A perspective on capacity and capability in the context of ecosystem accounting[1]

Version: 15 April 2015

Authors: Lars Hein, Bram Edens, Ken Bagstad – with inputs from Carl Obst

This work was undertaken in the context of the project Advancing the SEEA Experimental Ecosystem Accounting. This note is 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 authors and do not necessarily reflect the official policy or position of the United Nations, Statistics Netherlands or the Government of Norway.

Contents

1. Introduction

Ecosystem accounting involves the measurement of: (i) the extent and condition of ecosystems; (ii) the ecosystem's capacity to generate ecosystem services as a function of its extent and condition; (iii) flows of ecosystem services; and (iv) the linkages between ecosystems and economic activity (UN et al., 2014a). This note focusses on how to define capacity as a central concept in the ecosystem accounts.

Capacity has been described in general terms in the SEEA-EEA (UN et al., 2014), as being a function of condition and extent (SEEA EEA para 4.1). It has been related to expected services (para 2.36, 4.24 and 4.25) and (maximum) sustainable yield (para 2.37, 2.96). Nevertheless, operationalizing the concept requires further detail on how to apply it. The key issue is that capacity has been interpreted as the capacity to generate a specific ecosystem service, whereas in practice ecosystems provide a basket of ecosystem services, and the capacities for these services are interlinked. For instance, a high capacity to generate timber would be negatively correlated to the ecosystem's capacity to sequester carbon, support tourism, or capture air pollutants. Consequently, adding the capacity as calculated for each individual service would overestimate the capacity of the ecosystem as a whole. This note addresses this issue and proposes a potential way forward for further discussion.

In particular, the note proposes a definition for capacity, and the related concept of capability (table 1), and it proposes, as input into the discussions, a way of operationalizing the concepts of capacity and capability. Capability is related to the ecosystem's ability to generate ecosystem services regardless of potential effects on the capacity to generate other ecosystem services. Capacity would equal capability if, for example, the ecosystem only generates one ecosystem service. This is further elaborated in section 3 of this note.

The note is organized as follows. In section 2, a background is provided on the various elements of ecosystem accounting and how capacity is relevant for these elements. Section 3 presents a discussion on the concept of capacity and proposes a potential way forward, illustrated with an example.

The note is to be considered an Issues Paper, intended to provide inputs into the overall discussions on further developing and fine-tuning methodologies for Experimental Ecosystem Accounting under the guidance of UNSD and in the specific context of the Advancing the SEEA Experimental Ecosystem Accounting project. **It explores how to provide operational guidance for the concept of capacity for the purpose of contributing to the ongoing discussion.**

The note elaborates on the concept of capacity as described in the SEEA EEA in terms (maximum) sustainable yield of a basket of expected ecosystem services. The paper motivates why a more detailed definition is appropriate, how this more precise definition is applicable for the different types of ecosystem services, and how it has been tested in a number of examples.

2. Capacity in the context of the Ecosystem Accounts

Based on the SEEA-EEA (UN et al., 2014), the paper suggests that capacity could be recorded in the 'Ecosystem Capacity Account', as described below. A brief description of selected other accounts that may potentially be part of the ecosystem accounting framework is also presented in this note to illustrate the connection between accounts, and because a basic overview of these other accounts and their connection is relevant for understanding capacity.

Table 1 presents of the suite of ecosystem accounts that are part of the ecosystem accounting structure, which have been partly tested in various projects and studies. Recognizing that the SEEA Experimental Ecosystem Accounting (EEA) guidelines called for testing of the EEA approach, this current note intends to support the further testing as well as further conceptual development of the EEA approach by exploring one of the key concepts in ecosystem accounting, ecosystem capacity.

Table 1. Operationalizing the ecosystem accounts

	Note
Core Ecosystem Accounts	
Ecosystem Condition Account	
Ecosystem Services Supply Account	
Ecosystem Services Use Account	
Ecosystem Capacity Account	A proposal for how to define capacity for each type of service in this Note.
Ecosystem Component Accounts	
Land Account	Specific structure of the account under development by UNSD
Biodiversity Account	Some clarifications provided in this note
Carbon Account	Part of SEEA Central Framework, may also be adopted by countries following an Ecosystem Accounting approach because of its complementarity to the other ecosystem accounts.
Water Account	Part of SEEA Central Framework, may also be adopted by countries following an Ecosystem Accounting approach because of its complementarity to the other ecosystem accounts.
Work is ongoing by UNSD to define the full suite of accounts, potentially including additional accounts that would facilitate linking the core and/or component accounts above to the national accounts	

Core Ecosystem Accounts

As described in the SEEA EEA the following asset/stock and flow accounts are part of the suite of interrelated accounts.

The Ecosystem Condition Account (map and table). Ecosystem condition indicators reflect the main factors influencing the state and functioning of an ecosystem asset including key ecosystem components and processes. Condition indicators describe aspects such as nutrient and hydrological cycles in the ecosystem, species composition and productivity of the ecosystem, (e.g. Weber 2007; Weber 2014).

Condition indicators provide an understanding, in physical terms, of changes in the ecosystem over time (e.g. soil nutrient depletion or habitat fragmentation), and are also important to analyze the flow of ecosystem services (e.g. the condition account may indicate the presence of commercially valuable timber species in a forest) and the capacity of ecosystems to generate ecosystem services (e.g. soil fertility in a forest plantation affecting tree growth rates). Condition indicators may also enter into ecological production function models of ecosystem services (Stoneham et al., 2012; Villa et al., 2014). Often, one condition indicator will be relevant for multiple ecosystem services, and, at the same time, the capacity to supply a specific service will depend on multiple condition indicators that differ by service and location in their contribution to production of ecosystem services. Specific elements of biodiversity (including genetic, species, or ecosystem diversity), that are relevant for the functioning (including resilience) of the ecosystem, may be included as indicators in the condition account (for instance, abundance or diversity of pollinator species, or genetic variability of commercial timber or fruit species). In many cases, however, the relation between biodiversity and ecosystem functioning is complex and not fully understood in quantitative terms (Mace et al. 2012).

The Ecosystem Services Supply Account (map and table; physical and monetary). The Ecosystem services supply account reflects the supply of ecosystem services from the different land cover / ecosystem units to the economy and society, and this flow can be expressed in both physical and monetary indicators. Where ecosystem service flows are estimated or attributed in terms of flows per fine level spatial unit (e.g. per pixel), these service flows can be aggregated for different statistical units, for example in terms of the flow of a specific ecosystem service generated per spatial unit (e.g. a Land Cover / Ecosystem Unit). For provisioning services, the ecosystem services account specifies the contribution of ecosystems to products. For regulating and cultural services, appropriate indicators and metrics need to be found to reflect the physical flow of the service.

The Ecosystem Services Use Account (table only, physical and monetary). The Ecosystem services use account links ecosystem services to users of these services. Users may be classified by sector (e.g. households or government) and/or by economic activity following the ISIC code (International Standard Industrial Classification of All Economic Activities). The account itself is not spatially explicit, but draws upon the ecosystem services supply account in combination with analyses that link ecosystem services to beneficiaries (e.g. Bagstad et al. 2014). This account allows the detailed analysis of the effects of ecosystem change on different stakeholders.

The Ecosystem Capacity Account (map and table, physical and monetary) Unlike the condition account, which is recorded in physical units only, the capacity account can be expressed in both physical and, for some components of the capacity accounts, in monetary units. In physical terms, the account records the ecosystem's capacity to generate an ecosystem service. Following similar principles of produced assets, the capacity of of an ecosystem asset to produce a basket of expected individual ecosystem services can be defined, as follows: 'the ability of the ecosystem to generate a basket of ecosystem services under current ecosystem condition and uses at the maximum sustainable yield that does not lead to a decline in condition of the ecosystem'. Degradation of the ecosystem would be reflected in declines in ecosystem condition and a reduction of the ecosystem's ability to generate ecosystem services over time. The remainder of the issues paper provides further insights in how the capacity account can be measured.

Ecosystem Asset Accounts for components

The Land Account. The Land account presents the spatial basis for ecosystem accounting. All other accounts use, directly or indirectly, information on land and ecosystem cover from this account in order to register the condition, ecosystem services flows in terms of generation/production and uses by beneficiaries, and the monetary valuation of ecosystem assets.

Evidently, the spatial units of the ecosystem account would be strongly linked to land cover, but would not necessarily be confined to land cover only if the analysis is undertaken at a high level of granularity. For instance, in the Netherlands, dunes and floodplains (areas annually flooded by rivers, as spatially identified by the winter dykes), may need to be distinguished as specific spatial units (irrespective of their land cover being sand, shrubs, forest and grasses) given the specific ecosystem characteristics (prone to flooding), the consequences of these dynamics for ecosystem services supply, their role in water management and flood control, and the major interest of policy makers in these specific units.

The Biodiversity Account. Biodiversity including ecosystem, species and genetic diversity is both important in terms of supporting the supply of various other ecosystem services, and as a (final) service in itself (Mace et al., 2010). Biodiversity would not show up, in a sufficiently comprehensive manner, in the other accounts (in particular the 'final service' element of biodiversity is missing). Therefore, a separate account would be needed for biodiversity in the framework of the SEEA EEA approach. The biodiversity account would need to present a flexible approach to record information on ecosystems that is relevant for conservation including such aspects as overall species richness or richness of key taxa, the presence of rare and endemic species, species important for ecosystem quality or functioning, habitat condition, etc. (Jones and Solomon 2013, Boykin et al. 2013). Flexibility in the biodiversity recording mechanisms is important for this account given the large variation in ecosystems, in data availability and in policy issues world-wide. At least for the time being, the Biodiversity account would be expressed in physical units only as part of the condition of ecosystem assets with an opening and closing stock. In view of the need to select indicators that are measurable, easy to communicate, and for which there is a high likelihood that data are available, a potential option is to relate the biodiversity account to, in particular, the presence or abundance of iconic species, which may also reflect habitat conditions. However, the specific indicators would need to be selected as per the policy information needs and ecology of the country involved.

Carbon Account. See the SEEA-EEA guidelines. Basically, the carbon account records stocks of carbon and changes in these stocks (as opposed to the Ecosystem Services Supply account which records the ecosystem service 'carbon sequestration' in ecosystems). A spatially explicit approach may or may not be pursued depending upon country interests and resources.

Water Account. Basically, the water account records stocks of water and changes in these stocks (as opposed to the Ecosystem Services Supply account/table which records the various services provided by ecosystems in terms of regulating water flows in the watershed and providing water from ecosystem resources (SEEA-EEA guidelines). A spatially explicit approach to water accounting may or may not be pursued depending upon country interests and resources.

Note: the full suite of ecosystem accounts, including potentially additional accounts that would facilitate linking ecosystem accounts to the national accounts, are currently still under development by UNSD and partners.

3. Conceptualizing the capacity account

Capacity could be defined for individual ecosystem services, as follows: '*The ability of the ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum yield or use level that does not negatively affect the future supply of the same or other ecosystem services*'. In other words, the capacity of the ecosystem to generate an ecosystem service is the maximum yield or use level that would not lead to a reduction of the ecosystem's ability to supply the overall basket of ecosystem services currently generated by the ecosystem. In general, using ecosystem services at a level above the capacity would lead to a degradation of the ecosystem, as reflected in the various ecosystem condition indicators. The definition and clarification above is aligned with the SEEA EEA framework (para 4.1, 2.36, 2.37, 2.96, 4.24 and 4.25).

Crucially, this definition of capacity (for, say, timber) implies that the maximum yield would not lead to degradation of the ecosystem's capacity to supply the service involved (timber) as well as its capacity to supply all other services currently provided by the ecosystem (say carbon sequestration, recreation, nature conservation), whether or not these services are considered by an account. Given that any removal of materials from an ecosystem is likely to affect ecosystem processes, composition and/or ecosystem functioning in one way or the other, it is proposed that a crucial qualification of this definition is that with degradation is meant 'a sustained, significant decline in ecosystem condition affecting the supply of ecosystem services' at a time frame of, say, several years or more. Hence, use of an ecosystem that would lead to disturbances that the ecosystem fully recovers from within a few years would not be considered to lead to ecosystem degradation and would therefore not be considered to 'negatively affect the future supply of the same or other ecosystem services' qualification of the definition of capacity.

'Current ecosystem conditions' implies that the capacity is measured for the ecosystem 'as it is', i.e. irrespective of the possibility that sustainable use at a higher extraction rate may be possible under different management regimes or with for instance a different species composition in the ecosystem. 'Under current uses' implies that capacity considers the type of use or management regime currently in place for the ecosystem (which would also reflect a specific basket of ecosystem services). It may be, for instance, that extraction of timber is not possible because the forest stands are on steep slopes, in remote and inaccessible areas, or in a natural park where logging is not allowed. In cases where it cannot be expected that the ecosystem service 'timber harvesting' can be realized for any of the above, or for other reasons, the capacity needs to be assumed to be lower in view of these restriction on use, and could also be zero. The capacity to sustainably generate ecosystem services independent of these restrictions, and irrespective of potential impacts on the supply of other ecosystem services, is labelled the '*capability*'.

Note that capacity and capability may change over time (from one ecosystem accounting period to the next) due to changes in ecosystem condition. Degradation involves changes in ecosystem condition due to human activity with a sustained and significant effect on the capacity to generate one or more ecosystem services. Note that natural causes (e.g. storm damage) may also lead to changes in capacity, and that most ecosystems will normally be subject to changes in capacity over time due to natural variability (e.g. rainfall variability in dryland ecosystems) or due to ecological processes (e.g. succession).

For provisioning services, the capacity of an ecosystem to generate a provisioning service would normally depend upon the (re)growth of the service producing asset involved (e.g. timber or fish) – with (re)growth in itself usually a function of among others stock (in relation to carrying capacity) and ecosystem condition. Regrowth may also be affected by other natural and human factors that lead to increases or losses in the stock (e.g. fire or storm damage to the timber stock, ocean pollution impacts on fisheries). For provisioning services, the actual ecosystem service flow may be lower, equal to or higher than the capacity (in the latter case the ecosystem can be expected to be subject to degradation). Note that the capacity can only be higher than the flow in cases where an increase in the use of an ecosystem service (compared to actual harvest levels) does not lead to a sustained, significant decline in the availability of other ecosystem services. In practice, it may not often be the case that the extraction rate of an ecosystem service can be increased without significantly reducing the capacity of an ecosystem to generate other ecosystem services, in particular in case of intensively used ecosystems. Note that another qualification for capacity is that ecosystem use can reasonably be expected to take place, considering aspects such as access to the service and institutional and legal aspects regulating ecosystem use. The latter, for instance, would avoid showing a value for capacity to support timber harvesting in a natural park, which is likely to be undesirable in many policy contexts. The ability of the ecosystem to generate provisioning services at a maximum sustainable level, irrespective of the implications for other ecosystem services and irrespective of potential legal, institutional, economic or other restrictions that constrain or prevent human uses of ecosystem services is labelled the 'capability' to generate these services.

In case of degradation (due to human intervention) (flow>capacity), the future flow of services would decrease and the NPV of the expected future flow can be either lower or higher than the NPV of the flow associated with capacity – depending upon the discount rate and depletion rate. In this case, data and models allowing, a country could opt to include both aspects in the asset account (i.e. both the NPV of the capacity and the NPV of the expected flow of services). This is illustrated in Table 2 below.

Regulating services are usually a result of ecosystem processes and functioning and for these services capacity equals flow. In addition, capability can be defined, which reflects the functioning of the ecosystem and the potential supply of benefits, independent of any human use of the ecosystem service. The SEEA EEA (see para 4.80) is clear that capacity and flow occur if there are people benefiting from this service (for instance because there are people living in the zone where flood risks are reduced due to ecosystem functioning; or if there are people living in an area where air is filtered by vegetation[2]). This has been tested, for example, in (Schröter et al., 2014; Bagstad et al., 2014; Villa et al., 2014). As for the regulating services, only in case of carbon sequestration, capability equals capacity equals flow by definition (cf Schröter et al., 2014) since all carbon sequestration, independently of where it takes place, can be considered a service to people (i.e., providing greater global climate stability). For all other (non-global) regulating services, people may or may not benefit from the service depending upon spatial proximity and other factors. Note that valuing capability, in the case of regulating services, is problematic since capability is expressed independent of human use, and attaching a value to the part of capability not used by people is at the least very difficult and may in other cases be non-sensical (as in the case of flood control by forest in upper watersheds in Siberia where no-one is living).

For cultural services, capacity may be defined as the use level of cultural services that would not lead to declines in the condition of the ecosystem. Flow may exceed capacity, for instance, in the case of (i) overcrowding of tourists in a national park; or (ii) if the number of tourists or other activities related to cultural services is so high that it affects other ecosystem services generated by the park. There may also be degradation of areas outside natural parks that may negatively affect the parks, for instance due to water pollution in rivers entering the park from upstream activities or related to construction activities nearby parks. Defining capacity for recreational services or other cultural services is not straightforward and refining the concept of capacity for cultural services requires further work. The work of Bagstad et al. (2014) and Schröter et al. (2014) provide entry points to distinguish between capacity and flow of cultural services by analyzing a capacity independent of human use and relating flow to actual use of cultural services. The capability for cultural services reflects a broader conceptual interpretation of cultural services, basically the possibility for an ecosystem to accommodate tourism or other cultural services independent of current institutional, legal or other restrictions on ecosystem use, as in the case of tourism opportunities in areas now closed for tourism (e.g. wildlife refuges). It may not always be meaningful to determine capability for cultural services, in particular if it is unlikely that conditions restricting use of these services are unlikely to change.

The different concepts are explained in the Tables 1 and 2 below and an example is provided in Figure 1.

Table 1. Concepts and definitions

	Provisioning services	Regulating services	Cultural services
Flow	The amount of service actually extracted	The amount of service actually received by beneficiaries	The amount of service actually received by beneficiaries
Capacity	The ability of the ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum yield or use level that does not negatively affect the future supply of the same or other ecosystem services	The amount of service actually received by beneficiaries. In case of regulating services, capacity equals flow.	The ability of the ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum yield or use level that does not negatively affect the future supply of the same or other ecosystem services
Capability	Capacity to sustainably generate an ecosystem service under the current ecosystem conditions and uses, but with ecosystem use that would prioritize the sustainable supply of this specific ecosystem service (and that accepts a potential decline in the capacity to generate other ecosystem services) and regardless of institutional barriers to ecosystem use[2]. Corresponding to the Sustainable Yield. Note that capabilities for different ecosystem services may not be additive/compatible.	Capacity to generate a regulating service independent of use. This is the theoretical supply defined by Bagstad et al. (2014). Only for carbon sequestration capability equals capacity equals flow (Schröter et al., 2014).	Capacity to generate a cultural service independent of use. This is the theoretical supply defined by Bagstad et al. (2014). This may or may not be relevant for each specific cultural service, and requires further thinking.

[2] A key point of further discussion is if this qualification should be maintained. Capability would also be a relevant concept in case the institutional criterion would be maintained. In this case, for example, capability to harvest timber in a natural park where logging is not allowed would still be zero. Capability would be higher than capacity in this case because there would be no consideration of the effects of logging on other ecosystem services in defining capability to support timber logging.

Figure 1. Example of the different concepts for one service (timber harvesting)

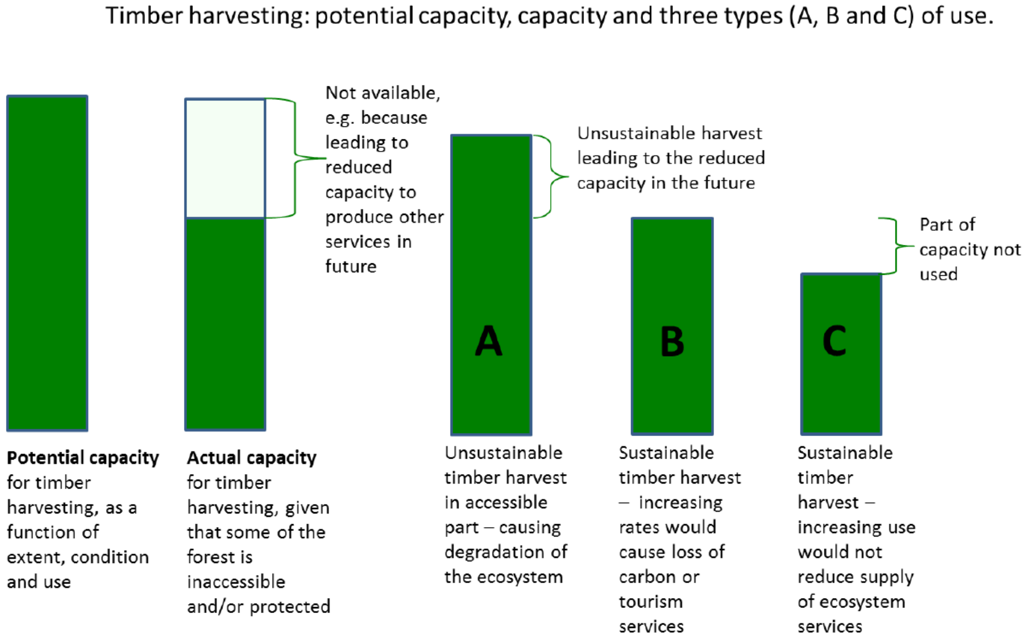

Table 2. Numerical example. Both the NPV of the expected flow and the NPV of flow associated with capacity are relevant in case of unsustainable harvest. The ecosystem accountant may select or include both of these monetary indicators in the asset account depending upon the information needs of the users of the accounts. Note: NPV sustainable management = NPV at capacity

	Variables	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10
provisioning	stock(tons) i.e. physical	100	95	89	81	71	59	44	25	1	0
	Sustainable Yield	25	24	22	20	18	15	11	6	0	0
	price per harvested ton	1	1	1	1	1	1	1	1	1	1
	SY revenue	25	24	22	20	18	15	11	6	0	0
	discount rate	0	0	0	0	0	0	0	0	0	0
	x	1	1	1	1	1	1	1	1	1	1
	actual harvest	30	30	30	30	30	30	30	30	1	0
	value provisioning service	30	30	30	30	30	30	30	30	1	0
recreation	maximum visits	20	19	18	16	14	12	9	5	0	0
	actual number of visits	17	15	13	11	8	6	3	1	0	0
	value of ES per visit	2	2	2	2	2	2	2	2	0	0
	SY revenue	40	38	36	32	28	24	17	10	0	0
	value recreation service	33	30	26	22	17	12	6	2	0	0
opening stock	NPV sustainable management	650	618	577	526	463	383	284	160	2	0
opening stock	NPV current mangement	272	235	199	162	127	93	60	30	1	0

In monetary terms, the capacity account for provisioning services could include the NPV of capacity rather than the NPV of the expected service flows. In that way, the account would look more consistent as both the physical account and the NPV would be based on capacity. However, the accounting guidelines could present the option of also including the NPV of the expected flow.

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