Linkages between ecosystem service accounts and ecosystems asset accounts

DRAFT

Author: Lars Hein[1]

Version: 1 (8 December 2014)

This work was undertaken as part of the project Advancing the SEEA Experimental Ecosystem Accounting. This note is part of a series of technical notes, developed as an input to the *SEEA Experimental Ecosystem Accounting Technical Guidance*. The project is led by the United Nations Statistics Division in collaboration with United Nations Environment Programme through its The Economics of Ecosystems and Biodiversity Office, and the Secretariat of the Convention on Biological Diversity. It is funded by the Norwegian Ministry of Foreign Affairs.

[1] *The views and opinions expressed in this report are those of the author and do not necessarily reflect the official policy or position of the United Nations or the Government of Norway.*

Acknowledgements (*to be completed*)

.

Contents

1. Introduction

This document is prepared in the context of the overall SEEA-Advancing Experimental Ecosystem Accounting project. Given that the Ecosystem Accounting approach aims to be consistent with the system of National Accounts 2008 (UN et al., 2009), measuring both flows and stocks of ecosystem capital and clarifying the relation between services and assets is crucial. This document provides guidance on how ecosystem service accounts and ecosystems asset accounts can be linked, in the general context of the relation between ecosystem services flows and stocks of ecosystem capital. The ecosystem service account deals with the measurement and recording of ecosystem services, and the ecosystem asset account deals with the stocks of ecosystem assets. This document describes the linkages between these two types of accounts. Note that both type of accounts, the ecosystem service accounts and the ecosystem asset accounts, are part of the overall System for Environmental-Economic Accounting – Experimental Ecosystem Accounting approach (SEEA-EEA). However, the SEEA-EEA guidelines (EC et al., 2013) do not explicitly describe the two type of accounts in the level of detail required to provide comprehensive and consistent guidance to agencies or researchers piloting the SEEA-EEA approach. This document aims to provide initial guidance on how the two type of accounts can be taken forward in the overall process of the continuous development of guidance materials for SEEA-EEA under auspices of the UN Statistics Division working with its partners UNEP and the CBD. In addition, the document presents a proposal for an overall structure of the Ecosystem Accounting framework, based on the experiences with the case studies that have been conducted to date and that have been reviewed for the purpose of this report (e.g. Schröter et al., 2014, Remme et al., 2014) and discussions with the SEEA-Advancing Experimental Ecosystem Accounting project team.

The document builds upon the SEEA Experimental Ecosystem Accounting Guideline, and on the basis of experiences gathered with spatial and biophysical modelling of ecosystem services as described in the scientific literature as well as global assessments such as MA (2005), TEEB (2010), EC (2011), UK NEA (2011) and the recent IPBES documents that are now becoming available. A key consideration is that the specifics of the relation between ecosystem services and ecosystem assets, as discussed below, are somewhat different for different (types of) ecosystem services.

The document contributes to the development of a more comprehensive framework for SEEA EEA by laying out and describing the various specific accounts that would be part of the EEA approach, and the linkages between these accounts. The document benefited from the technical discussions with the people involved in the SEEA-Advancing Experimental Ecosystem Accounting project, and their input is thankfully acknowledged.

2. The Ecosystem Accounts

Introduction to the ecosystem accounts. Ecosystem services need to be analyzed both in terms of flow and in terms of asset. The ecosystem asset is related to it's capacity to generate ecosystem service over time, under current land cover, management and environmental including climate conditions. The aggregated capacity of ecosystems to supply ecosystem services constitutes the ecosystem capital of an area; a reduction of this capacity implies development that is unsustainable from an environmental perspective. The capacity is influenced by the condition of ecosystems, for instance soil degradation may lead to a reduced capacity of forests to support timber production since lower soil fertility means, ceteris paribus, lower regrowth of forest stands following harvest. Trends in ecosystem condition, for instance due to overharvesting of resources or external pressures such as climate change, can reduce ecosystem capital over time. Both service flows and capacity can be expressed in physical as well as monetary terms.

Ecosystem accounting involves the development of the following accounts, see Table 1 below. These accounts are described below. Note that the accounts can be prepared in the form of maps as well as tables. Generally, there is a lot more information in the maps because in the case of maps all data pertinent to the account is specified for each basic spatial unit (which may be a pixel). The tables aggregate and synthesize the information contained in the maps. However, a country may decide that specific information sets that do not require a spatial approach to analyze the flow of ecosystem services or ecosystem assets are prepared in the form of tables only. For most regulating services, however, it is very difficult to not use a mapping approach given the large spatial diversity of these services. The supply-use account, specifying which sector is generating the ecosystem service (generally the land owner), and which sector is using the ecosystem service as an input can only be developed in the form of a table. As explained below, for this account the spatial relations are too divers and too complex to be mapped, for most ecosystem services.

Linkages between the ecosystem accounts. Ecosystem service accounts record the production of ecosystem services in the ecosystem. Therefore, this account has been labelled the 'Ecosystem Production Account', in order to ensure consistency in naming with the SNA (2009). The physical Ecosystem Production Account records flows in provisioning services (for instance m3 of timber per accounting unit per year), flows of regulating services (for instance tons of particulate matter air pollutants captured in ecosystems per accounting unit per year) and flows of cultural services (for instance number of tourist-days spent in the ecosystems in an accounting unit per year). In line with accounting practices, the temporal unit of choice is to record the flows of the services per year. In the monetary Ecosystem Production Account, these flows can be expressed in terms of the monetary value they generate per accounting unit per year.

The Ecosystem Asset account records the stock of ecosystem assets which is related to the capacity of the ecosystem to generate ecosystem services (EC et al., 2013). For example, for timber, the asset account would record the opening stock of timber stands (m3 of standing timber), the regrowth of the timber volume due to natural replenishment, losses due to natural factors (e.g. storm or fire damage) and the harvesting of timber (which equates to the flow of the ecosystem service). The capacity of the ecosystem to supply timber over time is related to the opening stock (a high opening stock means that harvesting can start the same year), the regrowth rate (fast regrowth, e.g. in the case of suitable climate and fertile soils means that the next round of harvesting can take place in less years compared to a situation with slow regrowth) and natural losses (recurrent storm or fire damages reduces the capacity to supply timber over time). A critical assumption in the Ecosystem accounting methodology (EC et al., 2013, Schröter et al., 2014) is that capacity is based on current ecosystem management. Further detail on the accounts and how they relate to each other is provided in the next Section.

The asset is account is linked to the production (ecosystem service flow) account in the sense that, for provisioning services, the flow of the ecosystem is included in the asset account: the flow of the service (e.g. the harvest of timber) leads to a reduction in the stock (e.g. the standing stock of timber).

For regulating and cultural services, the use of the service does not necessarily imply a change in the asset or stock, as explained in the next section below.

The asset account is linked to the condition account in the sense that the condition indicators determine the regrowth (/replenishment) of the ecosystem asset. For instance, soil fertility (a condition indicator) and rainfall (a condition indicator) determine (with other factors) the regrowth rate of forest stands after harvesting.

Table 1. The Ecosystem Accounts.

Account	Maps	Tables
Condition Account	X	X
Ecosystem production account	X	X
Ecosystem Asset Account	X	X
Supply-Use Account		X
Biodiversity account	X	X

2.1 The Condition Account

Ecosystem condition indicators need to reflect the main factors influencing the ecosystem's capacity to supply ecosystem services, including such abiotic and biotic factors as soil type, rainfall, elevation, NPP, biomass, species composition, etc. There may also be specific indicators in the Ecosystem Account that reflect the degree of degradation in an ecosystem, as in the case of Rain Use Efficiency (that can be analyzed on the basis of data that can be collected with remote sensing) being an often applied indicator for the status of semi-arid rangelands. The relevant indicators will always depend strongly on the ecosystem types and ecosystem services included in the account, as well on the relevant policy questions in the area covered by the account.

There are several criteria for the selection of indictors for ecosystem condition, including: (i) sensitivity of ecosystem services supply to the indicator; (ii) degree to which the indicator reflects the overall health of or key processes in the ecosystem; (iii) data availability; and (iv) possibility to cost effectively generate new data. Often, one condition indicator will be relevant for multiple ecosystem services, and the capacity to a supply a specific service will depend on multiple condition indicators. Clearly, these condition indicators are variable in space, and therefore they need to be mapped in the context of ecosystem accounting. Since many of the condition indicators are observable ecosystem properties, remote sensing analyses is of particular relevance for the analysis of ecosystem condition. Not that, whereas flows and capacities of ecosystem can be valued, in principle, in monetary terms, this does not apply to ecosystem condition accounts which only require a physical analysis. Even though individual condition indicators may influence the capacity of the ecosystem to generate services, and this relation may be specified using dose-response curves, it is not generally useful to try to value individual dose-response curves for multiple ecosystems since it is always the combination of condition indicators that determines the capacity to generate ecosystem services.

Ecosystem condition indicators also need to include what has been labelled enabling factors in the Experimental Ecosystem Accounting guidelines (EC/OECD/UN/World Bank 2013). These are the environmental factors that make regulating services relevant, i.e. the conditions negatively affecting economic production or human welfare as a consequence of pressures on the environment. For instance the pressure 'air emissions' may have decreased air quality (i.e. increased the ambient concentration of particulate matter pollutants). The concentration of air pollutants is an ecosystem condition indicator that is required for understanding the ecosystem service 'air filtration', since the higher the concentration of air pollutants the more economically relevant the capturing of pollutants by vegetation (Remme et al., 2014). In general, without these enabling factors there would be no need for the regulating service. The set of regulating services relevant for the Ecosystem Account under development determines the 'enabling factors', i.e. ecosystem condition indicators indicating a pressure exerted on the ecosystem, to be included. With the exception of atmospheric carbon levels (which is spatially variable but not at a level relevant for Ecosystem Accounting), all enabling factors are spatially variable.

A question is if Ecosystem Condition should be measured in comparison to a reference condition. It has been proposed for instance to use the ecosystem state prior to settler's modification of the landscape as reference ecosystem condition, and the SEEA EEA guideline provides an elaboration of how this can be done. However, in many parts of the world such a 'natural' or semi-natural condition is hard to establish, and this method is therefore not universally applicable. Hence, given that a reference condition may be difficult to establish, reach consensus on, and difficult to measure it may in many parts of the world be more practical to measure ecosystem condition using indicators measurable irrespective of a benchmark situation. For reasons of analyzing trends in ecosystem condition, a benchmark may of course still be useful, in this case a historical benchmark or a specific year can be selected (see also Edens and Hein, 2013).

2.2 The Ecosystem Production Account

The Ecosystem production account reflects the flow of ecosystem services from the ecosystems to the economy, and comprises both a physical flow account and a monetary flow account. Insofar as maps are used to quantify ecosystem services flow per spatial unit (e.g. per pixel), services flows can be aggregated for different statistical units, for example in terms of the flow generated of a specific ecosystem service per LCEU (Land Cover and Ecosystem Unit) or per district or municipality. Flows of different ecosystem services can generally not be added, but flows of one specific ecosystem service as generated within the various LCEUs or administrative units can be added in order to obtain a total physical flow. In the case of the monetary ecosystem production account it is of course straightforward to aggregate values of flows of ecosystem services, since a commensurate valuation system (based on the SNA 2008) is used. Note that these values reflect the contribution of ecosystem to economic production or consumption based on exchange values, hence the monetary ecosystem production account does not reflect the welfare generated by ecosystem service flows.

For provisioning services, the ecosystem production account specifies the contribution of ecosystems to products. The products themselves are already within scope of the SNA, also those products used for home consumption or illegally harvested, even though there may well be a difference between what is recorded in the SNA and the actual use of the ecosystem. For regulating services, appropriate indicators need to be found to reflect the physical flow of the service (see also the Paper 'Guidelines for Mapping and biophysical assessment of Ecosystem Services'). This may not always be straightforward, for instance the complex processes involved in regulating water flows are difficult to capture in one or a few specific indicators. For instance, for erosion and sedimentation control, the contribution of the ecosystem to avoiding erosion could be defined as the amount of avoided erosion due to the presence of a vegetation cover, compared to a situation with no vegetation cover. The amount of erosion that would occur in the absence of vegetation can usually not be observed but can be modelled with for instance the USLE (Universal Soil Loss Equation) or the derived models: RUSLE (Revised USLE) or MUSLE (Modified USLE). Validation of model results is possible using experimental plots (where vegetation is removed) or if available by measuring erosion rates in bare patches of the ecosystem.

Note that the benefit may be quite different from the service in the case of regulating services. For instance, erosion control can be seen as the service, but the benefit may well be avoided sedimentation in a downstream reservoir. Or the service may be the filtration of air through the absorption of polluting particles, e.g. particulate matter, by the vegetation, but the benefit is expressed in terms of a reduced exposure of people to pollutants due to a reduced concentration of pollutants in their living environment. In these cases, linking the service to the benefit, which is generally required to value the ecosystem service, requires an additional modelling step (for example to link erosion control to reduced sedimentation downstream). And valuing air filtration requires modelling air pollutant concentrations at locations where people live as a function of capture of pollutants by vegetation and several other factors (ambient concentration, distance between point of capture and location of people, prevailing wind patterns and vertical atmospheric mixing, etc.), see Remme et al. (2014).

Table 1 provides an example of a physical Ecosystem Production Account, developed for Limburg Province, the Netherlands (Remme et al., 2014).

Table 1. An example of a physical Ecosystem Production Account, developed for Limburg Province, the Netherlands (derived from Remme et al., 2014). In between brackets, the table presents the spatial standard deviation, indicating the spatial variability of the flow of the ecosystem service within LCEUs.

LCEU	**Ecosystem service**													
	Crop production		Fodder production		Drinking water extraction		Hunting		Air quality regulation		Forest carbon sequestration		Recreational cycling	
	Total	Mean (SD)	Total	Mean (SD)	Total	Mean (SD)	Total	Mean (SD)	Total	Mean (SD)	Total	Mean (SD)	Total	Mean (SD)
	Mtons MEQ	kg MEQ ha^{-1} yr^{-1}	ktons dm	kg dm ha^{-1} yr^{-1}	10^3 m^3 water	m^3 water ha^{-1} yr^{-1}	kg meat	kg meat km^{-2} yr^{-1}	tons PM_{10}	kg PM_{10} km^{-2} yr^{-1}	ktons C	kg C ha^{-1} yr^{-1}	10^3 trips	trips ha^{-1} yr^{-1}
Pasture	-	-	521	12,041 (1,573)	9,110	3,099 (2,231)	9,100	21 (17)	405	911 (532)	-	-	1,872	103 (78)
Cropland	2.46	36,314 (1,785)	-	-	14,855	3,082 (2,422)	14,732	20 (17)	715	956 (534)	-	-	2,631	99 (73)
Forest	-	-	-	-	4,577	3,214 (2,624)	8,100	24 (20)	686	2,040 (1,221)	55	1,563 (263)	1,472	126 (92)
Water	-	-	-	-	3,289	9,460 (3,698)	-	-	40	624 (569)	-	-	147	110 (92)
Urban	-	-	-	-	7,862	4,321 (3,527)	-	-	285	547 (562)	-	-	2,735	70 (57)

Heath	-	-	-	-	219	1,293 (821)	678	32 (25)	45	2,062 (1,111)	-	-	30	82 (59)
Peat	-	-	-	-	0	0 (0)	70	13 (3)	7	970 (345)	-	-	3	92 (44)
Other nature	-	-	-	-	1,187	3,093 (2,573)	1,513	25 (20)	69	1,155 (710)	-	-	226	128 (93)
Provincial total	2.46		521		41,099		34,193		2,252		55		9,116	

2.3 The Ecosystem Asset Account

The ecosystem asset account records stocks of and changes in stocks of ecosystem assets. It is linked to both the Condition Account. The linkage to the Condition Account is as follows. The Condition Account provides information on the environmental factors that determine the capacity to generate ecosystem services that is recorded in the Asset Account. For instance, information on rainfall, temperature, soil fertility, species composition that is recorded in the Ecosystem Condition Account is used to calculate the natural regrowth of the timber asset.

The Asset account typically comprise an (i) opening stock; (ii) changes due to economic activities (extractions such as harvest or additions to stocks for instance through replanting; (iii) changes due to natural processes (for instance additions to stock due to regeneration or growth and negative changes due to fire or storm damage); (iv) changes due to reclassifications; and (v) closing stock, The categories of changes, and their nomenclature, should as much as possible be aligned with the SEEA CF.

For provisioning services, stocks may or may not be easy to record. For instance stocks of water and timber may be well defined even if not always easy to measure. However stocks of annual crops such as wheat or paddy may well be zero at the time the opening stocks of the accounts are established. Also for some of the regulating services stocks are difficult to define or relatively intangible. For instance in the case of air filtration the asset represents the capacity of the ecosystem to capture vegetation (which in turn can be related to the Ecosystem Condition indicator Leaf Area Index, LAI, which can be derived from remote sensing images). Changes in that capacity may well occur between years, for instance due to changes in vegetation cover or due to changes in emissions leading to changes in background concentration and making the service perform more (in case of increasing concentrations) or less (in case of decreasing concentrations). However regulating service are generally dissimilar to provisioning services in the sense that changes in the asset are not influenced by the amount of service being generated. For example, the amount of capture of pollutants does not change the capacity of the ecosystem to capture pollutants (because the basic mechanism in this case is that the pollutants are deposited on the leaves, and are washed out to the soil when it rains). In this case, the asset account could record (i) opening stock expressed as ‘capacity to capture PM, expressed as amount of pm captured per year per BSU’; (ii) additions to stock (same unit, resulting from for instance reforestation projects increasing Leaf Area Index; (iii) reductions in stock (for instance due to loss of forests or tree cover); and (iv) closing stock. For carbon sequestration and storage, it is also meaningful to distinguish between stocks and flows/changes in stocks. An area (or spatial unit) may have an opening stock in terms of its carbon content stored in above and below ground biomass and soils, and a closing stock, there may be sequestration of carbon during the accounting period (i.e. the reflecting the service) and there may be emissions due to ecosystem degradation (for example drainage of peat or deforestation). The sum of sequestration and emissions equals the change in stock. Since the basic principle underneath the ecosystem accounts is only to include information that is meaningful both in terms of well-defined physical and/or monetary quantities and in terms of providing relevant information for decision making it needs to be considered on a case-by-case basis, i.e. for every service individually, which aspects (opening and closing stock, changes in stocks, etc.) are relevant for inclusion in the asset account.

2.4 The Supply-Use Account

Suppliers and users of ecosystems may be classified in terms of financial, non-financial industries, government, households and NGOs serving households as main categories. This account is linked, in particular, to the Ecosystem Production Account that generates the flow of ecosystem services produced by specific accounting units. The Supply-Use account subsequently records the users of these flows of services. However, there are several issues related to identifying the supplier of the ecosystem services. The 2008 SNA defines production as "an activity carried out under the control and responsibility of an institutional unit that uses inputs of labor, capital, and goods and services to produce outputs of goods or services" (UN et al., 2009). An important factor is that "All goods and services produced as outputs must be such that they can be sold on markets or at least be capable of being provided by one unit to another, with or without charge'. Recording ecosystem services in an accounting framework therefore requires an extension of the production boundary. There are different approaches that might be deployed to extend the production boundary. It is useful to distinguish between two approaches: ecosystems as assets used in production or ecosystems as independent producers (Edens and Hein, 2013).

(i) *Ecosystem as assets used in production*[2]. The first approach considers ecosystems primarily as assets which produce ecosystem services akin to the concept of fixed capital producing capital services (e.g. a truck provides transport services in the form of ton kilometers). This approach can be formalized by introducing a production function F which uses ecosystem assets together with other assets such as produced capital and labor and other inputs (e.g. fertilizers) to produce outputs. This model assumes that the ecosystem asset is owned by one of the standard institutional units. It entails an extension of SNA production boundary by relaxing the condition of marketability. To give an example, while according to the classical SNA view, a farmer buys a piece of land and produces agricultural products, in this approach, the farmer is conceived as buying an agricultural ecosystem, which allows him to produce not only agricultural products but at the same also provides non-SNA outputs such as carbon sequestration or amenity services.

(ii) *Ecosystems as independent producers*[1]. An alternative approach is to see ecosystems as independent producers of ecosystem services similar to an autonomous establishment (say a factory). This model also entails an extension of the SNA production boundary but in a different way: it relaxes both the condition of marketability and the condition of being under control of an institutional unit. In fact, conceiving of ecosystems as independent producers implies that ecosystems are recognized as additional types of institutional units. Therefore, it naturally leads to an additional sector 'ecosystems' in addition to the standard institutional sectors in the economy, such as the household or the corporate sector.

[2] Based on Edens and Hein, 2013

An additional consideration here is that ecosystems generate both final and intermediate services. Although the SEEA-EEA focusses on final services only, it is now becoming clear that ecosystem accounting, in particular where a spatial approach is followed to understand ecosystem assets also requires understanding key intermediate services. For instance, upstream forests may regulate water flows and thereby permit downstream agriculture. The hydrological service provided is in this case an intermediate service. Also for management of ecosystems understanding of key intermediate services is required, if not considered the surplus generated by the forest would be underestimated and that of the cropland overestimated (note that the surplus generated by the ecosystems at large, i.e. the sum of the cropland and forest would not change if intermediate services are considered).

The discussion on how best to include ecosystems as providers of services in the ecosystem account and eventually a full satellite to the SNA has not yet been concluded. One of the options it ecosystems to assume to be independent producers as for the non-SNA benefits provided by ecosystems (these benefits such as carbon sequestration or air filtration are usually not reflected in the market price of land nor are they usually part of the considerations of the ecosystem manager) and assets with regards to the other ecosystem services involved (see Edens and Hein, 2013). Presumably also intermediate ecosystem services would, in this case, be generated by an independent producer rather than an asset. Another option is to attribute all services to the asset 'ecosystems'. However in this case it may be not straightforward to deal with the intermediate services, that would basically become flows between assets (i.e. from the asset 'forest land' to the asset 'cropland' in the case of forests regulating water used for irrigating downstream cropland). Flows between assets do not seem consistent with the SNA recording framework. A third option would be to attribute all services to the independent producer (sector) ecosystems. In this case, an account would likely include several ecosystem types as different independent producers, for instance a sector forest ecosystems and a sector cropland, with the forest ecosystems providing an input into the crop production service of the cropland.

Note that the supply-use account will not be supported by maps. It is for many services too complex to spatially model the relation between the individual service providing spatial units and the individual users. For instance, in the case of air filtration, a myriad of vegetation elements in the landscape contribute to reducing air pollution loading in ambient air, benefitting a multitude of people living in the environment. Linking individual trees to individual beneficiaries is not meaningful.

2.5 The Biodiversity Account

The biodiversity account is complementary to the other accounts in the sense that it comprises information not covered in any of the other accounts, specifically information on aspects of biodiversity that are not related to the supply of other ecosystem services. Clearly, there is a link between ecosystem diversity, and the presence and abundance of many species in an ecosystem and the supply of ecosystem services. For example, forest diversity, quality and maturity of forest stands and forest species and abundance determines the capacity of the forests to supply timber. However, many rare, endemic and other species may contribute to the overall species diversity in the ecosystem but may not be important for maintaining the overall functioning of the ecosystem or for the supply of specific services (Mace et al., 2010). Since people are interested, in addition to the wide range of ecosystem services, also in the protection of biodiversity including its rare and endemic species, there is a need to capture this particular aspect of ecosystems in the biodiversity account. Hence, the

Biodiversity account captures biodiversity as a final ecosystem service, with the specific consideration that biodiversity indicators included in the account reflect the presence of and trends in specific species, genetic information sets or ecosystems and thereby does not express a flow of a service. It is also relevant to mention that the account cannot generally be expressed in monetary units. The biodiversity account is policy relevant in itself since it provides a tool to monitor the status of biodiversity. The specific elements and indicators to be included in the Biodiversity Account need to be formulated as per the policy issues and the local ecosystem conditions including species composition.

Particularly relevant for the Biodiversity account are the number and presence of specific species as well as the habitat for different species and the quality of the habitat (i.e. aspects related to assets and changes therein rather than flow). The occurrence of species and habitats is normally strongly spatially variable. Hence, maps would be required to understand and analyze biodiversity assets, with information synthesis in tables for easy understanding and clarification of trends.

Developing biodiversity accounts can build upon an extensive ecological literature. Wathern et al. (1986) mentioned already that over 100 techniques to quantify biodiversity and other ecological values have been described in literature. A brief summary of several potential indicators for the biodiversity conservation service is provided below, for the categories of species level and ecosystem level indicators (see also Hein, 2010).

<u>Species level indicators</u>

- **Number of species in specific classes**. Given the large number of species, indicators presenting the species richness of an area need to focus on (a combination of) specific taxonomic groups, such as mammals, meadow birds, or vascular plants. Although the number of species in specific groups is an indicator of the species diversity of an area, drawbacks are that it does not indicate the population numbers per species (which may be below viable population numbers) and that it gives equal weighing to each species.

- **Biodiversity indices**. The most well-known of these indicators are the Simpson and Shannon Indices. These indices express the species diversity in an ecosystem, based on species richness and the relative abundance of each species. However, the indicators are difficult to interpret, and they provide equal weighing to each species.

- **Mean species abundance**. MSA is an indicator of naturalness or biodiversity intactness. It can be defined as the mean abundance of original species relative to their abundance in undisturbed ecosystems. An area with an MSA of 100% means a biodiversity that is similar to the natural situation. An MSA of 0% means a completely destructed ecosystem, with no original species remaining (from: http://www.globio.info/what-is-globio/how-it-works/impact-on-biodiversity).

- **Numbers of red-list and/or endemic species**. The IUCN Red List has a global cover and provides taxonomic, conservation status and distribution information on plants and animals. Most taxonomic groups have been completely, or almost completely assessed (mammals, birds, amphibians, freshwater crabs, warm-water reef building corals, conifers and cycads). The list provides a good starting point for identifying the number of species of particular concern for nature conservation that are present in an ecosystem, even though the level of detail and understanding of the status of species varies between different parts of the globe.

- **Populations of keystone species**. The keystone species concept stipulates the existence of a limited number of species that regulate essential ecosystem processes such as nutrient recycling, see Pain et al. (2003) for an example. Whereas keystone species may exist for some ecosystems, it is as yet unclear if keystone species can be defined for all ecosystems. Where they can be identified, monitoring the abundance of keystone species provides an indication of the functioning of the ecosystem.

<u>**Ecosystem level indicators**</u>

- **Presence of species that are indicative for environmental quality**. Maintaining environmental quality is one of the preconditions for conserving biodiversity. Disturbance may affect biodiversity, with those species that have specific, narrow ecological niches particularly vulnerable to environmental change. Environmental quality indicators provide information on the degree of disturbance, and, hence, the sustained potential of an ecosystem as habitat for (rare and threatened) species.

- **Habitat for specific species**. In some cases, specific species can be indicative of the overall quality of the ecosystem, for instance because they have high requirements in terms of the condition of the ecosystem (e.g. the orangutan) or because they are at the top of the food chain and their survival depends on the species lower down the food chain (e.g. the tiger). An advantage of this indicator is that presence of such, iconic wildlife species may be better monitored compared to the status of most other species. Using Maxent (as described in the biophysical modelling guidelines), overall habitat quality for such species can be mapped using data from presence points only.

- **Land cover change**. Land cover change, or its inverse: the area of preserved ecosystem remaining, is a key indicator for biodiversity conservation. A physical loss of ecosystems, for instance through land use conversion, has clear impacts on its biodiversity value. However, it is often difficult to define and qualify the degree of disturbance to which ecosystems have been exposed, for example to relate deforestation to ecosystem disturbance. A number of methods have been developed, for example the Habitat Index (Hannah et al., 1994) or the Natural Capital Index, which is the product of the size of a natural area and its nature quality (Ten Brink and Tekelenburg, 2002).

- **Extent and effectiveness of protected areas**. Protected areas, provided that their protected status indeed translates into conservation of biodiversity and arresting outside disturbance of the park are an effective approach to biodiversity conservation. The total surface area of protected areas in a country is therefore a useful indicator of biodiversity status. Given that the effectiveness of protected areas varies considerably between and within countries, both the extent and effectiveness of the protected areas need to be analyzed in case this indicator is used to report on biodiversity trends.

- **Naturalness**. The naturalness of ecosystems may not always be straightforward to establish, given that ecosystems are dynamic systems and are changeable even under fully natural conditions. However, in specific cases, naturalness may be defined, for instance by relating ecosystem conditions to conditions with much lower human influence compared to present levels. In addition, naturalness is an inherent quality of ecosystems that may be appreciated by people, justifying by itself its potential use as an indicator for a Biodiversity account.

3. Conclusions

The Ecosystem Accounting approach requires a set of different accounts, that need to reflect ecosystem services flow (the ‘Ecosystem Production Account’), the ecosystem asset and changes in these assets (the ‘Ecosystem Asset Account’) as well as an account to record the factors that drive change in the capacity of ecosystems to generate services and thereby the regeneration part of the ecosystem asset account (the ‘Ecosystem Condition Account’). This would need to be supplemented with information linking suppliers and users of ecosystem services (the ‘Supply-Use Account’) and a biodiversity account to record such aspects as species diversity and nature conservation-related aspects that are not covered in the other accounts. Jointly, these accounts provide a comprehensive picture to monitor changes in ecosystems and to relate ecosystems to economic activity. The accounts are all connected. The flow of ecosystem services, as recorded in the Ecosystem Production Account, is also an entry in the Asset account in the sense that for provisioning services the flow of the service leads to a reduction in the asset. The Asset account is linked to the Condition account because the ecosystem condition determines how fast the ecosystem stock is recovering from use or harvest. The Supply-Use account is linked to the Production account, in the sense that it specifies how ecosystem services accrue to different economic sectors. The biodiversity account is only connected to the condition account, since some aspects of biodiversity are also relevant as Condition indicator.

References

Edens, B. and L. Hein, 2013. Towards a consistent approach for Ecosystem Accounting. Ecological Economics 90, 41-52

European Commission, Organisation for Economic Development and Co-operation, United Nations, & Bank, W. (2013). System of Environmental-Economic Accounting 2012 Experimental Ecosystem Accounting.

Remme, RP M Schröter, L Hein, 2014. Developing spatial biophysical accounting for multiple ecosystem services. Ecosystem Services 10, 6-18

Schröter, M., D. Barton, RP. Remme, L Hein, 2014. Accounting for capacity and flow of ecosystem services: A conceptual model and a case study for Telemark, Norway. Ecological Indicators 36, 539-551.

Sumarga, E. L Hein, 2014. Mapping Ecosystem Services for Land Use Planning, the Case of Central Kalimantan. Environmental management, 1-14

Ten Brink, B. and T Stekelenburg, 2002. Biodiversity, how much is left ? The Natural Capital Index, RIVM Report, Bilthoven, the Netherlands.

Wathern, P, SN Young, IW Brown, DA Roberts, 1986. Ecological Evaluation Techniques. Landscape Planning 12, 403-420.