. Island Press, Washington, DC.
Costanza, R., d’ Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O’Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world’s ecosystem services and natural capital. Nature 387, 253–260.
De Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L.C., ten Brink, P., van Beukering, P., 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecosyst. Serv. 1, 50–61.
Eickhout, B., van Meijl, H., Tabeau, A., van Rheenen, T., 2007. Economic and ecological consequences of four European land use scenarios. Land Use Policy 24, 562–575.
FAO, 1998. Rome Declaration on World Food Security and World Food Summit Plan of Action, World Food Summit 13-17 November 1996. Rome.
Kriegler, E., O’Neill, B.C., Hallegatte, S., Kram, T., Lempert, R.J., Moss, R.H., Wilbanks, T., 2012. The need for and use of socio-economic scenarios for climate change analysis: A new approach based on shared socio-economic pathways. Glob. Environ. Change 22, 807–822.
Leneman, H., Verburg, R.W., van der Heide, C.M., Schouten, A.D., 2013. Kosten en baten van de terrestrische natuur: Methoden en resultaten. Achtergronddocument bij Natuurverkenning 2010 - 2040 (No. 278), WOT-werkdocument. The Hague, The Netherlands.
Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grubler, A., Jung, T.Y., Kram, T., 2000. Special report on emissions scenarios: a special report of Working Group III of the Intergovernmental Panel on Climate Change. Pacific Northwest National Laboratory, Richland, WA (US), Environmental Molecular Sciences Laboratory (US).
Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T.B., Ringler, C., Msangi, S., You, L., 2010. Food security, farming, and climate change to 2050: Scenarios, results, policy options (IFPRI Research Monographs).
O’Neill, B., Carter, T.R., Ebi, K., Edmonds, J., Hallegate, S., Kemp-Benedict, E., Kriegler, E., Mearns, L., Moss, R., Riahi, K., van Ruijven, B., van Vuuren, D., 2011. Meeting report of the workshop on the nature and use of socioeconomic pathways for climate change research. Boulder, CO.
Polasky, S., Nelson, E., Camm, J., Csuti, B., Fackler, P., Lonsdorf, E., Montgomery, C., White, D., Arthur, J., Garber-Yonts, B., Haight, R., Kagan, J., Starfield, A., Tobalske, C., 2008. Where to put things? Spatial land management to sustain biodiversity and economic returns. Biol. Conserv. 141, 1505–1524.
Ruijs, A., Wossink, A., Kortelainen, M., Alkemade, R., Schulp, C.J.E., 2013. Trade-off analysis of ecosystem services in Eastern Europe. Ecosyst. Serv. 4, 82–94.
Rutten, M., Shutes, L., Meijerink, G., 2011. Sit down at the ball game: how trade barriers make the world less food secure (No. 3507), GTAP Resource Paper.
Schulp, C.J.E., Alkemade, R., Klein Goldewijk, K., Petz, K., 2012. Mapping ecosystem functions and services in Eastern Europe using global-scale data sets. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 8, 156–168.
Tekelenburg, A., ten Brink, B.J.E., Winter, M.C.H., 2009. How do biodiversity and poverty relate? An explorative study, Policy Studies. Netherlands Environmental Assessment Agency (PBL), Bilthoven.
Van der Lely, J.A.C., van Beukering, P., Muresan, L., Cortes, D.Z., Wolfs, E., Schep, S., 2013. The total economic value of nature on Bonaire. IVM Institute for Environmental Studies, Amsterdam.
Van Dijk, M., Rutten, M., Van Rooij, W., 2012. A global-to-local model approach to assess future land use dynamics: An application to Vietnam, paper submitted to the Agro Environ 2012 Conference.

Van Meijl, H., van Rheenen, T., Tabeau, A., Eickhout, B., 2006. The impact of different policy environments on agricultural land use in Europe. Agric. Ecosyst. Environ. 114, 21–38.

Verburg, P.H., Eickhout, B., Meijl, H., 2007. A multi-scale, multi-model approach for analyzing the future dynamics of European land use. Ann. Reg. Sci. 42, 57–77.

Verburg, P.H., Schulp, C.J.E., Witte, N., Veldkamp, A., 2006. Downscaling of land use change scenarios to assess the dynamics of European landscapes. Agric. Ecosyst. Environ. 114, 39–56.

Verburg, P.H., Soepboer, W., Veldkamp, A., Limpiada, R., Espaldon, V., Mastura, S.S.A., 2002. Modeling the Spatial Dynamics of Regional Land Use: The CLUE-S Model. Environ. Manage. 30, 391–405.