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An ecosystem typology for capacity accounts

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1. Introduction

One of the main objective of SEEA EEA is to provide relevant information on how economic activity and humans depend on ecosystem services and they may eventually reduce an ecosystem's capacity to continue generating ecosystem services. This kind of information differs from the traditional datasets that feed national accounts and the SEEA CF. It is not about (direct or estimated) measurement of quantities and amounts (mass); it is about ecological processes in many cases simulated by models that describe how ecosystem units provide flows of services. The SNA accounting structure remains the same in order to keep the linkage with the SNA and SEEA CF. However, some of its concepts need to be extended and changed. Otherwise, no consistent representation of the ecological-economic interaction can be provided. In this proposal, to considering ecosystem types as "producer units" in an enlarged production boundary perspective requires measuring the ecological delivery process before it interacts with economic sectors and households. The way this interaction takes place might affect the accounting mechanism that determines how to measure (and eventually represent) overuse and degradation.

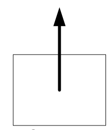
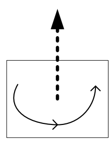
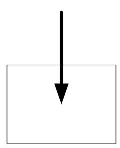
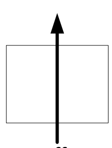
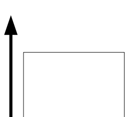
This mechanism can be explained through three steps: first, we frame ***the role of ecosystems in providing services***; second, depending on the role of ecosystems, we describe ***ecosystem services flows with an accounting perspective***; third, based on the typologies of ecosystem service flows, we show how the ***extended production boundaries*** would ***affect the current accounting frame***, especially when assessing capacity.

2. The role of ecosystems in providing services

Since current classification systems for ecosystem services (such as MA, TEEB, CICES, FEGS, NESCS) consider the purpose of the service, it may be useful to consider an additional aspect and thus to group ecosystem services according to the role of ecosystem types in providing the service. Therefore, all ecosystem services can be characterized according to different typologies of delivery or mediation of matter (more specifically, biomass, energy and information). We defined 5 types of ecosystem service potential according to the fate of energy, biomass or information which is produced, absorbed or mediated by ecosystems and which will determine in the last instance the actual flow of the service used (Table 1). This typology provides a framework for a consistent description of ecosystem services flows across disciplines, regardless the ecosystem service classification used. Table 1 provides an overview of how ecosystem service potential is transformed before becoming an actual flow that is used by people.

The process of changing from the potential flow to the actual flow implies an interaction with demand since the potential and actual service provision are two different things.

Table 1 - Typologies of ecosystem services potential

Role of the ecosystem	Fate of matter/energy/information	Description	Examples
 Source: productivity	Net delivery of biomass or energy eventually leaving the ecosystem	Ecosystems act as sources of matter and energy in the form of biomass. Reference with other classification systems: provisioning services.	Generation of mass and biomass
 Source: suitability	Delivery of biomass and energy generated within the ecosystem	Ecosystems act as sources of matter and energy by providing suitable habitats. Reference with other classification systems: regulating services (CICES), supporting services (MA), habitat services (TEEB)	Habitat maintenance, pollination, pest control and diseases control
 Sink	Matter or energy absorbed by the ecosystem	Ecosystems act as sink to store, immobilize or absorb matter. Reference with other classification systems: regulating services (CICES and TEEB), supporting services (MA).	Absorbing pollutants, carbon, nutrients, heat assimilation
 Buffer	Matter or energy flowing through the ecosystem	Ecosystems act as a transformer changing the magnitude of flows of matter or energy. Reference with other classification systems: regulating services.	Water retention, flood control
 Information	Information delivered by the ecosystem	Ecosystems deliver information The information generated does not modify the original state of the ecosystem. Reference with other classification systems: cultural services.	Scenic view, outdoor recreation activities, scientific investigation

Legend: squares represent an ecosystem unit and arrow represent the type of matter/energy/information delivered

Based on the five types of ecosystem flows, we frame ecosystem types as 'institutional units'. In fact, production in the SNA excludes natural processes so by considering the role of ecosystems in delivering services, we aim at assessing production and consumption activities together with their changes in regeneration and absorption rates. Changes in regeneration and absorption rates for some typologies of ecosystem services play indeed a role because their current use (recorded in SEEA EEA) may differ from their sustainable use. The typology shown in Table 1 will now be further explored.

3. Ecosystem services flows with an accounting perspective

In the SEEA CF, physical supply and use tables (SUTs) include the environment as an additional column alongside enterprises represented as industries, households, and the rest of the world. Environment is not considered an additional type of unit akin to economic units. In contrast, the environment is considered a "passive" provider of inputs to the economy and a "passive" recipient of residuals from the economy. An "integrated" accounting system for ecosystems and their services would offer the opportunity to attribute an "active" role to the environment instead of a passive role. The SEEA EEA starts promoting the active role of ecosystems and opens up to further important extensions (ref. Annex 6A of SEEA EEA). We aim to consider ecosystem types as an institutional unit in the same way it happens for economic units, i.e. we record natural processes in terms of production and consumption and by recording changes that occur in the processing ability. This implies an extension of the production boundary that would include not only industries and households but also the ecosystem units. The opportunity of operating conceptual variations is offered by using "external satellite accounts". An important advantage of considering ecosystem types as accounting units in SUTs, is the introduction, in the supply table, of information about what ecosystem types are able to offer independently of how much of it will be used. The ecosystem ability[1] to generate services (irrespective of the demand) is what we call here ***ecosystem service potential*** (or in short **<u>ES potential</u>**). ***An actual flow of ecosystem service*** (in short, **<u>actual flow</u>**) is generated when the ES potential interacts with the ***ecosystem services demand*** (in short, **<u>ES demand</u>**) and leads to actual use. If there is no interaction with ES demand, there is no actual flow. The actual flow represents the transaction that takes place between ecosystem types and economic sectors and households and is reported in official SUTs. The notion of ES potential does not fit all ecosystem services. There are ecosystem services where regeneration rate (source-provision services in Table 1) and

[1] This is what it is usually quantified in ecosystem service assessment with dimensionless indicators (from high to low ecosystem ability).

absorption rate (sink services in Table 1) may be affected by excessive use. In order to measure and account for this, we introduce the concept of ***ecosystem services potential flow*** (in short, **ES potential flow**) as the maximum flow of services that the ecosystem type can provide while ensuring its provision through time. Defined as such, the difference between the ES potential flow and the actual flow provides an indication of the extent to which the service is being used (un) sustainably. In the accounting format, the potential flow can be reported as complementary information that will not affect the accounting identity between supply and use of actual flow in official tables; the difference between potential and actual flow can be reported as additional mismatch account. For the ecosystem services belonging to source-productivity and sink types, it is possible to determine a sustainability threshold by considering the ecosystem type's regeneration and the absorption rates. In turn, this sustainability threshold determines the amount of ES potential flow. The overuse of the service occurs when the actual flow is higher than the potential flow and can cause degradation, i.e. decreasing the ecosystem capacity to provide the service (Figure 1a): the demand would be met at the expense of ES potential flow. Although the link between overuse and degradation is neither direct nor linear in time and space, it is important to measure and record this difference as it represents degradation over time in ecological terms, and depreciation of ecosystem asset in accounting terms. Source-suitability, buffer and information types (ref. Table 1) requires the ES potential and not the ES potential flow: the actual flow can never be higher than the ES potential delivered by the ecosystem type (Figure 1b and 1c). What determines the amount of the ES potential are the initial conditions of the ecosystem type (normally related to land cover and land use). For these services the ecosystem service potential becomes a flow only when interacts directly with the ES demand and thus generates the actual flow (Figure 1b and 1c).

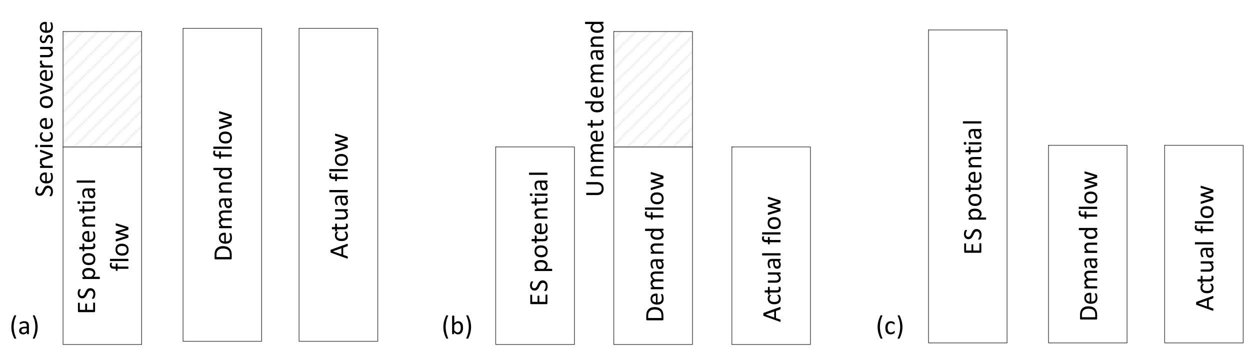


Figure 1 – Groups of ecosystem services according to the differences in the potential and actual flow (a) Demand exceeds the ES potential flow and services is overused, (b) Demand exceeds the ES potential but services cannot be overused, (c) ES potential exceeds demand.

The ES demand for the service can be higher than the ES potential available, and in this case we can record an unmet demand (Figure 1 (b)). For example, the protection against the risk of flooding (buffer type) depends on the planning and management practices of the territory, the ES potential is set by the initial conditions of the accounting period. The actual flow will not influence the initial condition and will not alter them. If human settlements are not protected against the risk of flooding, there will be an unmet demand. The human settlements demanded more buffer capacity from the ecosystem type than the ecosystem type could actually deliver due to its initial conditions. It can happen that ES potential is higher than ES demand (Figure 1c). ***Spatially explicit information is crucial*** to identify whether met and unmet demands occur and where they are located.

4. Extended production boundaries affect the current accounting frame

From the previous section we describe that: (i) for source-productivity and sink services a potential flow can be calculated once a sustainability threshold (referring to regeneration and absorption rates) is established and that the actual use could be higher, equal or lower than the potential flow; (ii) for source-suitability, buffer and information services the ES potential can be assessed and that the actual use could be equal or lower than the potential, but not higher. The former typology of services requires additional information to be added to the accounting tables. The supply and use tables contain the item "accumulation": in economic accounts this item is related to the formation of fixed capital and the changes in inventories. Consumption of fixed capital, or depreciation, is the decline in the current value of the stock of fixed assets as a result of physical deterioration such as wear and tear and obsolescence (ref. section 6.240 in (European Communities et al., 2009)). That implies that there is room in a full accounting system to record positive and negative changes affecting the ability of ecosystem types to provide flows of (individual) ecosystem services. For source-productivity and sink services, the threshold (set according to ecological [and policy] criteria) will allow to calculate the ES potential flow. We should always keep in mind that we deal with flows of ecological processes not with flows of material assets: the notion of "depreciation" is meant to translate in accounting terms the concept of ecological degradation due to unsustainable human practices. Being the ecosystem capacity "the ability of an 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" (ref. SEEA EEA Glossary[2]), it is possible to establish a connection between ecosystem service supply and use tables

[2] Ref. https://unstats.un.org/wiki/pages/viewpage.action?pageId=33292323

and capacity. In the SEEA-EEA, a single ecosystem asset can provide a variety of services, e.g. forest provide not only wood biomass but also carbon sequestration, flood protection, erosion control, soil decontamination, outdoor recreation and pollination. Capacity is commonly defined as the long-term ability of different ecosystem types to provide different ecosystem services. In order to account for capacity we should thus focus on individual ecosystem services (SEEA EEA TR., 2017) rather than ecosystem assets because on the one hand different ecosystem types can provide (all together) a single service, and on the other hand the a single ecosystem type can provide several ecosystem services.

In the SEEA EEA TR (2017) ecosystem capacity is recognized as central in establishing the connection between ecosystem assets and ecosystem flows, even though the nature of this connection is still not clearly articulated. The SEEA-EEA guidelines suggest to calculate capacity as the Net Present Value (NPV) of the annual flow of the ecosystem services. The NPV is the value at present of what will be provided today and for the years to come (lifetime). The NPV approximates, in monetary terms, the long-term ability of ecosystem assets to provide each individual ecosystem service, which can be considered as a "stock" (Figure 2). The term "stock" is here used just to highlight how, in this case, capacity (as NVP per ecosystem service) is not a synonym of asset.

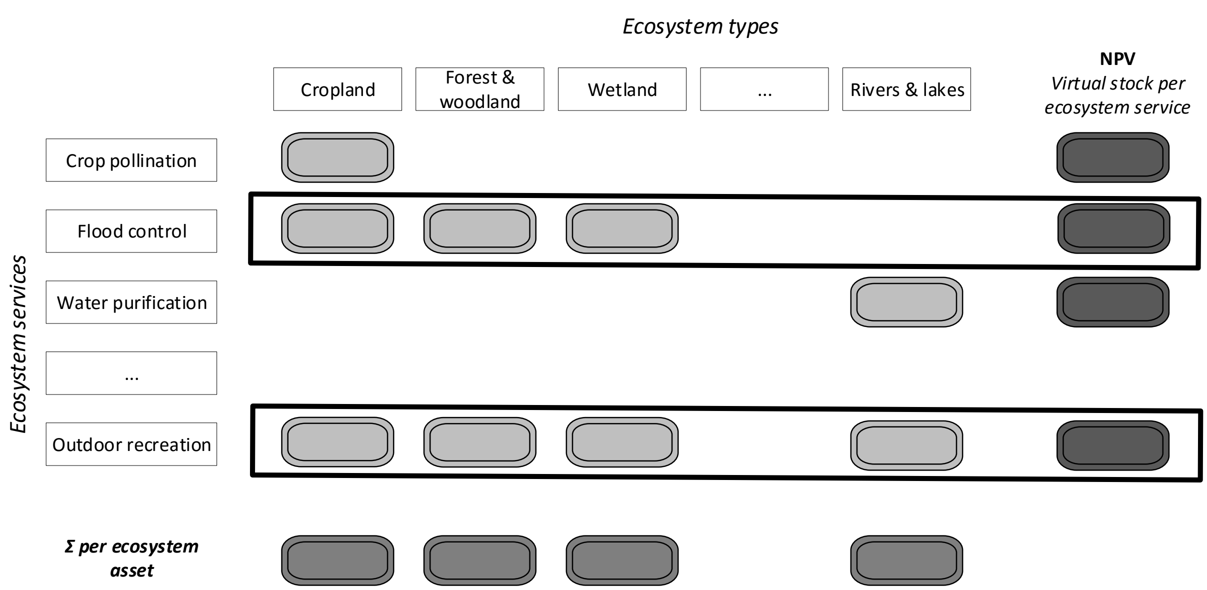


Figure 2 – Relationship between ecosystem types and ecosystem services in the supply table– capacity as virtual stock.

Figure 2 needs to be carefully interpreted: the last column describes the NPV for each specific ES, i.e. it is a function that depends on the ecosystem service flow expressed in monetary terms; while the last row is the sum of the annual flows of different ecosystem services per ecosystem type, expressed for the same spatial extent. The notion of ecosystem asset, which corresponds to each ecosystem type, is separated from the notion of capacity, which refers to individual ecosystem services. The latter is an unconventional "stock", meant to simplify the complexity embedded in ecosystem services measurement; which can only be measured in monetary terms. This stock can be called "virtual" because we deal with the ability to keep on generating an ecological process over time (expressed in monetary terms) and not with something that can be physically accumulated. Figure 3 shows that capacity at time t represents the opening stock of the 'long term available ecosystem service' in monetary terms. For source-productivity and sink services it is possible to calculate ES potential flow. If the actual flow of the service (the use) is equal or below the ES potential flow, then the capacity to provide the same (or enhanced) amount of ecosystem service is guaranteed. If the actual flow is higher than the ES potential flow, then a "mismatch accounts" would record overuse that (in the medium/long term) will eventually lead to degradation. The capacity to provide the ecosystem service for the following year should thus be calculated by using the ES potential flow. Actually, the capacity calculated using the actual flow in cases of overuse (unsustainable use) would be higher than the capacity calculated using the potential flow, which considers sustainability criteria when assessing the services delivered by the ecosystems. This latter application of capacity would neglect the foundation of ecosystem accounting: overuse of the service and the subsequent ecosystem degradation should in fact be reflected in a decline in capacity.

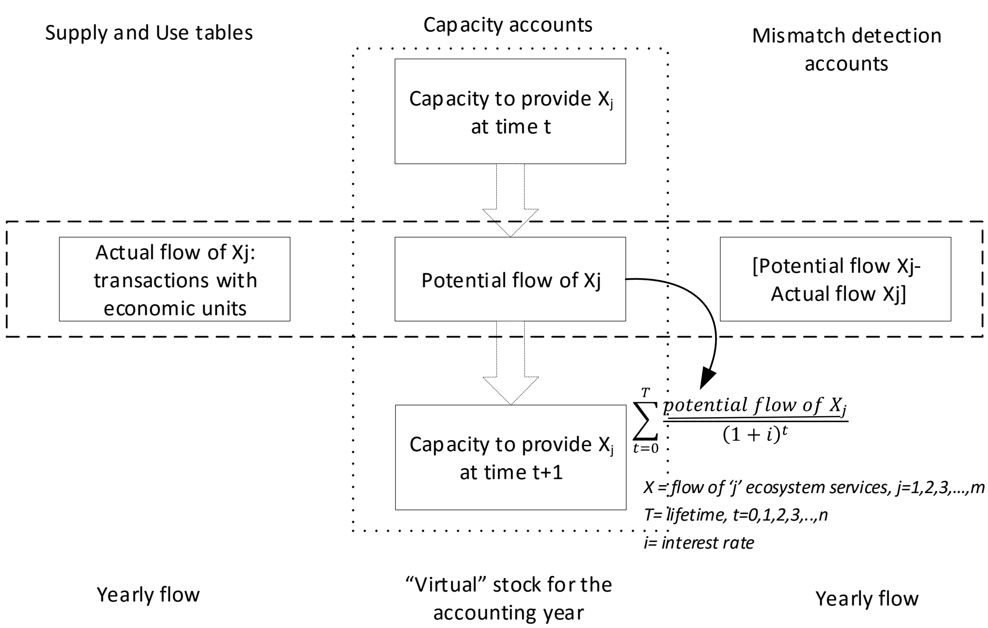


Figure 3 – Capacity as "virtual stock" account. This simplified visualization shows the linkage among capacity as NPV, supply and use tables and mismatch account.

The ES potential flow shown in Figure 3 is not going to be part of the conventional supply and use tables, which will only report the actual flow (i.e. transaction with economic actors). ES potential flows can be used to fill in complementary tables for all those ecosystem services characterized by regeneration and absorption rates, such as provisioning services or sink-related services. However, when there is a mismatch between potential and actual flow, this difference needs to be measured and future capacity (opening stock at time 1) should be calculated from the potential flow.

5. Summary and conclusion

Although it is important to always highlight the correspondence between the biophysical and monetary dimensions, when dealing with capacity specifically in this section, we explicitly choose to follow the guidelines of SEEA EEA TR and thus consider how capacity can be monetized on the basis of the NPV (ref. chapter 7, UN. 2017). In the SEEA EEA (UN et al. 2014, UN et al. 2017) the reference is made to “ecosystem asset” through an “expected basket of ecosystem services” and the NPV is calculated collectively; we here explicitly disaggregate the basket into individual flows of ecosystem services and calculate the NPV of each of them. For source-suitability, buffer and information services the NPV can be calculated from the actual flow as currently suggested in the SEEA EEA. ***For source-productivity and sink services, the asset account for the institutional sectors ‘ecosystem types’ needs to be accounted differently: interaction with economic sectors and households may generate overuse of the yearly flow of the service (actual flow recorded in SUTs). This overuse could undermine the ability of ecosystem types to provide the same amount of service flow for future accounting periods***. In this case, the NPV should consider whether a difference between the potential and actual flow occurs. In an extended production boundary accounting for the potential flow provided by ecosystem types modifies the capacity assessment, where capacity is intended as the critical ecological functioning basis needed to sustain that yearly flow. We should keep in mind that in this context accounting is not about mass that can be accumulated and added up but rather about processes affected by current use or by changes in initial conditions.

The difference with the current approach in SEEA EEA is the modified procedure adopted when dealing with source-provision and sink services (ref. Table 1) compared to source-suitability, buffer and information services (ref. Table 1). To account for the NPV of individual ecosystem services does not contrast with the ideal “basket of expected ecosystem services”. When a representative number of ecosystem services are assessed and valued the sum per ecosystem type can be performed as yearly flow or as NPV (Figure 2).

Reference material

La Notte A., Vallecillo S., Marques A., Maes J. (under review) Beyond the economic boundaries to account for ecosystem services [can provide draft on request]

Vallecillo S., La Notte A., Polce C., Zulian G., Ferrini S., Maes J. (2018) Ecosystem services accounting: Part I - Outdoor recreation and crop pollination, EUR 29024 EN; Publications Office of the European Union, Luxembourg.

Questions for the London Group

1. Do you agree with the proposed set of ecosystem services typologies? Suggestions/modifications?
2. Do you think it is useful to distinguish between ES potential and ES potential flow?
3. Do you think that for source-productivity and sink services it is correct to calculate capacity as NPV of ES potential flow?
