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Background paper
Session 3c: Ecosystem services

Towards defining ecosystem services for SEEA EEA
position paper

Prepared by: SEEA EEA Revision Working Group 3 on ecosystem services (led by Lars Hein, Wageningen University, the Netherlands)

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Position Paper

Towards defining ecosystem services for SEEA EEA

6 June 2019

Lead author: Lars Hein (Wageningen University)

Contributing authors: Alessandra La Notte (JRC EU), Benjamin Burkhard (Leibniz Universität Hannover), Anthony Dvarskas (Stony Brook University), Charles Rhodes, Jan-Erik Petersen (EEA EU), Roy Haines-Young (Nottingham University), and UNSD staff

Disclaimer. In this draft, the authors have attempted to properly understand all individual ecosystem services papers presented at the January 2019 meeting in New York to the best of their abilities. It may nevertheless be that there are misunderstandings or misrepresentations of the text as prepared by the authors of the New York papers. In no case has this been done intentionally. All mistakes made in interpreting the papers are solely the responsibilities of the authors of this paper, and in no way does this paper attempt to question the validity of the reasoning of the papers. This paper is meant to further contribute to the discussions on defining ecosystem services: by identifying potential areas of interest for further discussion, and by providing some very first reflections on these topics.

Note on the revised paper

This paper presents a review of the individual ecosystem services papers discussed in January 2019 in the SEEA revision meeting in New York, following the review of a draft paper by UNSD and a set of experts. Compared to the first draft, two new, key parts of the paper are:

1. A synthesis of main issues across the individual ecosystem services: Section 2

2. A preliminary set up of the workshop including questions to be discussed in June 2019: Annex 3

Both these new sections are meant to inform and support the discussions in the planned June 2019 SEEA EEA revision meeting in Glen Cove, and form critical parts of this report. The reader who has no time to read the entire report could consider focusing on these two sections.

Contents

1. Introduction

1.1 Background

In the context of the SEEA revision there is a need to come to a better, shared understanding of how to define ecosystem services for SEEA, building on earlier studies and work that have developed classification systems for ecosystem services. This requires a process engaging groups of experts and stakeholders, involving a range of papers, workshops and reflections. In the context of this process, which is managed by UNSD, this paper provides a synthesis and review of the current state of thinking on defining ecosystem services for SEEA. Specifically, the paper presents a review and synthesis of 11 papers presented at the UNSD expert forum on ecosystem services analysis for SEEA EEA (22 to 24 January 2019). Each of these papers presents a logic chain and description of one or a few related ecosystem services.

1.2 Objectives of the paper

The paper aims to support the June 2019 SEEA Technical Expert Meeting (in Glen Cove) by synthesizing and reviewing insights and thoughts harnessed on defining ecosystem services for SEEA EEA to date, and by discussing selected themes relevant for the development of a systematic definition and typology of ecosystem services for SEEA. The purpose of the paper is to reflect upon the outcomes of the individual ecosystem services papers, to assess the papers with a view of eventually reaching a set of ecosystem services definitions that is internally consistent, and to identify issues and options for further discussion and clarification. The paper does not attempt to provide a classification or typology for ecosystem services, which may potentially be informed by a clear definition of key ecosystem services for SEEA.

It needs to be noted that the individual papers presented in the January 2019 meeting offer a wealth of other information (e.g. on modelling and valuation) that is not considered in this review/synthesis paper that focuses on trying to make progress towards defining ecosystem services. Clearly, these individual papers have substantial value that goes beyond the aspects in these papers that are covered in this current paper.

1.3 Structure

Section 2 presents a synthesis of the review of the individual ecosystem services papers. Section 3 to 12 of this paper presents the review of logical chains of individual ecosystem services developed to date, including 11 groups of ecosystem services as listed in Annex 1. Section 13 concludes and Annex 2 presents the cross-cutting issues discussed in a separate paper, and not analyzed in detail in this current paper. Annex 3 presents recommendations for the set-up of the section on ecosystem services definition for the June 2019 technical expert meeting.

1.4. Approach followed in the synthesis and review

The paper builds upon the individual papers presented at the January SEEA Technical Expert Meeting, the SEEA EEA framework and Technical Recommendations, the work undertaken for CICES and NESCS, several other papers prepared in support of the SEEA revision process, as well as the scientific literature and SEEA accounts produced to date.

The following criteria were used to assess the individual logic chains, based on earlier discussions and papers presenting the requirements of a consistent definition of ES for SEEA.

However it needs to be noted that this list of assessment criteria is provisional, and during the workshop in June or in the discussions leading up to that workshop criteria may be modified, or additional criteria may be formulated.

Criteria:

- Ecosystem services should be defined in a consistent manner – reflecting that ecosystem services are the contributions of ecosystems to human benefits. In this chapter, for each individual logic chain it is analyzed to what degree the definition aligns with the treatment of ecosystem services in the SEEA EEA Framework and Technical Recommendations. The definition of services should also be such that it allows a clear and consistent treatment of intermediate versus final services

- Ecosystem services should be defined in such a way that they are quantifiable, both in physical and monetary terms, either using data that is available in statistics, measurement and monitoring, data that can be derived from existing or newly developed (usually) spatially explicit models or earth observation programs not yet covered in national statistical programs.

- Ecosystem services need to be defined in such a way that they are relevant and understandable to users of SEEA accounts

For the service for which there are potential options for defining the logic chain, these options are compared using the four criteria specified above. In addition, questions for clarification for individual logic chains are presented, plus potential entry points for addressing these questions. Finally, the consistency between the approaches proposed in the logic chains is assessed, grouping provisioning, regulating and cultural services.

The work of LaNotte and others make a distinction between regulating and maintenance services. In regulating services, ecosystems act as a "sink" (to absorb or store matter) and as a "buffer" (to transform and change the magnitude of flows); while in maintenance services, ecosystems act as a "source" of matter and energy, by providing suitable habitats (La Notte et al. 2019). These two groups are not universally differentiated, and further discussion is needed to examine if these groups should be differentiated in SEEA EEA and if so if there are only two categories of regulating services or if other sub-sets should be added, and if there are indeed only two sets if it is helpful to rename the term regulating services as used in the SEEA EEA framework and SEEA EEA TR to 'regulating and maintenance services'. This topic is therefore included in the list of discussion topics for the Glen Cove meeting in June 2019.

2 Key issues

2.1 Generic logic chain

The basic logic of the SEEA EAA in analyzing ecosystem services is that ecosystems generate ecosystem services that contribute to, or directly lead to a benefit for people. Often, the service – representing a natural capital input is combined with produced capital (e.g. a saw), intermediate inputs (e.g. petrol) and labor in order to generate a human benefit (e.g. harvested timber). For provisioning services, the benefits are or can be readily included in the SNA. The ecosystem service is usually not recorded in the SNA. This starting point leads to the following generic logic chain:

Ecosystem asset -> service -> benefit (with ecosystem assets being part of the stock of natural capital, and services and benefits being flows that can be measured in a certain time scale, typically a year).

For provisioning services, the generic chain can usually be applied, although it is not always straightforward to define the ecosystem service, for instance in the case of the service 'contribution to agricultural production'. The definitions for individual services are elaborated, based on the positioning papers dealing with individual services, below. This section (2.1) describes two generic elements: (i) the establishment of logic chain for regulating services; and (ii) a synthesis of the key discussion points for individual services (summarized in table 1 below).

The establishment of a generic logic chain for regulating services. In the SEEA EEA, the generic logic chain is assumed to apply to both SNA benefits and non-SNA benefits. There is a crucial difference however that SNA benefits (products such as crops) are transacted and recorded in the national accounts, but non-SNA benefits are not. For regulating services, this raises the question, whether two transactions would need to be recorded in the ecosystem accounts (one for the service itself, and one for the benefit – similar to regular products), or whether the service = benefit for non-SNA benefits (i.e. by definition). Another option may be to reason that the service is conceptually different from the benefit, but that the benefit is only used to value the service (and hence need not be recorded as a separate transaction).

A review of the individual services papers shows that these papers tend to clarify that, in line with the assumptions of the SEEA EEA TR, from a physical perspective there is a distinction between service and benefit for regulating services. For instance, a forest captures particulate matter (air filtration service) and this leads to a benefit, in another location, where the exposure of people to air pollution is reduced. In the Netherlands accounts, the capture of pollutants is included in the biophysical ES supply and use account, and analyzing the reduced exposure is required to value the service, as is done in the monetary ES supply and use account. A spatial difference between the area where the service is generated and the area where the service is used also applies to many other regulating services (e.g. water filtration, erosion control). The individual papers, and the experiences in compiling ecosystem accounts both in the NLs and the UK indicate that there is a need to differentiate between service and benefit for regulating services as well. The ecosystem service can be included in the biophysical ES supply and use account, and the benefit (e.g. a health benefit resulting from reduced exposure) can be included in the monetary ES supply and use account.

A synthesis of the key generic discussion points for ecosystem services.

1. **Defining provisioning services**. It seems reasonable to look for a way to define provisioning services that is internally consistent. If this is pursued then a first main choice is between defining the ecosystem service as the actual contribution of the ecosystem or as a the harvested product. A second main choice is whether to differentiate between managed and natural ecosystems or not. The second option for defining service represents more clearly a flow indicator, but does in managed ecosystems not reflect that the service, if defined this way, is produced with capital and intermediate inputs and labor. Based on comments received on the draft positioning paper there seems to be a minor preference for taking harvested products as a proxy for the service, in both natural and managed ecosystems. An alternative is to take products as output in natural systems, and – for managed systems - to leave it to individual ecosystem account compilers to use output as a proxy or to derive indicators that more directly reflect the contribution of the ecosystem.

2. **Linking provisioning and intermediate services**. The SEEA EEA TR gives a specific definition of intermediate services. They are services generated in an ecosystem asset that support the functioning of and thereby the supply of ecosystem services in another asset. Hence, the regulation of water flows benefiting downstream water users located in other ecosystem assets is an intermediate service, soil formation that supports the supply of ecosystem services within the same ecosystem asset where the soil formation takes place is not. The latter could be called a supporting service, aligned with the Millennium Ecosystem Assessment. Adding intermediate services to final services would lead to double counting. They are, nevertheless, defined in the SEEA EEA TR because they are in some cases important for ecosystem management. For instance, forests in upper watersheds can regulate waterflows and reduce peakflow and increase baseflows in downstream areas. This service may have a positive impact by reducing flooding of infrastructure (a final service) and it may also reduce floods in another ecosystem thereby reducing the loss of ecosystem services from that second ecosystem. In the latter case, there is an intermediate service, i.e. a service from one ecosystem asset to the next. This is relevant because sometimes the intermediate regulating ecosystem services are important in the local context and ecosystem managers want to consider these. If there were no place for intermediate services in the accounts, the accounts would be of less value in terms of providing the knowledge base for managing the ecosystem. Clearly not all intermediate services can be included in an ecosystem account, only those intermediate service s of prime importance for ecosystem management should be included. The SEEA EEA TR explains how this can be done.

    a. A first question in June 2019 is if this treatment of intermediate services is well understood by all readers of the SEEA EEA TR, or if there are fundamental objections to this definition (and in the latter case what the alternatives would be).

    b. A second question is how to define pollination. Pollination occurs within or between ecosystem assets. In the case of pollination within ecosystem assets (e.g. pollinators residing in a forest pollinating fruits harvested in that forest) – there is no transaction from one ecosystem asset to the next. Hence there is no need to register this type of pollination in an account that specifies ecosystem services by asset type (it would lead to double counting). In this case the pollination service can be interpreted as a 'supporting service', in the terminology of the Millennium Ecosystem Assessment. Pollination services can also be supplied by one ecosystem asset to support crop production in another ecosystem asset. For instance by a hedgerow that acts as a habitat for insect pollinators, and in this case provides a service to another ecosystem, for instance an agricultural field with crops that need pollination. In this case the service can be seen as an intermediate service. However, the definition of the crop provisioning service (as indicated above) has ramifications for the exact definition of the pollination service. It is therefore proposed to discuss the definition of the pollination service and considering it to be an intermediate or a final service after the crop provisioning service has been defined.

3. **Water purification versus water provisioning and a comparison of the logic chain for water and air filtration.** Water is, on the one hand, a resource that is extracted from an ecosystem, and on the other hand, the ecosystem enables the extraction of water of a certain quality by purifying water. Even though these are separate services, there can at times be a certain overlap and it is important to clarify this. The authors of the three papers on these ecosystem services (discussed in sections 7, 9 and 10 of this paper) have all defined a scope for the specific service. Comparing the scopes as defined in these papers it appears as if there is sufficient difference between them to consider them as separate ecosystem services. Water supply deals with extraction, flood control focusses on the regulation (of excess water) in quantitative terms of flooding patterns, and water purification relates to the ecological processes that lead to an enhanced quality of water in rivers, lakes, oceans and in the soil.

   A potential overlap is, nevertheless, between water extraction and water purification, especially since some extractive uses of water require water of certain quality. An interesting example is the water filtration system in the western part of the Netherlands, where water is piped from the main rivers to dune ecosystems, where it infiltrates and at a certain depth, the filtered water is pumped up again. Hence, the water is extracted from the river (a provisioning service) and filtered in the dunes (a regulating service). In this case it is possible to identify two distinct services, but further discussion on this topic is needed.

   Furthermore, water purification (indirectly) supports many other ecosystem services such as provisioning of fish and recreation. This could potentially be interpreted as an intermediate regulating service (if water purification leads to better water quality in other ecosystem assets) or a supporting service (if water purification leads to better water quality within the ecosystem asset in which it takes place). In addition, water purification is important for biodiversity, and contributes to the aesthetic values of an ecosystem. Further discussion of these linkages, and in particular the relation with biodiversity could be put on the agenda of the June 2019 meeting.

   An interesting difference occurs in the logic chain for water and for air filtration. In the water filtration logic chain (section 7), the service and benefit are related to the possibility for pollutants to discharge pollution. In the air filtration logic chain, the benefit is related to people breathing air being exposed to lower pollutant concentrations. In both cases, polluters benefit from dilution (which has not much no do with the ecosystem's functioning, even if a river ecosystem is dead it can be used to dispose pollutants) as well as from cleaning (e.g. denitrification in rivers, filtering of particulate matter in vegetation). In both cases, users of water and air benefit from the water being available in a cleaner state compared to a situation without dilution and cleaning. Hence, it seems reasonable to assume that a similar logic chain could be provided for both types of services, yet the proposed approach to quantify the service and the logic chains (section 6 and 7) are quite different. Note that there are important implications related to the selected approach, in one case the service comprises a benefit for producers, in the other a benefit for consumers. The selection may also be context driven: in case polluters are not constrained by any emissions regulation it may well that the possibility to release pollutants is a major benefit to them. Where such regulations exist, they need to comply with these regulations and treat the water before disposing it, perhaps diminishing the value of the service for them. Clearly, even if all polluters (to air and water) are compliant there is still residual air and water pollution in many environments. Households benefit from the purification of this residual pollution by ecosystems. Potentially, therefore, a consumers based perspective is more aligned with the reality that regulations drive the release of pollutants. Another advantage of this approach is that the filtration depends upon the condition (health) of the ecosystem: in a dead river or forest there is only very little purification remaining, making this approach more clearly an ecosystem service. Give the implications for mapping and modeling water purification as discussed in January 2019 this needs further discussion in June 2019.

4. **Other issues**. For various cross-cutting issues (such as dealing with sink services), a specific position paper has been prepared to support the June 2019 discussions in Glen Cove. Annex 2 presents the various topics in this position paper.

2.2 Demand, potential supply, capacity, actual supply and use: concepts and terminology

Some somewhat different concepts are used in relation to defining ecosystem services both in the literature and in the discussions in the SEEA revision to date.

In the SEEA EEA TR, supply (by the ecosystem) equals use (in the economy), by definition. Demand may be higher, but it is not attempted to quantify demand. Note that in economics it is assumed that demand can be specified with a demand curve, i.e. demand (as well as supply) varies are a function of price. In the recent publications of JRC in the context of KIP INCA, building upon earlier work published in particular in the EU, a slightly different conceptualization is followed. In this approach : "the actual flow is determined by the demand of ecosystem services by the socio-economic system and importantly, by the spatial relationship between the areas providing the service (Service Providing Areas, SPA) and the areas demanding it (Service Demanding Areas, SDA)" (Vallecillo et al., 2019). Indeed, this second approach clarifies that the area where the service is generated (e.g. the forest filtering air) is not the same as the area where the benefit is enjoyed (e.g. a nearby village where ambient air pollution levels are reduced). An issue with the terminology of Vallecillo et al. (2019) is that it is assumed that demand can be divided into a quantifiable 'met' and 'unmet' demand. However, the basic premise of micro-economics is that demand cannot be quantified in this way. Demand is a function of price (as is supply). Actual demand can be observed, but unmet demand will always be a function of the price at which that unmet demand can be supplied. Hence, the notion of a fixed, quantifiable unmet demand independent of price is not tenable. However, the notion that there is a spatial relation, in particular for regulating services, where the service is 'produced' by the ecosystem and where it is used by the economy is very important. The SEEA EA TR allows (as shown in the UK and NLs SEEA EEA accounts) covering this spatial relationship without the need to quantify a total (met + unmet) demand for ecosystem services.

A further difference pertains to the concepts of potential ecosystem services supply and capacity to supply ecosystem services. In the SEEA EEA TR this concept is treated building upon Hein et al. (2016), where capacity is defined as 'The ability of an ecosystem to generate a service under current ecosystem condition and uses, at the highest yield or use level that does not negatively affect the future supply of the same or other ecosystem services from that ecosystem.' 'Current ecosystem condition’ means that the capacity is measured for an ecosystem as it is now,’ i.e., not in relation to what its condition might be under alternative situations. ‘Under current uses’ means that capacity considers the type of use or management regime currently in place for an ecosystem, which would also reflect the supply of a specific basket of ecosystem services.

Vallecillo et al. (2019) specify : “The ecosystem's capacity to generate services (irrespective of the demand) is what we call ES potential.”. It is not specified in the JRC report is potential implies a sustainable supply, and it would be helpful to discuss this in June 2019. If it is, then there is a large degree of overlap between the term potential supply by JRC and the term capacity in the SEEA EEA TR. If potential is not assumed to represent sustainable supply then it would be helpful to discuss how potential supply is constrained (e.g. is it cutting all wood in a forest? the mean annual increment? The commercially harvestable species? Are harvest costs and timber price levels considered in establishing the potential supply or is it based upon physical indicators only?

However, beyond the terminology there is another difference in the conceptualization of capacity (by Hein et al. in part followed on in the SEEA EEA TR) and potential supply (by JRC). The paper by Hein et al. also indicates that capacity is a function of there being a demand for the service. Capacity is assumed to be zero if there is no demand for the service (as in flood regulation in uninhabited parts of Siberia. With potential supply the idea is that it also occurs if there is no demand for the service. This is another aspect that merits further discussion.

3 Terrestrial biomass provisioning services

Paper authors: Lars Hein, Jane Turpie, Silvia Cerilli, Gem Castillo

3.1 Synthesis and review

Critical to the depiction of the logic chain for this group of services (see below) is that the ecosystem asset generating the ecosystem services exists on a continuum of naturalness (from largely natural to fully modified by people) which will affect the measurement of ecosystem services. A key question then is whether the degree of naturalness of the ecosystem asset affects the description of the ecosystem service itself, rather than only the quantification of the flow. Related to this is the question what this means for defining the service. In accounting efforts to date, as well as in the global ecosystem services assessment (TEEB, MA, IPBES) two options have been followed: (i) defining the service sensu strictu as the ecological contribution of ecosystems to crop production (reflecting e.g. earth worm activity, nutrient storage and release in soils, and a great deal of other processes); or (ii) defining the service as the harvested or harvestable crop biomass itself, while recognising that this is the result of both the ecosystem and the way it is managed (by the farmer, with produced and often with financial capital). A parallel here is that in many cases if not all the output of the system is a function of both the natural processes occurring in the ecosystem and the way the ecosystem is managed. However, in the case of some farming systems (as in intensive aquaculture systems) the importance of managed processes compared to natural processes is relatively large. The figure presented in the paper, and reproduced below is closer to the second position, but it needs to be recognized that this issue this is still open for discussion.

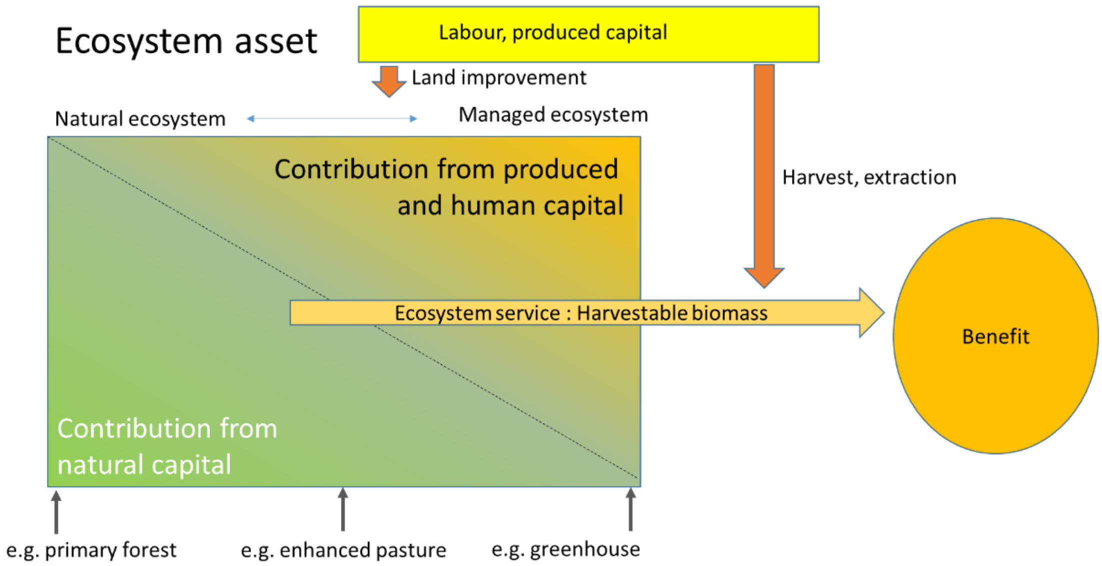


Figure 1. defining the crop provisioning service.

3.2 Questions and options

The main challenge for this service is to identify the entry point (agricultural biomass, as in Figure 1, or ecological contribution) and subsequently to develop measurable and meaningful indicators for measuring terrestrial crop production in physical terms, or the ecological contributions in relevant physical terms.

Measuring the harvested or harvestable biomass is relatively straightforward, as is discussed below. Much more complex is measuring the contribution of the ecosystem. In order to quantify the service in case an approach is used based on assessing the ecological contributions to crop provisioning, often an approach is considered based on soil quality. There are several dozen ecological processes (e.g. earth worm activity) and properties (e.g. soil quality) that influence the suitability of land for crop production, which in turn depends upon climate, land preparation carried out by the farmer (e.g. levelling of undulating terrain, etc.), and ultimately magnitude of yield also depends upon how well the farmer is using these resources. Of these processes, soil conditions (incl. soil type and texture, structure, fertility, nutrient content, soil biodiversity) are clearly linked to the ecological properties of the ecosystem (e.g. vegetation cover, topography, structures). An example of a comprehensive effort to assess the suitability of land is the qualitative German "Müncheberg soil quality rating" MSQR However, it needs to be noted that soil condition indicators will vary considerably between different agro-ecological zones, and that hence if this approach is followed, also countries with few data on agricultural soils would need to develop such indicators and monitoring systems. Also, not in all agro-ecological zones, soil is the strongest predictor for the ecosystem's potential to support farming. In dry areas, water availability may be the limiting factor; in cold areas temperature, etc. In all cases, defining an aggregated indicator properly reflecting agricultural potential is not straightforward, and quite different approaches need to be followed for individual countries and often also within countries.

An alternative (option 2) is to define this service in physical terms as the amount of products resulting from agricultural land. A key issue is that this reflects the benefits rather than the ecosystem service. Clearly, crops are produced with ecological capital as one of the inputs in addition to labour, energy, fertilisers, herbicides, pesticides, knowledge, irrigation water, seeds, intermediate inputs (e.g. fuel for the tractor) and machinery.

This option could lead to misleading messages: in fact, high production can depend on intensive farm management inputs, where the ecosystem contribution is lower compared to extensive farming. To assess ecosystem contribution and separate it from human input can help to overcome this problem, as shown in Vallecillo et al. (2019), but is not trivial in practice.

A potentially relevant consideration pertains to obtaining consistency between provisioning services. Although the SEEA may choose to follow different approaches for different services, it is relevant to consider this consistency at this point in the assessment of options. In this context, the ecosystem service 'provisioning of timber' (i.e. the amount of standing timber that is harvested, quantified in terms of volume and quality just prior to the actual harvest) also takes the physical output as the indicator for the service, rather than the various processes that lead to biomass production, at least in natural forests. However, a distinction may be made between natural and managed ecosystems. In this case, the SNA specifies that the accumulation of biomass in plantations would be the benefit. It may be possible to, for this benefit, define the service as the ecological processes (photosynthesis/net primary production, nutrient and water cycling) contributing to the service. In natural systems, the output is seen as the benefit in the SNA, and in this case the ecological processes contributing to this benefit may be very hard to quantify, among others because not all ecological processes result in a benefit (e.g. many of the trees in a natural forest may not be harvested).

An intermediate option is to define the services as reflecting the various processes, but taking the physical output as a proxy for the physical service. This can be combined with using a lease price or a residual (resource rent) approach to assess the service in monetary terms. This however is not particularly easy to explain to users of the accounts and does not fully resolve the inconsistency with the SEEA.

Another, perhaps less appealing option it to use the hectares (ha) of land used for terrestrial biomass provisioning services as the service indicator (extent account). An issue of course with this option is that the amount of ha may not reflect the crop yields on these ha, since the ha may be of very different quality. Potentially, therefore, a qualitative indicator (such as the German Müncheberg index, but other systems are available) can be used to group soil quality of land in different classes. A challenge then is that these will essentially be national systems given the diversity of farmlands between (and often of course within) countries. A second important concern here is that land with suitable soils will not necessarily provide high crop yields : this also depends upon the skills of the farmer, etc. Hence, strictly speaking this indicates the capacity (or potential) of the land to produce crops, not the actual amount, and in this sense it is also not consistent with the SEEA EEA notion that a service is a flow.

What appear to be the main options are summarized in Table 1 below.

Table 1. Options to define selected provisioning services. For reasons of comparison, aquaculture and timber provisioning are added in the table, even they have not been discussed above.

Activity/services	With distinction between natural and managed land		No distinction between natural and managed land	Comments
	Natural land	Managed land	Farmland ecosystem	
Activity: Farming				
Annual crop provisioning as output	Harvesting of wild plants	Harvesting of cultivated plants	Harvesting of crops and plants	
Annual crop provisioning as process	Less relevant (?)	Providing land with ecological properties and processes conducive to farming	Providing land with ecological properties and processes conducive to farming	
Perennial crop provisioning as output	Harvesting of wild plants	Harvesting of cultivated plants; OR: Increase in biomass measured on annual basis	Harvesting of cultivated plants;	Note: the option to measure this service as an increase in biomass measured on annual basis seems less appealing since not applicable to natural ecosystems.
Perennial crop provisioning as process	Less relevant (?)	Providing land with ecological properties and processes conducive to farming	Providing land with ecological properties and processes conducive to farming	
Activity: Aquaculture	(there are some very extensive aquaculture systems, such as un-stocked ponds)	(e.g. high intensity shrimp farming)		
Aquaculture product provisioning as output	Harvesting of wild fish and other species	Harvesting of cultivated fish and other species	Harvesting of crops and plants	
Aquaculture product provisioning as process	Less relevant	Providing land with ecological properties and processes conducive to aquaculture	Providing land with ecological properties and processes conducive to aquaculture	
Activity: Forestry				

Timber provisioning as output	Harvesting of trees	Harvesting of trees; OR: Increase in biomass measured on annual basis	Harvesting of trees; OR: Increase in biomass measured on annual basis (but this second option is only relevant for man-made forests; hence some kind of distinction needs to be made if this option is applied)	NB: most logical seems to be to measure this service in physical terms as standing stock of timber that is harvested (=contribution of the ecosystem) – at least in natural forests. In plantation forests the physical service can be measured in the same way, or alternatively as increase in biomass (since all biomass will be harvested)
Timber provisioning as process	Less relevant (?)	Providing land with ecological properties and processes conducive to forestry	Providing land with ecological properties and processes conducive to forestry	

The table above presents some insights in how provisioning ecosystem services can potentially be defined, without giving a preference to any of them. It may be more difficult to assess these services in physical than in monetary terms, where both actual/market rent or resource rent approaches could potentially be relevant. Table 2 synthesizes some of the findings of the more elaborated table above, in the light of the criteria for assessing ecosystem service definitions provided in Section 1.

A potential consideration is that if it is chosen to not distinguish between natural and managed lands seems not well aligned with recording provisioning services in terms of an increase in biomass, since this latter option is only relevant for managed ecosystems (e.g. plantation forests rather than natural forests).

Table 2. Options for crop provisioning

	Option 1. Defining ES as the contribution of ES to crop production	Option 2. Defining the ES as harvested crops (at the point in time of harvest)
Consistency with SEEA framework	+	-
Measurability in physical terms	-	+
Measurability in monetary terms	+	+
Ease of interpretation	-	+

Note that some discussion on the scores provided in table 2 above is possible. It may be argued that option 2 leads to an inconsistency in defining ES in physical and monetary terms, since strictly speaking, another concept is measured if a resource rent is applied as monetary indicator, and the total amount of crops produced is used as physical indicator. A way to go about this, potentially, is to state that the physical amount of crops produced is a proxy for the actual service, i.e. the contribution of the ecosystem to crop provisioning. Ease of interpretation is given a lower score in option 1 since the physical processes involved are manyfold, and are in most cases not easy to explain to someone not versed in agronomy.

4 Fisheries biomass provisioning services

Coordinator: Anthony Dvarskas, Stony Brook University; Experts: Eli Fenichel, Yale University; Beth Fulton, CSIRO

4.1 Synthesis and review

(extract from the paper by Dvarskas et al. with minimal changes)

Fisheries biomass generated by marine and coastal ecosystem assets forms the base for a range of potential ecosystem service flows and benefits, ranging across provisioning services (food for consumption), cultural services (fish catch for recreational enjoyment), and regulating services (influencing the biomass of other fish populations). Each of these service flows and benefits impacts different end users and therefore rely on different methods for their measurement and valuation. The focus of the paper is on the provisioning flows that arise from coastal and marine ecosystem asset production of fish biomass and strategies available for measuring the physical size of the flows as well as valuing the flows that enter consumption and production processes. Valuation of recreational and existence uses of biomass is briefly discussed. The figure below provides a logic chain summarizing the overall flow from asset to human end user for this provisioning service of biomass.

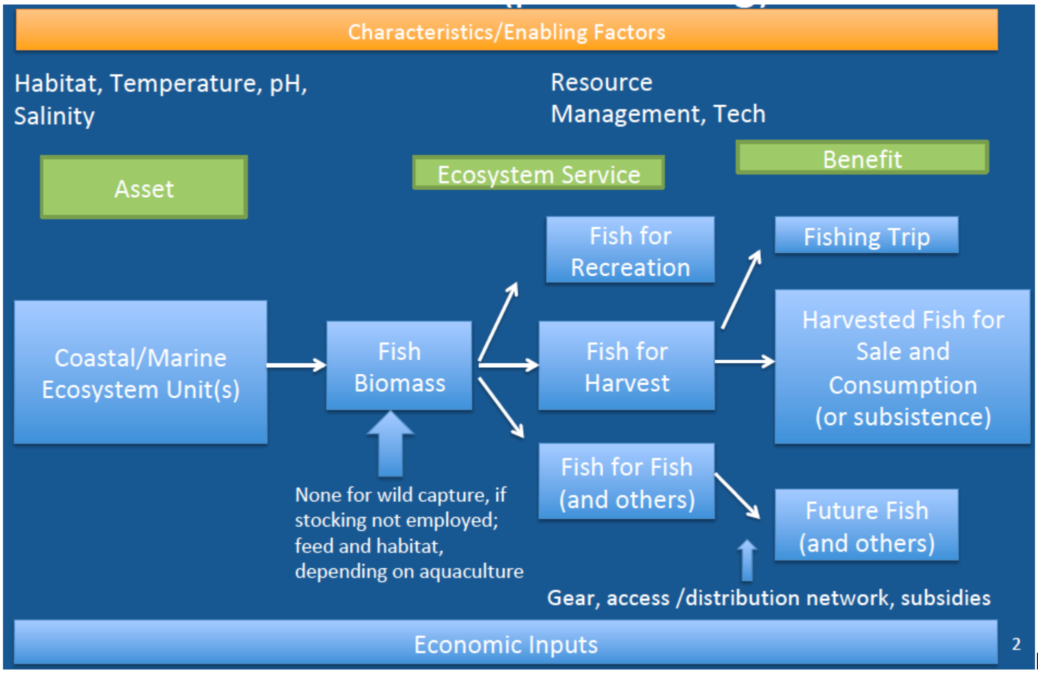


Figure 2. Logic chain for the fish provisioning service

4.2 Questions and options

The focus of the paper on this service was on commercial fisheries with additional text provided on recreational and subsistence fisheries. In the paper, the ecosystem service is defined as the fish biomass for harvest versus fish biomass that may be used for other purposes (e.g., recreational, as a component of the food web). As with the use of terrestrial biomass, a challenge lies in bringing specificity to the definition of the service. Is fish available for harvest an appropriate indicator for a flow? Fish available for harvest seems to describe a stock variable. Another question is if the fish is available in a sustainable fishery or in an actual fishery. A related question is, if the fish are not harvested, is there an ecosystem service flow? In the context of the SEEA framework, it would be appropriate to use a term that reflects a flow variable, such as harvested fish as an indicator for the service.

A specific challenge is to define the spatial contributions of the various coastal and marine ecosystem assets to the production of fish biomass that is eventually harvested (or used for other purposes). The asset and service can in principle be related to specific geographical locations (such as individual country's EEZs, and/or FAO fishing regions), but detailed habitat maps may be needed to allocate the production influence of different nursery (e.g., mangrove, salt marsh) and feeding habitats. For the benefit, it may be generated at the same location as the harvest of the fish, or at the point (harbor) where the fish is landed. The global nature of seafood markets adds additional complexity to the tracing of fish provisioning benefits as some of the beneficiaries (e.g., consumers) may be distant from the point where the ecosystem service flow enters the economic system.

An assessment of options to define the service against key criteria is provided in the table below.

Table 3. Options for fish provisioning

	Option 1. Defining ES as fish available for harvest	Option 2. Defining the ES as harvested fish (at the point in time of harvest)
Consistency with SEEA framework	?	+
Measurability in physical terms	-	+
Measurability in monetary terms	?	+
Ease of interpretation	+	+

Option 1 may have particular challenges in terms of measurability and definition of what is meant by "available" as discussed above. This can complicate attempts to assign a monetary value. Option 2 may be preferred, pending further discussion. Harvested fish can be seen as a proxy for the ecosystem service, which avoids needing to make a determination about what and what is not harvestable and what is and is not sustainable within the accounting framework. A challenge with option 2 is the distinction between the service and the benefit. A possibility here is to use the fish brought on board as the service, the fish landed on-shore (traded in the market) as the benefit. In practice, however, these may often be the same. Related to this is the question what to do with by-catch and discarded catch, would they be excluded or included from the physical volume of the ES? This requires some further discussions, once the definition of the service is agreed.

Note that it may be preferred to have consistency between the definition of fish as a provisioning service and crops and timber as provisioning services. In which case a harvest based approach seems to be most preferred since a process based approach seems less appropriate for fish. However this does not necessarily need to be a hard requirement.

5. Soil retention services

Benjamin Burkhard, Carlos A Guerra & Brynhildur Davíðsdóttir

5.1 Review and synthesis

Description of the service

(Extract from the paper by Burkhard et al., 2019)

Measuring soil retention should consider two main environmental processes: (i) soil erosion by water and (ii) soil erosion by wind. Soil erosion by ice is considered to be a rather specific case limited to comparably small areas, which are usually less relevant for human activities. Water- and wind-caused soil erosion processes comprise different mechanisms and can be affected by different drivers. Namely, in the case of soil erosion by water, precipitation and vegetation cover are two very significant factors when addressing soil retention, while in the case of soil erosion by wind, the equivalent factors are wind speed and direction together with vegetation structure. Also, in the case of soil retention, it is important to separate between the supply of the service and the benefit generated. Soil erosion is a ubiquitous process and, therefore, in one way or the other, always present in multiple ecosystem types. The retention of this eroded soil generates a benefit when the ecosystem type or the specific territory is used and benefits from having more stable soils.

Soil retention (soil erosion prevention) encompasses on-site and off-site effects. On-site effects of erosion include the loss of topsoil material, which decreases cropland productivity and can potentially lead to further erosion. Topsoil material, usually rich in organic matter, nutrients and soil fauna, can be transported by wind, water or ice. Off-site effects occur at places of soil material accumulation and can lead to sedimentation or pollution of water channels, roads or other ecosystems. A critical threshold for soil retention is the ratio between soil formation *vs*. soil degradation/loss. In cases were more soil material is lost than can be build up in a long term, an irretrievable ecosystem degradation occurs.

The supply of soil retention across ecosystems can therefore mitigate these impacts with direct effects on the retention of soils and fertility, but also on above- and belowground biodiversity and soil carbon sequestration and pools. These direct and indirect benefits, including more sustainable crop yields, have very significant implications for human wellbeing (e.g. increased stability of soil conditions correlates with a reduced propagation of soil and plant pathogens), climate change (e.g. supporting higher carbon pools), and nature conservation (e.g. by promoting more stable habitats for both above- and belowground biodiversity.

The key users and beneficiaries

(Extract from the paper ’Burkhard et al., 2019)

Key users and beneficiaries of soil retention can be located in areas of on- and off-site effects. On-site effects usually lead to improved soil quantity and quality, which is benefiting land users especially from agriculture or forestry and the ecosystem services they produce. Especially intensive forms of land use such as agricultural production systems involve complex interplays of ecosystem service users (mainly benefiting from regulating ecosystem services such as soil retention, water, nutrient and local climate regulation, pollination), providers (many provisioning ecosystem services and agricultural products) and (partly external) environmental effects such as biodiversity loss or greenhouse gas emissions.

Off-site effects of soil retention regulating ecosystem services include reduced sedimentation, benefiting water users by supporting water quality regulating and water supply provisioning ecosystem services. However, there are not only positive off-site effects of soil retention. Soil fertility in river areas and floodplains is often strongly dependent on regular sediment inputs from upstream areas to increase or maintain soil fertility downstream (see also paragraph 2a below).

Indirect effects of soil retention regulating ecosystem services include flood regulation by reduced surface runoff, climate regulation by retaining soil organic material such as carbon or methane and pollution control by not further spreading pollutants. Soil retention is furthermore very relevant by providing stable substrate for housing, infrastructure, habitats or other activities.

Thus, beneficiaries of soil retention regulating ecosystem services can be found on all spatial scales, from local to global. The spatial patterns of service provision include *in situ* relations (where the Service Providing Area (SPA) is the same as the Service Benefiting Areas (SBA)) or directional (omni-directional as well as directional relations with or without slope-dependence). Linear landscape structures such as hedgerows or ridges are important elements hindering or interrupting soil erosion processes.

Soil retention can, as many other regulating ecosystem services, in landscapes not take place spatially separated. The SPA and SBA, if not in an *in situ* relation, always need to be physically connected (via a Service Connecting Area SCA), e.g. by natural sediment flows on slopes, hydrological flows within watersheds, human-made infrastructural measures or natural elements. Soil retention can neither be transported nor imported from other regions. In specific cases of wind erosion and material transports over long distances (e.g. Sahara sand transported to Europe), the SPA and SBA could be considered physically disconnected.

A summary "mapping" of the ecosystem services supply chain

(Extract from the paper 'Burkhard et al., 2019)

Figure 3 illustrates the soil retention regulating ecosystem service supply chain. Soil is the central ecosystem asset in this case and its extent and condition are together with the soil type and land cover determining factors for the quantity and quality of service delivery. Economic inputs such as land use and land use change, soil management (e.g. tillage) and protection measures (e.g. no-tillage agriculture) are key anthropogenic factors further influencing soil retention ecosystem services. The actual soil retention is enabled by the natural factors climate, geology, soil type and texture, landscape topography and soil biodiversity. One way to value soil erosion is by calculating damage costs without sufficiently provided soil prevention ecosystem services. Beneficiaries (as described in paragraph 1d above) profit from healthy (stable and fertile) soils, which are the base for various forms of land use with agriculture as a key beneficiary and provider (and user) of many other ecosystem services.

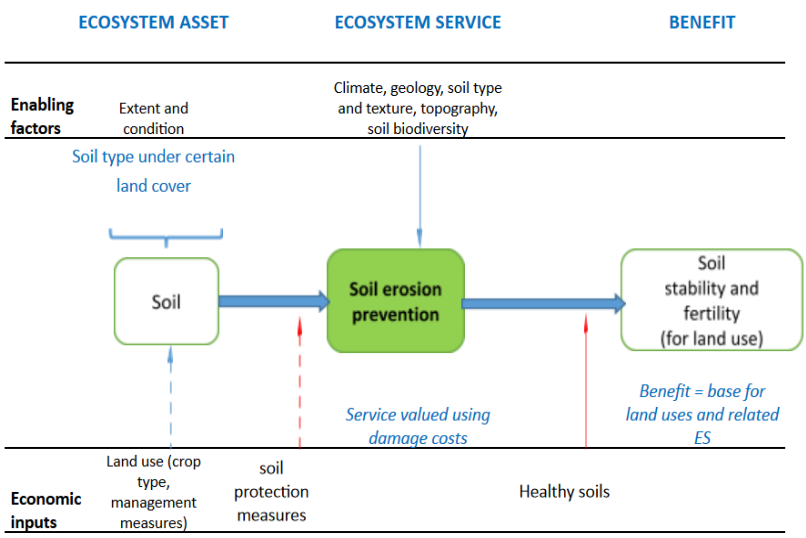


Figure 3. Logic chain for soil retention

Scales relevant to this service

An important aspect, as also brought out clearly in the position paper on this service, is the scale of analysis, and specifically the level of detail of the extent account.

At the **local scale**, a crucial question here is if landscape elements that prevent erosion, such as hedgerows, or strips of grass are distinguished as separate ecosystem units or not. If they are, it could be stated that such small landscape elements contribute to reducing erosion in the fields immediately downhill (by offering a zone where water can infiltrate rather than proceed downhill as run-off). It is a regulating ecosystem service contributing to the maintenance of crop productivity downhill by soil retention and conservation of soil structure. In case the ecosystem type cropland is inclusive of the small landscape elements that prevent erosion, it is of course still the case that these landscape elements, in combination with the vegetation cover prevent erosion. In this case however it is a process that is internal to the ecosystem unit, and erosion control becomes a supporting service.

At the scale of the **watershed** (or catena), soil retention is also important related to its control of sedimentation rates (as an offsite effect of soil erosion). Generally, reduced sedimentation rates are seen as a positive, for instance it prolongs the lifetime of irrigation or hydropower basins. As stated in Burkhard et al. (2019): "Given the complexity of the phenomenon, it is important to refer that increasing soil retention without accounting for local ecosystem conditions may have severe unexpected implications. As an example, large river systems such as rivers Nile, Yangtse or Mekong benefit from having constant loads of sediments coming from upstream ecosystems. Overexploitation of these upstream systems may result in an overload of the river system, but completely eliminating sediment generation may also impose significant impacts downstream, e.g., like the reduction of soil fertility and the disruption of floodplain ecosystems. At the same time, soil displacement can also contribute to propagating invasive species (e.g. by displacing propagules attached to soil aggregates) and contaminants (e.g. phosphorus dispersal into the river systems by soil transport after a fire event)."

5.2 Questions and options

(building upon questions raised in Obst, 2019)

Is the ecosystem asset the soil or an ecosystem type (e.g. forest)?

This question cannot be answered on a service-by-service basis. To date, the thinking as expressed in the SEEA EEA Framework and TR is that soil is an integral part of the ecosystem, together with above-ground elements such as vegetation cover, water bodies, etc. The Natural Capital of soil resources cannot be seen independently of the use of these soil resources, e.g. for agriculture or forestry. In this context then, it is potentially more appropriate to consider – in the framework of the SEEA EEA - the ecosystem asset as including the soil resources part of this asset.

Does "soil erosion prevention" reflect the contribution / role of the ecosystem or a benefit?

In the terminology of the paper by Burkhard et al., soil erosion prevention - or soil retention - comprises the service, and the maintenance of soil stability and fertility indicates the benefit. The following table is provided by Burkhard et al., see Table 4.

Table 4. Commonly used indicators to estimate soil erosion retention.

Indicator	**Description**	**Unit**
potential soil erosion	amount of soil loss when no ecosystem service provider is present and no service is supplied	$t.ha^{-1}.y^{-1}$
actual soil erosion	fraction of soil loss after the ecosystem service is supplied	$t.ha^{-1}.y^{-1}$
soil retention	amount of ecosystem service supply	$t.ha^{-1}.y^{-1}$
supply capacity	proportional mitigation capacity of the ecosystem service provider considered in relation to the potential soil erosion	0 to 1

It appears appropriate to indeed call this service soil retention (or alternatively soil erosion prevention). The term 'soil retention' may be better since it more accurately describes the contribution of the ecosystem – in most hillside ecosystems and climates there will not usually be a complete prevention of erosion even with fairly good vegetation cover.

However, a problem with the definition and conceptualization above is that it is not only about soil. A critical element of the service is the increased infiltration and potentially storage of water during rainfall events. Run-off leads, in most cases, to (overland, rill or gulley) erosion. An important part of the service is that a high infiltration rate reduces run-off, for a given climate. This, in turn, prevents erosion in downhill areas. This element needs to be further discussed in the June 2019 meeting in Glen Cove.

The definition of soil retention as avoided soil loss compared to a baseline seems appropriate and in line with current pilot ecosystem accounts. The question then is what the baseline should be. A realistic baseline will always be context dependent (e.g. dependent upon soil, climate, ongoing land use change processes in the area). There will always be a degree of subjectivity in selecting a baseline. To come to a clear and uniform definition, it may therefore be better to relate soil retention to the avoided erosion compared to a baseline of bare soil (which is usually relatively straightforward to model). This also aligns well with the counterfactual of no vegetation proposed in Harris et al. on air filtration (see next section).

The term supply capacity may require some further thinking. It seems to indicate the ratio between the actual and the potential soil erosion. It may be helpful to have this ratio but it may be better to avoid the terms supply and capacity since they have specific and slightly different meanings in the SEEA framework as developed to date.

Furthermore, it is important to further consider how to connect this service to the various benefits, see also the figure below. If the service is soil retention, then the local benefits are maintaining soil stability and fertility – but as noted above this is, strictly speaking, only relevant in case the service has an effect on downhill ecosystems that have a reduced run-on and therefore run-off compared to a situation with no vegetation cover in uphill ecosystems. In case the benefits of the erosion control service within a specific field, i.e. within a specific ecosystem asset or ecosystem type are added to the benefits pertaining to crop provisioning or other services, this unavoidably leads to double counting. In case an ecosystem asset reduced erosion downhill in another asset, it is an intermediate service, that contributes to maintaining agricultural production in that downhill ecosystem. In this case it may be policy relevant to measure this contribution. However there is still a risk of double counting in case the values of the two services (i.e. soil retention and crop provisioning) are added. Moreover, an important benefit of this service (which as explained in Burkhard et al. may in rare cases be a cost not a benefit) is reduced sedimentation downstream, in particular when there is a water reservoir downstream (e.g. for irrigation or hydropower).

It seems appropriate to consider linking this benefit to the service, and potentially to include in the logic chain. This is expressed in Figure.. below. Note that potentially there may be other (intermediate or final) benefits related to this service. For example, forests may reduce erosion / retain soil compared to a counterfactual of no vegetation and lead to reduced sedimentation rates in local rivers, which in turn contributes to the health of local coral reefs (an ecosystem very vulnerable to sedimentation).

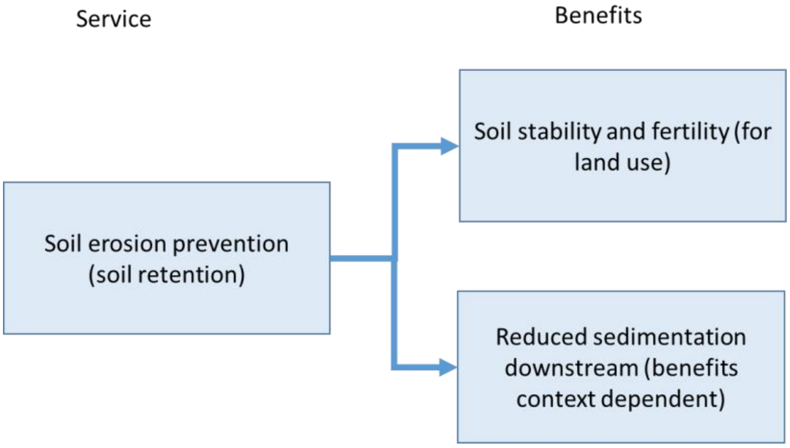


Figure 4. Proposal for a minor modification of the logic chain, for discussion.

Further thinking is also required on how to incorporate in the discussions the notion that some regulating services (protection from wind erosion, storm damage, etc.) relate to hazards (storms, floods, pests). The occurrence of these hazards varies by year, and thereby the service flow would also vary by year, unless an expected value approach is used whereby the service is quantified based on an expected value for the occurrence of the relevant hazards. Care needs to be taken however to relate this risk to the demand for the service, since this notion of demand is much removed from the general micro economic approach to defining demand and the SEEA EEA should be acceptable for as broad a number of disciplines as possible.

6. Air filtration services

Coordinator: Rocky Harris; Experts: Stefan Reis, Laurence Jones, Matthew Agarwala, Giles Atkinson, David Nowak

6.1 Review and synthesis

Description of the service

(Extract from the paper by Harris et al., 2019)

Poor air quality is estimated to result in 4.5 million attributable deaths globally every year and is a major cause of morbidity. It also impacts negatively on visibility, infrastructure such as buildings, and on the state of habitats and species. By improving air quality, vegetation helps to mitigate these impacts on individuals' health and well-being as well as supporting habitat function and species survival.

Vegetation provides an air quality regulating service by capturing airborne pollutants and removing them from the atmosphere through: (a) the internal absorption of pollutants via stomatal uptake; and (b) the deposition of pollutants on external surfaces such as leaves and bark. CICES (5.1) defines this as mediation of wastes or toxic substances of anthropogenic origin by micro-organisms, algae, plants and animals. For the purposes of this paper Harris et al. are restricting the service to the mediation of air-borne pollutants.

Defining the service

The starting point for consideration of the definitional boundary of this service is CICES 5.1: "*Mediation of wastes or toxic substances of anthropogenic origin … by micro-organisms, algae, plants, and animals … that mitigates their harmful effects and reduces the costs of disposal by other means. Examples of the service include dust filtration by urban trees*." This definition immediately raises two issues. First, to what extent is it meaningful or appropriate to limit the filtration service to pollutants of anthropogenic origin? It is clearly desirable to avoid multiple counting of the natural flux of emissions and re-absorption of volatile organic compounds from trees, for example. However, if such pollutants are blown in from another country, does it make sense for the absorption of the pollutants by local ecosystems not to be recorded as an ecosystem service (for the benefit of residents of that country)? And in any case, in practice it seems difficult if not impossible to distinguish between pollutants from natural sources and pollutants of anthropogenic origin. For both these reasons we conclude that the service should not be limited to just those pollutants of anthropogenic origin.

The second issue arising from the CICES definition is the limitation of the supply of the service to that delivered by micro-organisms, algae, plants, and animals. While bare soil and water are both components of natural ecosystems, and act as a surface for deposition of pollutants, it could be argued that the rate of pollution deposition to them is not biologically mediated, i.e. it does not differ if the soil is inert and lifeless, or is teeming with life yet still devoid of vegetation.[1] This would suggest that the contribution that ecosystems make to an improvement in air quality should be measured by reference to current levels compared with a counterfactual of 'no vegetation', which would imply that bare earth and water on their own cannot be seen as providing an air filtration ecosystem service.

Although further research is needed, in practice it seems likely that the average rates of dry deposition of pollutants to water and bare soil calculated from model outputs (Jones et al. 2017) are much lower than the rates for all vegetation types, including the generally lower values revealed for absorption by crops, for O_3 and NO_2 in particular, although they can be similar to the rates for crops in the case of PM_{10} and $PM_{2.5}$. For the purpose of scenario comparison in model-based assessments, the use of bare soil can be seen as the most appropriate

[1] A possible exception here is the removal of carbon monoxide by biological agents in the soil.

counterfactual when assessing the benefits of existing vegetation. One caveat to consider, however, is that when using bare soil as a counterfactual, an increased contribution of wind-blown dust (crustal material) to modelled concentrations of $PM_{2.5}$ and PM_{10} needs to be accounted for.

For the purposes of estimating the service provided by trees, the counterfactual often adopted is to model the effect of trees versus a baseline condition without trees (i.e. with the baseline condition of base water, soil and herbaceous vegetation in the area). This approach would avoid double counting the service provided by other forms of vegetation.

Our conclusion is that open freshwaters, as they are part of the range of ecosystems in any area, can and probably should be included in order to be consistent with counterfactuals assumed for other services, but that in practice unless they cover a large area they are unlikely to absorb large quantities of air pollutants.

Measuring the ecosystem service

The reduction in pollutant concentrations or exposure to pollution at any location due to vegetation is an outcome of all the interactions between vegetation types, meteorology and the concentration and chemistry of pollutants that have occurred in the parcel of air before reaching that location (Jones et al. 2017). The location and timing of these interactions may be different due to differences in the location and timing of the reductions in concentrations and exposure.

Beneficiaries

The benefit is largely defined by the number and location of the users/beneficiaries in relation to the service provided. While a metric of exposure can be calculated as a change in population-weighted concentration, i.e. giving a greater weighting to the concentration changes occurring in areas with the greatest population, this is probably most accurately considered as a proxy. The health benefit can be calculated as the estimated reduction in health impacts arising from that change in concentration. For vegetation in urban centres, this should consider the temporal aspects of population mobility, bringing larger numbers of receptors into more highly polluted areas during working days (Reis et al., 2018). While this does not affect population level exposure assessments at the national scale, for local scale and individual/small population group exposure, the differences in the impact of pollutant removal by vegetation in urban centres could be substantial.

Distinguishing between the ecosystem service and the benefit

While the capture of pollutants is likely to be seen as the most relevant physical metric for the service, it is important to recognise that the service can only be seen as taking place when it provides a benefit in terms of reduced exposure. Note also that the absolute volume of pollutants captured is not a good measure of the value of the service, because the capture of the smallest particles (e.g. $PM_{2.5}$) provides most benefit in terms of the impact on human health

The following logic chain is a first attempt to set out where some of these factors feature in determining the flow of services. For reductions in the impact of air pollution on buildings, the beneficiaries are the owners of the buildings.

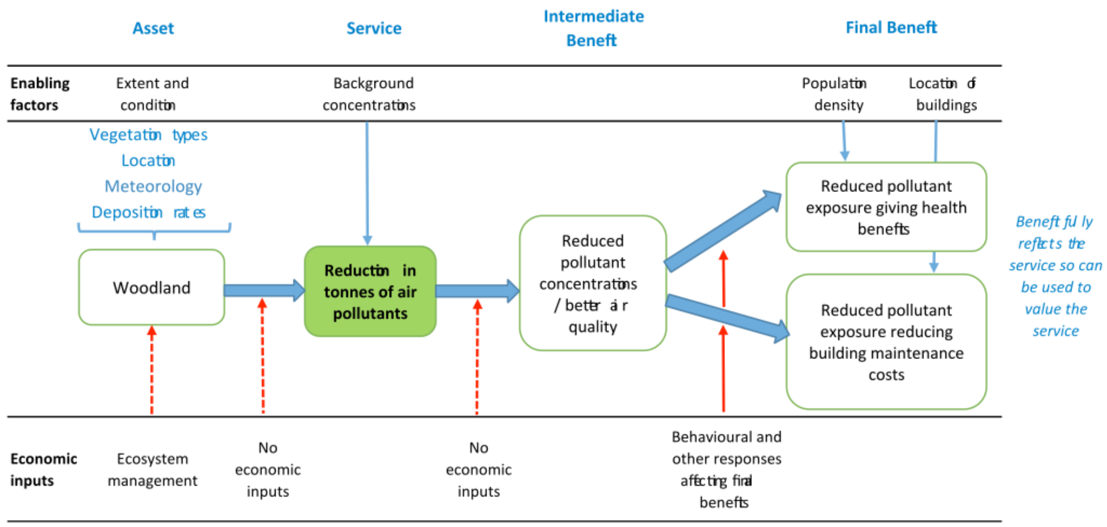


Figure 5. Logic chain for air filtration

6.2 Synthesis and review

The logic chain for this service seems well-aligned with the overall SEEA framework, and it is also clear and consistent with the logic chains of other regulating services. Perhaps it would be possible to insert the name of the actual service in the logic chain ('air filtration') in addition to indicating in the logic chain how the service is measured. An innovation in this logic chain is differentiating between intermediate and final benefit. This raises the question if the intermediate benefit is an additional accounting entry or purely a modelling construct. Note that, in principle, it may be possible to also formulate 'intermediate benefits' for other regulating services. An intermediate benefit of soil retention is lower sediment concentrations downstream with as final benefits a longer lifetime of a water reservoir compared to a counterfactual of a deforested watershed.

A potential question however is if the intermediate benefit is really a benefit. In case of soil retention, the intermediate benefit is only a benefit if there are final benefits -> if there is no reservoir and the sediment is deposited in a coastal area that is accustomed to sediment deposition there is no final benefit and therefore no intermediate benefit. If there is nobody living in the area with lower air pollution there is no final benefit and therefore no intermediate benefit. A question for discussion in Glenn Cove #3 therefore is if the term intermediate benefit should be maintained (and in that case potentially be applied across regulating services).

A more technical question is what to do in areas with low population density. In the Netherlands accounts, it was assumed that air filtration is only a service if there are people living nearby the forest. To assess this, the country was divided into 1 km grids. Only forests in grids with at least 1 person living there could provide the air filtration service (hence assuming that forests influence air quality at a distance of up to 500 meter). Typically, it appears that there were houses in every grid cell. There may be a parallel with the differentiation between intermediate and final benefits – the ecosystem service (and hence the intermediate benefit) only materializes if there are final benefits.

However it remains to be discussed if measuring intermediate benefits is potentially policy relevant, if so if it should be considered an accounting entry, and if so if intermediate benefit is the best term. In case the answer to the first two questions is yes it should be examined if the concept needs to be brought into the discussion on other regulating services.

An important point for consideration here is the parallel with final and intermediate ecosystem services, as defined in the SEEA EEA framework. **Note that the meaning given to final and intermediate benefits is quite different from that of the meaning given to final and**

intermediate services. Intermediate services are services that support the supply of ecosystem services in other ecosystem assets and/or types. Intermediate benefits are now suggested to be defined as an intermediate step in the supply of a given final benefit (usually within the SAME ecosystem unit). This may potentially be confusing to future ecosystem accountants.

A related question is if intermediate benefits, in the sense of benefits supporting benefits in OTHER ecosystem units exist. For example, clean air may increase the attractiveness of an area for tourism and recreation. This is not entirely hypothetical as indicated by some of Switzerland's tourism campaigns. Clean water (see below) may increase the attractiveness of an area for swimming and sailing. Furthermore, clean air may also have benefits not only for human health but also for fauna, flora and ecosystem health, processes and functions (this would be an 'intermediate service' in the SEEA EEA TR – but this issue should be further discussed.

Another question to be discussed is who is actually demanding this ES – the polluters or (solely) human society (same for water purification ES). Polluters are profiting a lot when their emissions are purified by ecosystems – thus they could be included as beneficiaries also.

7 Water purification services

Lead author: Alessandra La Notte; Contributing authors: Bruna Grizzetti, Silvia Ferrini, Sergio Vallesi.

7.1 Review and Synthesis

(extract from the paper by LaNotte et al. with minimal changes))

Description of the water purification ecosystem service

Ecosystem-based water purification can be considered as a sink-related service (La Notte et al. 2019a), whose flow strongly depends on the type and amount of pollutants emitted directly into water bodies either directly or indirectly, e.g. via percolation through soil (flowing then into water bodies). Starting from its definition in current classification systems, our description of ecosystem-based water purification will thus focus on the pollutants, processes and ecosystems involved.

Definition of water purification service in international classifications and conceptual frameworks

The ecosystem service water purification refers to the removal of pollutants from water that is mediated by microorganisms, algae and plants and other ecosystem processes such as filtration, sequestration and storage. In the Millennium Ecosystem Assessment (MEA 2005) water purification and waste treatment are considered benefits obtained by regulating ecosystem processes, which contribute to human well-being by securing access to and availability of clean water. This service depends on the intrinsic self-purification capacity of the ecosystems, which filter out and decompose wastes introduced into inland waters, coastal and marine ecosystems. In the Economics of Ecosystems and Biodiversity methodological framework (TEEB 2010) the service is mainly classified under the waste-water treatment class, which refers to the capacity of soil and wetlands microorganisms to detoxify pollutants and decompose waste. In the ongoing IPBES assessment (Diaz et al 2015), water purification services should be mainly included in the reporting category of nature's contributions to people "Regulation of freshwater and coastal water quality" (e.g. the regulation by ecosystems or particular organisms of the quality of water by filtration of particles, pathogens, excess nutrients, and other chemicals) (IPBES/5/INF/6, Progress report on the guide on the production of assessments, March 2017). Finally, in the Common International Classification of Ecosystem Services (CICES v5.1, consistently with its previous version CICES v4.3, 2013) the water purification service is among the regulating and maintenance (biotic) services, classified in the groups Mediation of wastes or toxic substances of anthropogenic origins by living processes and Water conditions. Indeed, under the first group the CICES v5.1 mentions, for example, the filtration by macrophytes and in the second group it makes references to the removal of nutrients in buffer strips along water courses. However, it has been noticed that for bio-remediation and water quality maintenance services there are overlapping classes in CICES that are hard to discriminate in a practical assessment context (Czúcz et al. 2018).

Water purification: pollutants, processes and ecosystems involved

The water purification service is associated with the need for water quality for human well-being and ecosystem health. Water quality requirements are generally defined according to specific water uses, such as drinking, domestic supply, recreational activities, aquaculture, irrigation, livestock, industrial cooling, etc. Sufficient water quality standards are also needed for maintaining the natural habitat and biodiversity of water ecosystems and sustaining the aquatic life. Elements impairing water quality can affect its microbiological characteristics, such as pathogens and coliforms, or alter its chemical composition. Sediments, nutrients, organic matter and metals, are naturally present in the water medium, but their excess, due to agricultural practices or human domestic and industrial wastes, can strongly affect the aquatic environment. Similarly, man-made chemicals, such as synthetic compounds, plastics, pesticides and pharmaceuticals, once discharged in waters pose harm to human and ecosystem health.

Different processes contribute to water purification, depending on the type of pollutant and the ecosystem involved. Water purification can take place in soils, groundwater, wetlands, rivers, lakes, estuaries, and in coastal and marine environment. Indeed, in a river basin the fate of pollutants depends on the processes of transport and transformation associated with the hydrological water cycle. In soils, water-dissolved chemicals and organic matter can be decomposed by fungi and bacteria. Vegetation in forests, natural grassland and wetlands has the important role to slow down the movement of water, thereby favouring the biological processes. Metals, sediments and chemicals are filtered out and adsorbed by soils particles in wetlands and riparian areas. Some plants and macrophytes have also the capacity to uptake toxic compounds, improving water quality. Pathogens are degraded by microorganisms in soils and groundwater. Nutrients (nitrogen and phosphorus) can be reduced by algae and plant uptake in aquatic ecosystems and wetlands. In particular nitrogen is also lost to the atmosphere by the process of denitrification operated by bacteria in anoxic conditions, which can occur in soils, wetlands, groundwater, hyporheic zones, riparian areas, and in sediments and in the water column of lakes, estuaries and large rivers.

Thus the water purification service affects different pollution sources and types, involves several chemical-physical and biological processes of removal, and can take place in both aquatic and terrestrial ecosystems. These aspects explain the complexity of assessing this service. In addition, the relevance and type of pollution is different according to local geomorphological features and in relation to the different general economic sectors of the area. For example, nitrogen pollution and aquatic eutrophication are of greater concern in industrialised countries, where agriculture is intensive and domestic waste and drinking water generally receive adequate treatments, while pathogens and coliforms are of major concern in countries with poor sewage treatment facilities, other sanitation infrastructures or drinking water treatment plants, and contamination from metals or specific chemicals can be relevant in urban and industrial areas. Figure 6 presents the proposed logic chain for this service.

	ECOSYSTEM TYPE	SERVICE	BENEFIT
Enabling actors: Agriculture Other economic sectors Households			
	No economic input	No economic input	

Figure 6 – Water purification logic chain for accounting (see also Figure 7 below)

On the left-hand side, we can find the main components that will structure the supply table: ecosystem types. As previously mentioned, water purification takes place in soil and water: the ecosystem types that will provide the service flow are shown in Figure 6. The ecosystem types include the component of the water purification service that takes place in soil. In fact, soil can play a double role: as "sink" service (i.e. soil decontamination) can mediate the pollution, as “buffer” service (i.e. component of water purification) can reduce the magnitude of unmediated flows that ends up into rivers and lakes. To identify the role of ecosystems in delivering different typologies of services can be of help from an accounting perspective (ref to Annex I for a summary table).

The amount of pollutants unmediated by soil passes to the ecosystem type “rivers and lakes”, which includes the “sink” component of the water purification service that takes place in inland waters. The amount of pollutants that is not mediated by inland waters ends up into the sea. If water catchments were unable to mediate pollutants (because too degraded) the river network would become a passive corridor that makes the pollutants flowing directly into the sea.

7.2 Questions and options

It is interesting to compare the logic chain for this service with that of soil retention and air filtration. A key difference is that cleaned water is identified as a benefit for the water purification service, whereas this would be an ‘intermediate benefit’ in the logic chain of Harris et al. A related question is if cleaned water is also a benefit if there are no people benefiting from the cleaned water.

This difference emerges from the slightly different perspective taken in the paper by LaNotte et al., where the perspective of water purification as a sink service is selected. In this perspective, water purification is a sink, benefiting producers. Another perspective is to treat water purification as a service that benefits water consumers. In the second perspective, the presence of pollutants in the water is taken as a given, in the first perspective the presence of the water is seen as an opportunity for polluters to dispose their water. The debate on this issue is explicitly mentioned in the minutes of the January 2019 meeting, where the need is stated to “elaborate the potential for polluters to be beneficiaries of sink services”.

Furthermore, there is a need to define the counterfactual: the water with vegetation may be cleaner compared to a situation with no vegetation. Is the counterfactual indeed the absence of vegetation? Also, as well recognized in the paper of LaNotte et al., there is also an important spatial element here, the entry of water pollutants into terrestrial, aquatic inland, coastal and marine ecosystems is spatially variable, as are the processes leading to the breakdown and absorption of pollutants. And finally, there is also an important spatial component to the extraction and uses of the water.

A potential point for discussion is also in terms of terminology. Cleaned water suggests that the resulting water is clean. However it may only be cleaner not necessarily clean or cleaned. Hence it may be appropriate to discuss the specific terminology for this service in June 2019 in Glenn Cove. A related question is if, in this context, pollutants’ dilution in water also classifies as water purification ES? The pollutants are in fact still there, but just in a lower (and perhaps uncritical) concentration.

In taking stock of the benefit of cleaner water, it seems as if, aligned with the other regulating services, some more attention needs to be given to the actual benefits, which again may include both final and intermediate benefits.

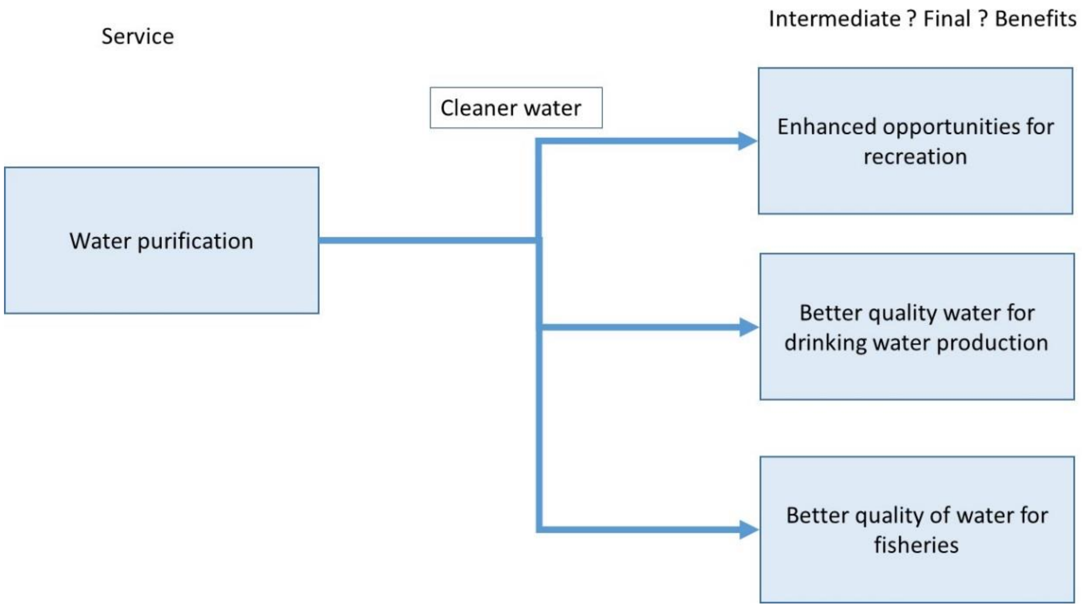


Figure 7. Potential modifications, for discussion, for water purification service. Note this is a first, very indicative draft figure to try to better understand the relation between service and benefits.

A question that arises is to what degree there are final services resulting from water purification. The difference with air filtration is that air is breathed in directly by people, whereas it is much rarer that water extracted in ecosystems (rivers, groundwater) is consumed directly, i.e. without processing. Of course this direct extraction does occur, in remote rural areas which may have their own source of water and perhaps a basic filter system, or in developing countries in areas without access to public water. In these cases, however it is perhaps most logical to interpret this as a provisioning service. In many other cases, it seems as if water purification contributes to the supply of other services, as expressed in the figure above.

What should be avoided is to mix regulating and provisioning services, because they address different policy questions in different ways. Specifically:

- the purpose of water provision is to provide m^3 of water (this is the service)
- the purpose of water purification is to clean pollution (e.g. ton of N removed/km of river) to water bodies (this is the service).

A body of scientific literature justifies why there should be rules governing this issue. In fact, a list of national regulations worldwide exists to confirm this statement. One simple (even if not exhaustive) argument could be: the service itself is justified by the need to address regulation.

Not last, there is an SDG target for it (6.3 By 2030, improve **water quality** (not increase water quantity no matter what) by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials [from the UN website])

Given the complexity of the questions related to this service, this merits further discussion in the June 2019 Glen Cove meeting.

8 Carbon sequestration services

Bram Edens; Peter Elsasser; Emil Ivanov

8.1 Review and synthesis

The paper on carbon sequestration presents a number of detailed and well-motivated proposals for defining carbon sequestration in the context of SEEA:

- Carbon storage should not be seen as a distinct ecosystem service - the main service being carbon sequestration. Total carbon stored is a stock variable, which may be used as a condition indicator.
- The transaction model of the SEEA allows to see carbon sequestration as a final service (which differs from FEGS and CICES where sequestration is considered as an intermediate service or process); in fact NPP can be seen as the process (or intermediate service), with sequestration being seen as the ecosystem service.
- Within an accounting framework, sequestration can be defined as: the removal of carbon from the atmosphere by ecosystems, by storing it in carbon pools (other than the atmosphere) for more than a year [unit: tC/ha/yr]. NECB (net ecosystem carbon balance) seems the most suitable metric to assess carbon sequestration. The NECB equates to the net accumulaiton of carbon in an ecosystem, correcting for carbon emisisons due to heterothrophic and autotrophic respiration, harvest and fires.
- The definition and measurement of carbon sequestration should be aligned with / be complementary to IPCC guidelines as much as possible. In line with IPCC carbon sequestration requires carbon to remain in the ecosystem for a period of at least one year.
- Accordingly, the benefit can be defined as: reduced concentrations of carbon in the atmosphere.

- Scope should address contemporary and future sequestration that is occurring through both biotic (NPP) and abiotic elements, in terrestrial and aquatic ecosystems, hence excluding geological forms like oil and gas.
- On valuation, an important proposal in the note is to use the European carbon trading scheme 'ETS' prices to value carbon sequestration, where they are available. In countries without an ETS it is recommended to use these ETS prices also as "best available estimates" for those sectors which are not covered by the respective ETS.
- In countries without an ETS, the certificate prices of Clean Development Mechanism and/or Joint Implementation projects appear as most compatible approximations.
- It seems sensible to complement ETS based carbon valuations by an additional valuation based at a (global) SCC estimate (as this can be done easily), as long as this estimate comes from models that exclude consumer surplus and the applied discount rate is consistent with discount rates used elsewhere in the accounting system. Care needs to be taken however that double counting is avoided.
- Degradation costs (as a result of air emissions) can be defined in respect to changes in the CO_2 concentration of the atmosphere. Such costs are only recorded when emissions are beyond the sequestration taking place in the accounting period (for the country in question).
- There are a couple of boundary issues that need to be further discussed – especially in the context of linkages to air emission accounts (HWP; soil respiration; energy crops).

The figure below presents the logic chain as presented in the paper on carbon sequestration.

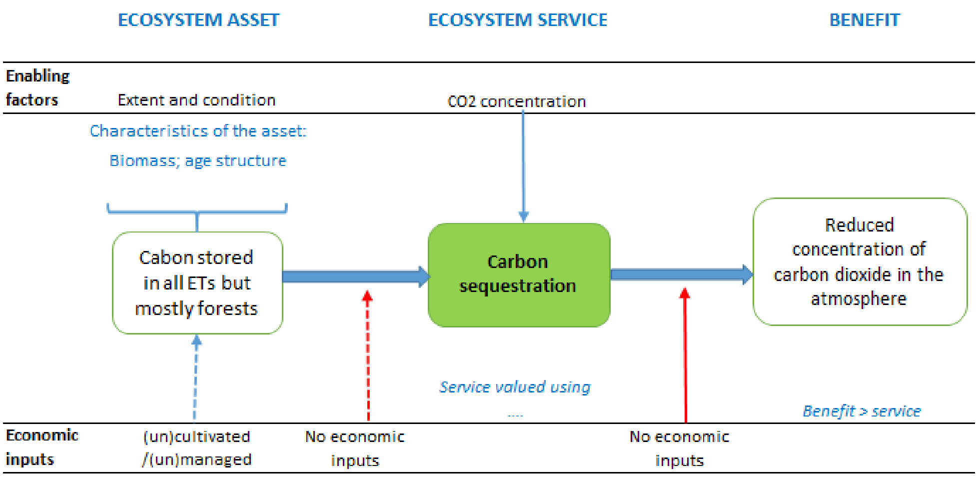


Figure 8: Logic chain of the carbon sequestration service

8.2 Questions and options

Since the paper is very detailed and presents clear recommendations for defining, scoping and measuring the service, it opens the possibility to express a range of questions. These questions for further discussion are listed below. This note cannot provide answers to these various questions but where appropriate a few additional thoughts are provided or some of the options resulting from the questions are described.

Questions identified by the authors (plus some tentative reflections on these points)

- NEP versus NPP (sometimes portrayed as a difference between "gross" and "net"); should emissions due to processes that may lead to carbon emissions by ecosystems different from plant respiration such as soil respiration or emissions due to soil subsidence be netted off?

A consideration here is that emissions due to the oxidation of peatlands (which may be a better term then due to soil subsidence since there are several soil subsidence processes that do not release carbon) will where they occur often far exceed sequestration in the ecosystem.

- NECB (NBP) and Harvested wood products (HWP): should harvested timber be netted from carbon sequestration? In other words, should sequestration be equated with the effective change in carbon storage (of a particular ecosystem)? Clearly, this depend on the final use of the harvested timber (i.e. burning vs. construction purposes), and specific models (e.g. CO2fix) are available to estimate the net effect on CO_2 emissions. of using timer in wood products

An advantage of doing this is that it leads to consistency between sequestration and changes in stocks. If not all carbon flows are considered in sequestration (and emissions) there will over time be no balance between the aggregated flows and the stock.

- Short-lived versus long-lived biomass: should we include all sequestration (NPP or NEP) or only sequestration leading to long-stored carbon. The latter would be aligned with the IPCC guidelines (2006 IPCC) (and seems recommended in the TR)

As the authors state it may be reasonable to use 1 year to distinguish between short and long carbon cycles, which is potentially also a logical choice given that the general use of an accounting period of one year in SEEA.

- (Un)Managed lands; this is another boundary issue vis-a-vis climate change reporting. The IPCC Guidelines for instance only include emissions (and sinks) from managed lands (as the objective is to assess anthropogenic causes). The definition of managed land need not align with the distinction between cultivated and non-cultivated lands in the SNA/SEEA CF.

Indeed, and pls. also note that UNFCCC distinguishes between natural and managed processes (even on the same lands). For instance, fires in peatlands leading to CO_2 emissions are seen as man-caused and included in reports to the UNFCCC. Oxidation of peat (without fire) is seen as natural and is not required to be reported to the UNFCCC. Indeed this is a potential difference between what is proposed in the TR on carbon accounting and the reporting to UNFCCC. Another difference is that emissions due to changes in land cover within a year (forest conversion, for instance) are reported as emissions within that year to UNFCCC. In the carbon account they would show up if we have 1st of January as an entry point and 31 of December as the other entry point. However if we use an average carbon stock contained in vegetation in a year for each year this impact of land clearing only shows up when comparing carbon accounts **between** years. This was a major discrepancy between the SEEA carbon values and the values reported to LULUCF in the Netherlands.

- Scope: do we only include sequestration taking place in specific ecosystem types (e.g. terrestrial, grasslands; forests etc.) or also within aquatic systems. A specific question is if CO_2 sequestration in oceans is included, noting that oceans absorb currently around half of the globally emitted CO_2. The absorption itself is a chemical process, the subsequent carbon cycle within the ocean is strongly influenced by biological aspects (e.g. plankton photosynthesis).

There is much less data on carbon sequestration in blue systems except oceans, and a question is if this is an ecosystem service or merely a physical flow. On the other hand it is a potentially important source of carbon removal from ecosystems and estimating it may in some cases be required to balance the books.

Questions identified in Obst, 2019.

- Is carbon stored in soils within scope of the different ecosystem types (including forests)?

The authors of the note propose to not consider storage as indicator, but in the measurement approach proposed by Edens et al. the sequestration in soils (e.g. through increases in root biomass) seems to be in-scope.

- Is it necessary to articulate further/wider benefits beyond the reduced concentrations?

A very tentative reflection is provided below.

- Who are the users and beneficiaries?

This would perhaps be future generations? Alternatively/additionally current buyers or sellers of carbon credits?

Additional questions

- Definition of the final benefit

It appears that there may be an inconsistency between the definition of final service in the paper by Edens et al. and the definitions proposed by Harris et al. In the logic of Harris et al. the reduced carbon concentration would be an 'intermediate benefit' with as final benefits the avoided losses due to climate change. Hence it may be possible to somewhat expand the logic chain for this service in the figure presented below. Note that this note does NOT propose to use this alternative framing, it only shows what an alternative framing could potentially look like if the intermediate versus final benefits model proposed by Harris et al. would be applied to this service. Note also that a particularity of the carbon sequestration service is that it involves translating future benefits (related to reduced impacts of climate change) into a present benefit. Even though some other regulating services (e.g. coastal protection form mangroves) also mitigate future extreme events (floods), the time scales involved in the carbon sequestration services are considerably larger.

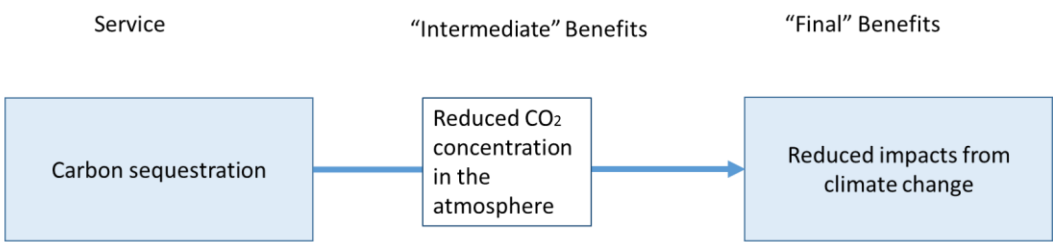


Figure 9. Potential, minor modification of the logic chain for discussion.

- Is it appropriate to not give more attention to carbon storage or carbon emissions?

From an accounting perspective the logic of Edens et al. is clear: storage concerns a stock, sequestration is a flow and it can only be sequestration that provides a service. From a policy perspective, however, the emissions of carbon (and other GHGs) from ecosystems is in some areas crucial (peatlands, CH_4 emissions from paddy fields and livestock, NO_2 emissions from croplands). Moreover, the whole concept of REDD+ (Reduced Emissions from Deforestation and forest Degradation – including in peatlands) is based on a payment for storing carbon (i.e. not emitting carbon as would be expected in a no-payment situation). The REDD+ market currently has a ~50 million euro turn-over globally and is expected to grow very quickly in the coming decade. It seems inappropriate that there is a market mechanism to pay for 'something' the ecosystem does and not include it in the SEEA ES services supply and use account. Note that REDD+ values storage but translates storage into a flow: it is the avoided annual emissions that are being paid for.

Another, related aspect here is how to deal with the spatial component. If SEEA accounts are used in support of ecosystem management, it is useful to know what areas are emitting CO_2 (as was established in the BPS/WAVES Supported Indonesia peat account). An approach where emissions and sequestration are netted out at the national scale does not inform on where the emissions are taking place. To provide some additional context, in the Netherlands the emissions from drained, oxidizing peat exceed the sequestration in forests and other ecosystems by a factor two.

It may therefore be justified to further discuss this issue in June 2019.

- Valuation of the service

A potential concern is that the ETS indeed presents the largest market for carbon at the moment but that market prices are to a degree artificial in that they are influenced by thresholds set by the EU as a function of climate policies. Current prices of around 20 euro per ton seem 'reasonable' in relation to conservative damage cost assessments, but they have varied considerably in the course of the last decades (also as a function of speculative trading). Moreover the ETS does not include forest carbon. Even though this may not be a problem from an accounting perspective, it may be an issue to convince policy makers that this price is also appropriate for carbon sequestration in ecosystems.

9. Water flow regulation services

Neville D. Crossman, Stoyan Nedkov, Luke Brander

9.1 Review and synthesis

The authors of the paper provide the following key issues and challenges:

- The water flow regulation ecosystem service can be subdivided into river flood regulation and coastal flood regulation. They are quite different and there are major differences in biophysical processes, scientific disciplines, data, models and methods.
- The measurement of river flood regulation relatively very well studied, whereas coastal flood regulation much less so.
- Water flow regulation in coastal and inland ecosystems is functionally related to the provision of multiple other services so care needs to be taken with defining ecosystem service boundaries.
- Beneficiaries can be spatially disjointed especially for river flood risk reduction where upstream vegetation mitigates damage downstream – this is a challenge for scale and selection of appropriate spatial units.
- The demand for water flow regulation by ecosystems is determined by the magnitude of the costs of flood risk (the minimised sum of incurring and/or mitigating the damage) which is highly context specific.
- It is not possible to generalise the value of the service using a fixed unit value (e.g. US$/ha/year) because both the demand for and supply of water flow regulation service are highly spatially variable.

The following description of the ecosystem service is provided:

The ecosystem service of water flow regulation to mitigate extreme events is the process of vegetation or other ecosystem structures acting as a barrier or buffer to water flow and thereby reducing the frequency and severity of flood events. The TEEB (2010) classification defines this service as "Moderation of extreme events. Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage". This definition is somewhat broader than the service we address in this paper since we examine the regulation of extreme water flows (or floods) only. The Common International Classification of Ecosystem Services (CICES) version 5.1 defines this service as "Hydrological cycle and water flow regulation (including flood control and coastal protection) ".

This ecosystem service is provided by a wide range of ecosystems. Regarding the regulation of river flooding, the most relevant ecosystems are wetlands and forested watersheds; regarding the regulation of coastal flooding, the most relevant ecosystems are mangroves, coral reefs and dunes; but also kelp forests, oyster beds, seagrass, and unvegetated sediment.

This ecosystem service is functionally related to the provision of multiple other services so care needs to be taken with defining ES boundaries. For example, a riverine wetland that regulates water flow and flood risk may also deliver more reliable water supply – these are distinct but highly related services. An example for coastal flood regulation is provided by a coral reef that acts as a physical barrier to storm surges and also provides a cultural service in the form of biodiversity that can be viewed while scuba diving – both these services might contribute to the tourism sector but are distinct benefits provided by the reef.

The beneficiaries of water flow regulation for mitigating extreme events are the people that face lower flood risks due to the presence of ecosystems, e.g. households and firms located in exposed coastal areas and floodplains. In the case of coastal flood mitigation, beneficiaries are likely to be in close proximity to the ecosystems providing the service; whereas for river flood mitigation, beneficiaries and ecosystem units may be spatially distant downstream.

In their paper, the Crossman et al. deal with both river and coastal flood mitigation as one ecosystem service. From the perspective of quantifying economic value this is not an issue since the methods for valuing reductions in flood risk are the same. From the perspective of quantifying the biophysical nature of the service, however, there are major differences in terms of biophysical processes, scientific disciplines, data, models and methods.

Crossman et al. provide the following logic chain:

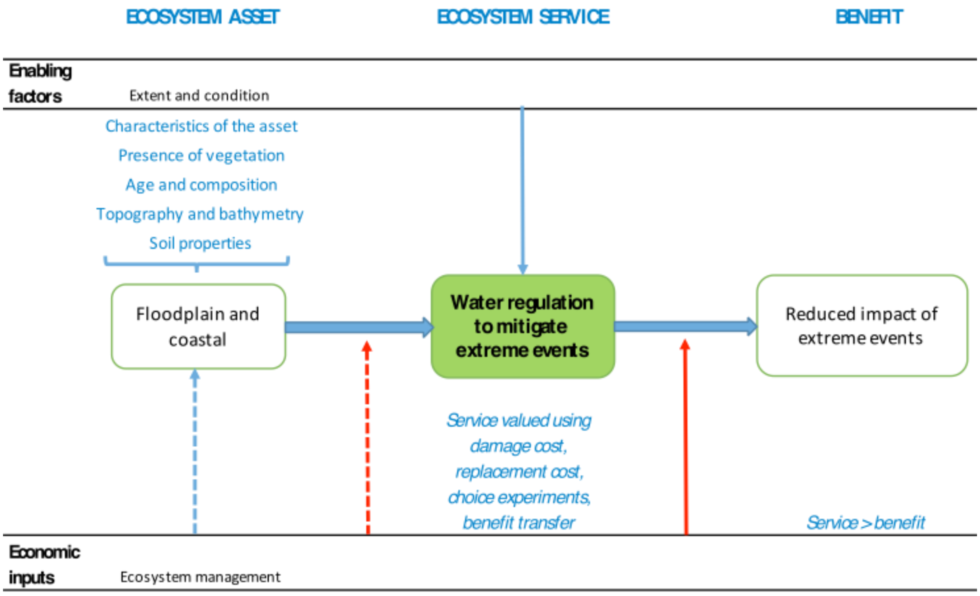


Figure 10. Regulation of water flow to mitigate extreme events

9.2 Questions and options

Observations in Obst, 2019:

- Why is the service > benefit?

Indeed a question is if the authors intend to indicate that not in all cases a service translates into a service, for instance in the case where there would be an ecosystem regulating waterflows but no beneficiaries would be present downstream to benefit from this services. Such an approach to define services and benefits, however, would not be aligned with the SEEA EEA framework, where there can only be a service if there are beneficiaries. Potentially something different of course is indicated, and some further clarification would be helpful in June 2019 Glen Cove meeting.

Note that there may be a parallel here with the definition of services in the case of air filtration, as described above. Specifically, it may be that a (final) water regulation service is provided if there is at least one person living/one element of infrastructure present in the flood risk zone. The service itself can be measured in terms of physical indicators that relate to reduced flood risks (e.g. chance of occurrence, expected value of peak flows of a certain occurrence, etc.), whereas for the benefits also the number of people, and the amount and value of infrastructure need to be considered, among others.

As suggested for soil retention, air and water purification, an approach based on actual demand for this ES (based here on the risk of extreme flood events) may be considered. There are only benefits from this ES in cases where there is a risk, otherwise this ES is not needed/demanded.

Other questions.

- Scope of the service

As mentioned by the authors there is a clear link between the role of wetlands, forests and other ecosystems which can act as 'sponges' – i.e. absorb water during periods of high rainfall and gradually release it later[2], in the flood mitigation service these forests can provide, and in their ability to supply water to rivers during time of drought. Usually, both effects can be modelled with the same datasets and models. As shown in for instance Duku et al., 2016, the release of water during drought or during the dry season can be critical for downstream agriculture. Hence a question for discussion in Glen Cove in June 2019 is if this aspect doesn't need to be brought in the description of this service. Note that this may involve adding a benefit (as in 'providing water to streamflows during drought' or rephrasing the current benefit (e.g. to 'storage during peak rainfall and gradual release of water'). However of course this does not align with the protection function from coastal ecosystems which is quite different as the ecosystems point out. It may be added that a similar protection service (as provided by coastal systems such as dunes) is provided by riparian ecosystems. Hence there seem to be two options for defining this service (i.e. one additional approach to that of Crossman et al, see the table below.

Table 5. Options to define the service

Service definition	Water regulation to mitigate extreme events (as in Crossman et al.)	Distinguishing between: (i) the water absorption and release service of forests, wetlands and other ecosystems (providing benefits related to reducing peak flows and maintaining base flow); and (ii) the linear storm protection service of coastal and riparian ecosystems
Consistency with SEEA framework	+	+
Measurability in physical terms	0	+ (it may be that distinguishing between the two elements provides a more consistent and easier approach to measure this service, since different measurement approaches are required to value the absorption and the linear protection elements).
Measurability in monetary terms	+	+

[2] Note that not all forests are equally good in acting as a sponge. In particular newly reforested areas may not have yet built up a layer of organic matter, and a diversity of soil life (earth worms, etc.) in the topsoil that increases porosity and can store water.

Ease of interpretation	0	+ It may be that it is easier to aggregate linear protection services with other linear protection services (using e.g. km or km2 of coastal or river floodplain protected) and water flow regulation with other water flow regulation elements (using indicators such as m3 of water base flow sustained, or m3 of reduction in peak flow).

- Ecosystems supplying the service

As the authors point out the service is complex to model and highly spatially variable. Different parts of upstream forests provide different contributions to regulating water flows. These contributions are interdependent, and influenced by the pathways water flows follow in the landscape. Cutting a specific part of upstream forest will change the relative importance of water regulation in forests up and downstream of this forest (see Brookhuis and Hein, 2016). Furthermore the service and the benefit depend upon the risk for flood damage in the areas potentially affected by extreme events (floods, storms, etc.) – especially the frequency of occurrence of extreme events, bathymetry, geomorphology and land use including degree of urbanization of risk zones. These challenges are clearly described in the paper by Crossman et al. A question may be to what degree ecosystem types providing the service (e.g. riparian and upstream forests, dunes) need to be identified in the figure depicting the logic chain for this service (which now only indicates floodplain and coastal). It needs to be noted in this context that patterns of ES are very different in coastal and river systems; specifics of both should be elaborated more in detail.

- Physical and monetary indicators for the service

A topic for which some additional discussions are needed, in particular after agreeing upon the exact scope and elements of the service, is which indicators are potentially useful for quantifying this service. Again this is highly context dependent – but the range is quite broad. In the Netherlands accounts this was also one of the key methodological challenges in the physical domain that was not resolved in the course of the production of the first set of SEEA EEA accounts. The ministry responsible for water management and safety issues related to flooding did not accept the idea of quantifying storage of water in flood plains and considering this an ecosystem service, given that the dykes regulating the flood risks are man-made, and given that the ministry is used to express this service, and the impacts of investments in physical structures such as dykes, in terms of reductions in flood risk. Further discussions are needed to assess the validity and policy relevance of different indicators (e.g. related to risks, area, linear elements, water volumes, inundation depths), and potentially how these indicators relate to one another.

10 Water supply services

Rosimeiry Portela, Maíra Bezerra, Kashif Shaad and Mahbubul Alam, Onil Banerjee

10.1 Review and synthesis

(extract from the paper by Portela et al. with some editorial changes)

Water supply services involve the abstraction of water from freshwater and marine ecosystems. Given the detailed guidance for water accounting in the SEEA-Water framework, the authors take SEEA-Water as a starting point, highlighting the extensions that an ecosystem service accounting perspective entails. The ecosystem service of water supply commonly refers to the amount of water being used by different economic sectors and households It focuses on water abstracted as a material input for production and consumption. The sink function of water is more strongly related to the water purification services described above.

Abstraction is defined as "the amount of water that is removed from any source, either permanently or temporarily, in a given period of time for consumption and production activities" (SEEA-Water pg. 45). Water sources for abstraction include inland water resources (rivers, lakes, artificial reservoirs, glaciers, snow and ice), sea water, direct collection of precipitation and soil water. These water sources are generally replenished (and complemented, e.g. in agriculture) by precipitation.

The SEEA-Water framework accounts only for the water that is physically removed from the environment that is then used in activities involving production and consumption. Services such as water supply for hydropower and water used cooling and for navigation/shipping is not considered in this synthesis, although clearly, as clearly described in Portela et al., these services also need to be considered in the SEEA EEA revision.

The working definition in this paper for water supply is the amount of water that is used as material input for activities to the production of benefits to economic users for consumptive purposes (including households, firms and the government), and non-consumptive purposes, and is dependent on ecosystem condition/capacity.

In terms of ecosystem service classification and related terminology, we follow the conventions outlined in CICES V5.1, 18/03/2018, while acknowledging the Final Ecosystem Goods and Services Classification System (FEGS-CS) (Landers and Nahlik. 2013). Both classification schemes address the link between final ecosystem services to specific beneficiaries of such services. The most recent FEGS-CS, however makes an additional effort to link final ecosystem services to standard categories of both ecosystems and beneficiaries.

Water provisioning services cannot be considered in isolation of water quality conditions; an abundance of water that can be made available for humans, but is of such poor quality that it is not ingestible, renders the water unusable and incapable of generating a benefit. Indeed, the EEA states that water supply services combine elements of both provisioning and regulating ecosystem services (UN et al., 2014, p. 65).

The benefits from this service may be defined as SNA benefits and non-SNA benefits. SNA benefits are goods and services that are consumed and are produced by economic units. The measurement boundary is defined by the production boundary used to measure GDP in the SNA and includes also goods and services produced by households for own consumption. Non-SNA benefits are benefits enjoyed by individuals but are not produced by economic units. These benefits are not the result of production processes as defined by the production boundary of the SNA. In most circumstances, SNA benefits are those that can be traded in the market while non-SNA benefits generally cannot.

The SEEA-Water framework defines boundary as very broad and includes all inland surface water bodies (rivers, lakes, artificial reservoirs, glaciers, snow and ice), groundwater and soil water (SEEA-Water pg. 27). For accounting purposes, SEEA-Water indicates that, since priority should be given to the spatial scale of conventional economic accounts and economic information that is compiled according to SNA, the broader boundary should be considered the country (SEEA-Water pg. 36). As Vardon (2014) points out, a key distinguishing feature of EEA vs. SEEA and SEEA Water is that spatial units are the basis for the accounting. Units can be land cover, ecosystem types, river basins or administrative areas among others.

Three main boundaries might be drawn to depict the biophysical scape: waterbody, watershed, "precipitation shed". The waterbody scape refers to any body of water forming a physiographical feature, e.g., rivers, streams, lakes, aquifers, and seas. Within the SEEA-Water framework, waterbodies are the assets. The watershed scale (or catchment scale) refers to the drainage basin scape, that is "a part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water" (USGS 1995). Recent reviews have regarded watershed scale as the appropriate scape to observe and quantify processes related to the water cycle, hence, to quantify and value water-related services (Grizzetti et al. 2016). The "precipitation shed" with a much broader scope refers to the recycling of moisture over land surface where evapotranspiration from one region will drive precipitation in another. For example, studies show that up to 70% of the rainfall for the Río de la Plata Basin in Argentina/Uruguay originates as evaporation from the Amazon forest (Van der Ent et al., 2010).

Several metrics can be used to measure water availability and water supply. Most common are metrics in form of volume per unit time such as: discharge, volumetric flow rate of water (volume per unit of time, m^3/s, ft^3/s). Other metrics include discharge per unit of area; annual runoff (volume); water yield (volume) or 'stock' (volume) per year. The figure below presents the logic chain prepared by Portela et al.

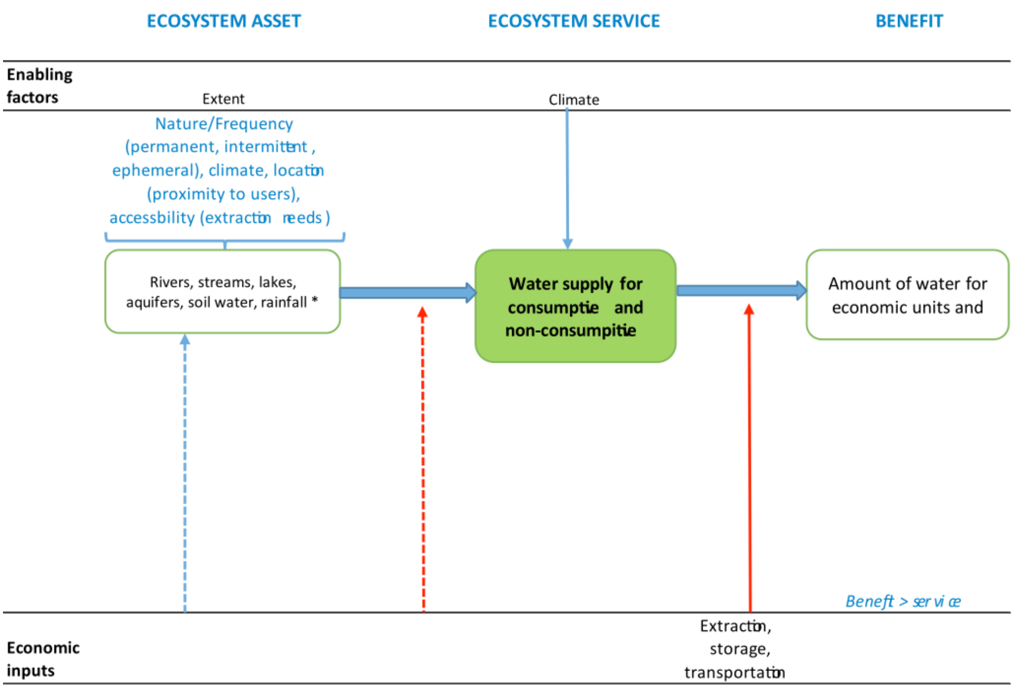


Figure 11. Logic chain for the water supply service

10.2 Questions and options

Observations Obst, 2019:

- In what way is rainfall an ecosystem asset?

It is perhaps relevant to note that even though the figure above includes rainfall as an element of ecosystem assets, the text of the paper does not seem to support this idea. Perhaps it could be clarified in Glen Cove in June 2019 if rainfall is indeed relevant in defining ecosystem assets. It can also be observed that part of the figure appears to be missing (the figure depicting the benefit).

- For non-consumptive use how would the volume of water be considered in the measurement of the benefits?

The authors make a very important point, i.e. that water quality is an important element in water supply. If water is too toxic to be physically or economically suitable to be used for drinking water production even an abundant flow of water is not of much benefit, and a service cannot be provided. For non-consumptive uses there may be less restrictions on water quality (e.g. cooling water, hydropower – but it is likely that there may still be restrictions e.g. related to temperature, silt or sediment contents of the water). Only navigation, which appears a different type of ecosystem service altogether, does not appear sensitive to water quality. For some non-consumptive uses volumes of water may be relevant (as in the amount of water used for cooling or hydropower, which can be measured in terms of, potentially m3/s. However as indicated by the authors there is a need to further discuss in Glen Cove in June 2019:

1. The type of water related service in scope for defining the service water supply (see the figure below for a potential contribution to this discussion)
2. The relation between water extraction and water quality and how to include this in the service classification

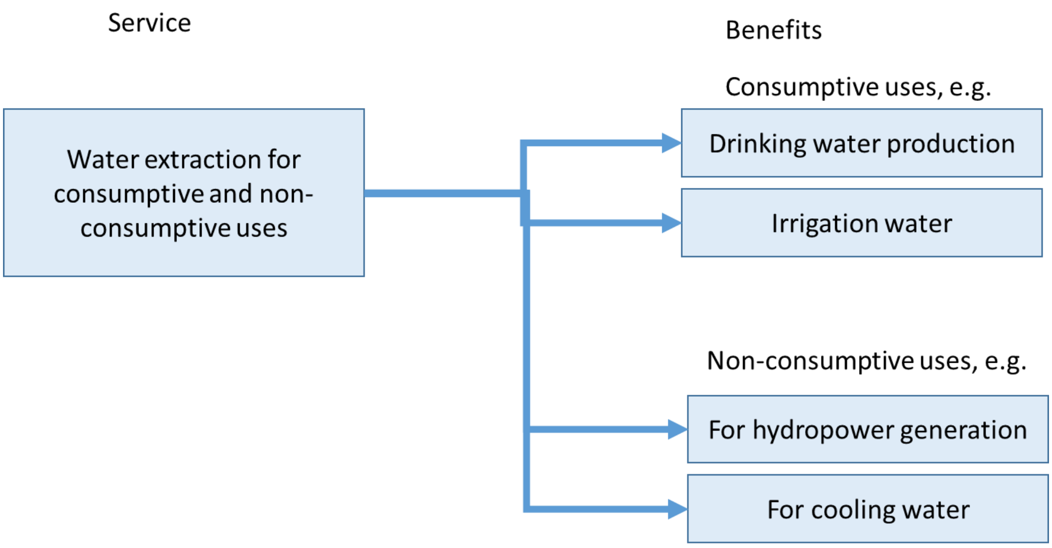


Figure 12. Potential, minor modification of the logic chain for discussion

- Do we fully understand the beneficiaries?

In few cases, water from ecosystems may be directly consumed (i.e. untreated) by households, or it may be used treated or untreated by industry (e.g. for cleaning, cooling or as inputs to produce soft drinks or paper), or by farmers for irrigation. In other cases the service is supplied to the drinking water sector (ISIC 36, water supply industry) for treatment and processing.

- How to define assets for water resources?

Importantly, the SEEA Water includes as an entry the physical volume of water resources, including both surface (lakes, rivers) and groundwater. The SEEA EEA only quantifies assets in monetary terms. Pilots involving the SEEA water show the difficulty of defining the stock (volume) of water in the beginning and at the end of an accounting period. Especially river water volumes are very difficult to assess in this way – should the water flowing present in the river bed in the first second of the year be taken as stock? Or the average volume during the first day or week? The issue here is that this volume doesn't mean very much in terms of the water that can be supplied by a river (which depends upon the through flow of the water at various points along its course, i.e. m3/second) – and that this physical volume is very hard to quantify involving detailed bathymetric modelling of a river. In this sense it is helpful that SEEA EEA does not require to assess ecosystem assets from a physical perspective.

- On the connection between water supply, mitigation of extreme events (flood control) and water purification.

11. Recreation services

Carl Obst and David Barton

11.1 Synthesis and Review

(extract from the paper by Obst and Barton with minimal changes)

The recreational service is strongly related to the other cultural services – but much less so to the other services analysed in this note. In addition, the main author of this current review paper already provided inputs into the paper during the writing process, and the paper on recreation is fairly comprehensive. It is therefore believed that the review has relatively limited to add compared to the messages already provided in the recreation paper itself.

This discussion paper spans outdoor recreation in landscapes ranging from urban built environments to wilderness. Attempting to cover the heterogeneity of recreation contexts that occur within a national accounting scope, calls for a distinction between recreation requiring natural capital/ecosystems (outdoors) and other recreation (indoors). Outdoor recreation services are part of leisure and a wider set of cultural practices of people interacting with environmental spaces, and are part of the general category of cultural ecosystem services .

The purpose of measurement in the context of the discussion paper by Obst and Barton is to quantify the contribution of the natural biotic and abiotic characteristics of outdoor spaces to recreation services, and value the benefits from recreation services to people.

To open discussion, Obst and Barton propose a definition similar to CICES wherein 'recreation services are the biotic and abiotic characteristics of open space that enable health, recuperation and enjoyment through outdoor activities'. Thus, the point at which environmental structure and processes give rise to outputs that directly enter human preference functions (profit, utility, well-being) can be defined as an ecosystem service. In this context, 'enjoyment' is a synonym for utility and well-being.

Note that the benefits in this definition are health, recuperation and enjoyment, with outdoor activities being a mediator of benefit. In other words, indicators of outdoor activities are proxy indicators of recreation benefits. Obst and Barton state that the drawback of this definition of recreation services is that asset 'condition' and 'service' are not easily distinguished. Furthermore, the definition of recreation activities as a mediator/proxy of benefit, is unfamiliar to environmental economics, where visitation data have for long been equated with recreation benefit. Possibly, the relative ease in obtaining available visitation data has established this definition of recreation benefit in environmental economics, while other literatures define recreation benefits from a perception of well-being or health end-point.

Another conceptual problem as identified in Obst and Barton is that enjoyment, recuperation and health are not mutually exclusive types of benefit, but nested. Enjoyment is in situ and immediate, recuperation may extend beyond the recreation experience on the short term, whereas health is integrative extending potentially to a person's lifetime. Obst and Barton provide an elaborate discussion and motivation of this definition and its implications, the reader is referred to their paper for more detail. The logic chain they prepare is presented below.

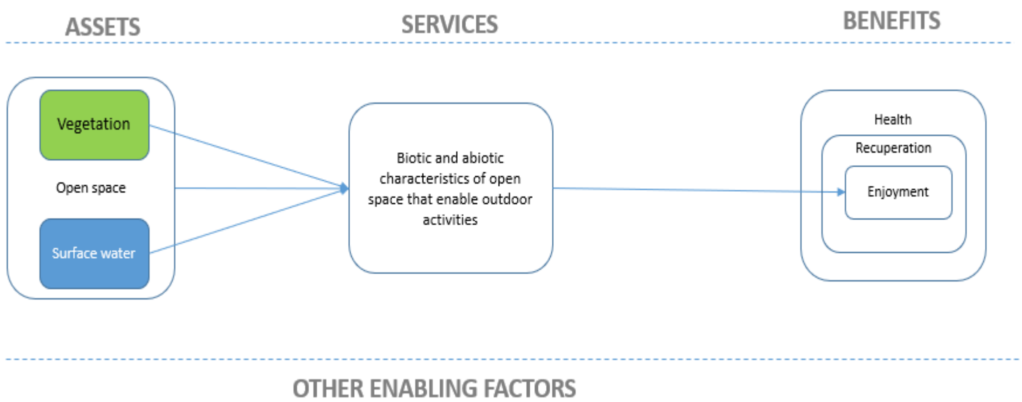


Figure 13. Logic chain for the recreation service.

11.2 Questions and options

The authors identify the following key Questions for Discussion (with some additions by the reviewers):

- Is the concept of information flows useful in describing and defining recreation services and other cultural services?

An important aspect of defining the service is the flow element. Most papers presented in the January 2019 SEEA EEA revision meeting in New York stressed the importance of a service being a flow. However, the definition of Obst and Barton, strictly speaking, does not comprise a flow since the definition stresses the characteristics or properties of the area, as also recognised by the authors. Another question that may or may not be relevant is: how about an area that provides excellent biotic and abiotic characteristics that enable health, recuperation and enjoyment through outdoor activities' – but that is so remote that nobody visits? Or that is not remote but private property with no access allowed? Perhaps proximity to people and access are implicitly included in the abiotic characteristics.

The difference between environmental features and the service flow is explicitly addressed in the application undertaken for the EU (Vallecillo et al. 2019), where the Ecosystem Potential (where all the biophysical characteristics are quantified together with accessibility) interacts with the Demand (represented by inhabitants living at different distances from the natural attraction spot). From this interaction the actual flow is assessed in physical terms as number of potential visits and in monetary terms with the travel cost method.

An alternative is to frame this service more in terms of 'information flows' (i.e. from the ecosystem to people). These flows depend, as other services, upon demand for people for information (e.g. a visually attractive landscape during recreational activities) and upon the capacity of ecosystem to supply such information flows (e.g. the 'natural beauty' of the landscape). In the first conceptualization and typology of ecosystem services (Van der Maarel and Dauvellier 1978, unfortunately in Dutch) indeed the authors use the term information services not cultural services. A potentially interesting element is that increasingly voluntarily shared georeferenced data on the internet allows tracking and quantifying these interactions, in terms of number of people, type of activity (cycling, hiking, photography).

A potential question for the June 2019 meeting in Glen Cove is if the current definition as proposed by Obst and Barton is specific enough (in terms of connecting the service to a flow) and/or if it would be potentially relevant to further explore how the concept of information flows could be used to further substantiate the service.

- What is/should be the role of the abiotic characteristics in the supply of ecosystem services?

A potential consideration is that even abiotic characteristics may be partially shaped by biotic processes in the past (e.g. under a different climate). Another consideration is that it may confuse users if they would have had to disentangle abiotic and biotic contributions to recreation in natural landscapes, and perhaps find out that some tourist landmarks would not be considered relevant for SEEA ecosystem accounting.

- Do we need to more clearly distinguish between the concepts of condition and capacity?
- Should 'characteristics of the ecosystem enabling recreation' (CICES approach) be conceptualized as the recreation service, or as ecosystem condition for recreation?
- The concepts of recreation services and benefits seem to have a number of layers, and depending on the answer to the question above may be overlapping – can these be better described?
- Is there a notion of primary and secondary ecosystem services arising from a single interaction with an ecosystem and if so, how should this be treated?
- How can we best use information on demand curves estimated with respect to benefits arising from ecosystem services?
- How compatible do the institutional assumptions of simulated accounting price methods have to be with the current institutional context?
- How can we take advantage of the methodological triangulation strengths of travel choice, simulated exchange value and hedonic property pricing to value recreation services while avoiding double counting?
- How can we compute standardised accounting units of 'greenspace of good condition' for recreation accounting and valuation purposes?
- Can we sort pricing methods into tiers by cost/complexity?

Additional questions that may be considered for discussion

- Should recreation and tourism be differentiated?

The UK accounts do not distinguish between tourism and recreation, defining recreation as follows: 'Recreational visits in nature are valued based on expenditure on that trip (that is, fuel, public transport costs, admission charges and parking fees). This expenditure is currently assumed to proxy a marginal price for accessing the site. It is therefore an exchange value.' (Source: DEFRA Urban ecosystem account, 2018). The Netherlands ecosystem account on the other hand do differentiate between them, defining tourism as involving overnight stays (and including costs of overnight stays in the value of this service). Both approaches see to have advantages and disadvantages. When the two are separated, it is hard to attribute expenses of visitors to sites to tourists or recreationists (i.e. people visiting on a day trip from their regular home). On the other hand, users of the accounts may be interested in better understanding the economic importance of the tourism sector in their area of interest, based on the assumption that tourists generate additional income.

- Is the term open space specific enough?

In the definition of the service the term open space is used. A question is if dense forests also qualify as open space, and if green zones that have buildings spread out in the area are open spaces.

12. Habitat and biodiversity related services

Steven King, Simon Ferrier, Kerry Turner and Tomas Badura

12.1 Review and synthesis

(extract from the paper by King et al. with minimal changes)

This paper by King et al. presents arguably the most complicated element of SEEA accounting. Again, this review paper can only provide a brief synthesis and elicit some key questions and discussion points, in particular also on biodiversity vis-a-vis (other) ecosystem services. A key point of discussion which is very well tackled in the paper is what is the ecosystem service related to biodiversity? The authors present a number of proposals that are reflected upon below in section 10.2.

As in previous SEEA-EEA documentation, King et al. adopt the Convention on Biological Diversity's (CBD's) definition of biodiversity as: *"the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"* (https://www.cbd.int/doc/legal/cbd-en.pdf). Note the strong emphasis on biological "variability" or "diversity" in this definition, an emphasis previously highlighted by the SEEA Experimental Ecosystem Accounting: Technical Recommendations report (2018).

This emphasis has important implications for any consideration of the relationship between biodiversity and ecosystem services in ecosystem accounting. Such consideration needs to focus specifically on the potential values of, or roles played by, diversity itself at multiple levels of biological organisation, or at least of the components comprising this diversity (e.g. individual species as components of species diversity). We therefore regard as 'out of scope' any assessment of services as a function of the overall amount of biological material within an ecosystem (e.g. biomass), or the overall functioning of that system (e.g. primary productivity), without explicitly considering the diversity of organisms underpinning these system-level attributes. Such services are addressed by other papers in this series.

A similar caveat applies here to our use of the term "habitat" which is defined by the CBD as *"the place or type of site where an organism or population naturally occurs"* (https://www.cbd.int/doc/legal/cbd-en.pdf). A forest, for example, qualifies as habitat only in the sense that it provides suitable conditions for particular organisms to live - i.e. it supports the existence and persistence of biodiversity. We therefore regard the role that this same forest might play in, for example, sequestering carbon as a function of the overall biomass and/or functioning of this ecosystem as, again, falling outside the scope of "habitat and biodiversity related ecosystem services".

People value biodiversity in many different ways, and a plethora of conceptual frameworks, classifications and typologies have been proposed over the past two decades, in an attempt to make better sense of this complexity. Here the authors adopt the relatively simple typology proposed by Bolt et al. (2016) (Figure 14) to frame our discussion of biodiversity values in an ecosystem accounting context. However, in doing so, they cross-reference this typology to two other prominent typologies: 1) the well-known classification of ecosystem services employed originally in the Millennium Ecosystem Assessment (MA, 2005), and later adapted and extended in the Common International Classification of Ecosystem Services (CICES v 5.1); and 2) the relatively recent typology of "Nature's contributions to people" proposed by the Intergovernmental Platform for Biodiversity and Ecosystem Services, IPBES (Pascual et al 2017). (See Figure 14)

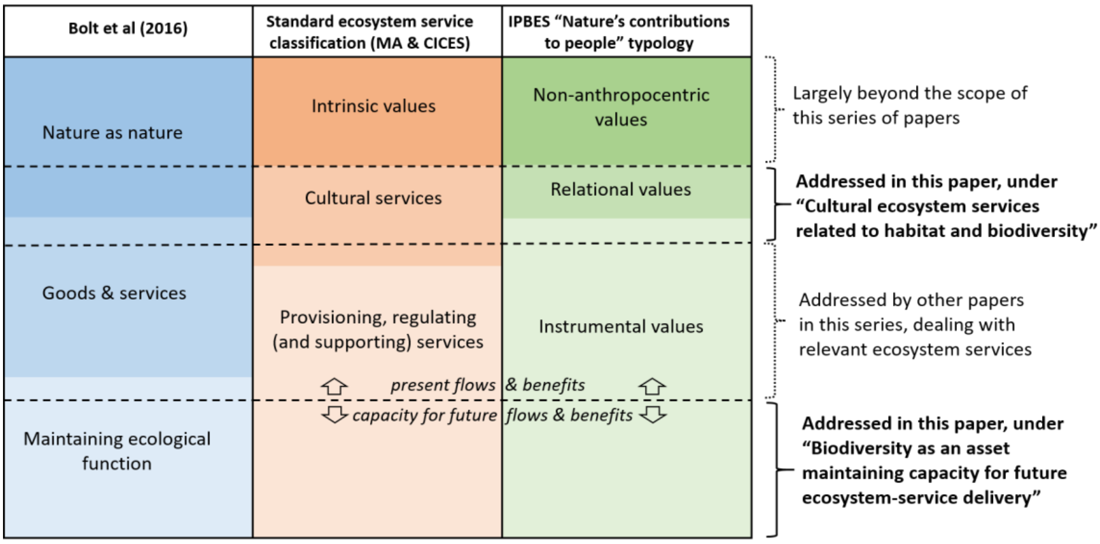
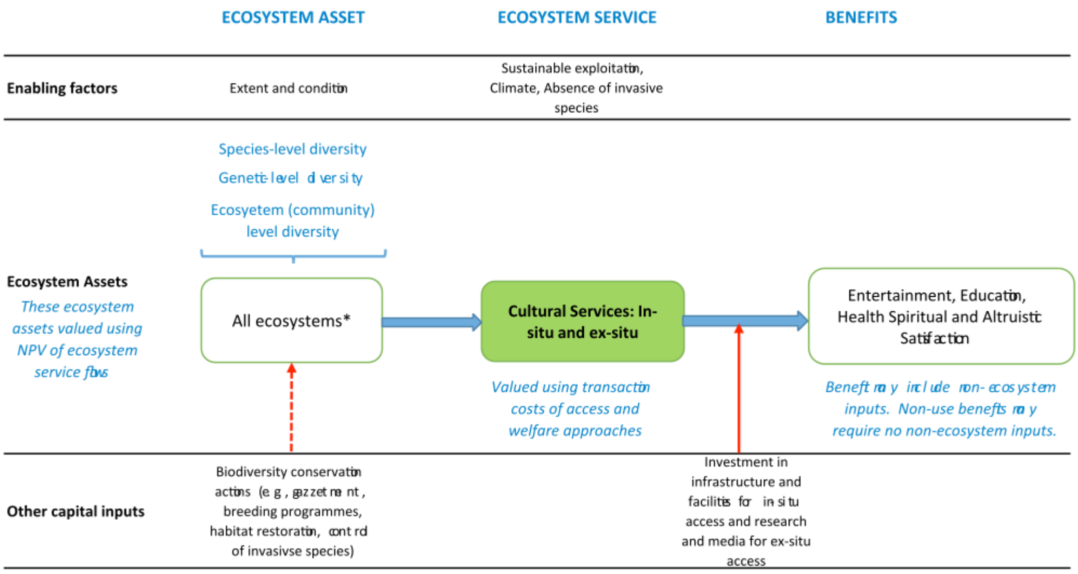


Figure 14. Cross-linkages between major typologies, or classifications, of biodiversity values and associated services, and the topics addressed in this paper

Ecosystem services include inputs that are not physically consumed but do support some form of in-situ interaction. These form part of the bundle of **Cultural Ecosystem Services** and include recreation, education and aesthetic appreciation of habitat and biodiversity and the benefits they brings. For example, national parks that provide habitat for iconic species that attract tourists and habitats that support species that provide opportunities for education. Our treatment of cultural services in this paper focuses on those services not already addressed in the papers on "Nature based tourism related services" and "Urban recreation related services".

Nature as nature: This relates to the way that stocks of habitats and biodiversity are perceived by people (either in-situ or remotely). They include public preferences for maintaining the extent and condition of key habitats and addressing species population loss because they value its existence for themselves and/or wish the benefits biodiversity provides to be available to others (bequest value) now and in the future. They also include the symbolic and spiritual recognition of habitats and biodiversity people may have, such as national emblems or totemic species. In addition, they also provide material for entertainment, such as nature films. Many of these values can also be viewed as forming part of the **Cultural Ecosystem Services** bundle provided by habitats and biodiversity, and are therefore addressed as such in this paper. However, stricter non-anthropocentric perspectives on the intrinsic value of biodiversity are considered as falling outside the scope of this, or any other paper, in the series (Figure 1).

Maintaining ecological function: Another crucial value of biodiversity highlighted in Figure 1 is its importance in the maintenance of ecological systems and functions that underpin the ongoing delivery of ecosystem goods and services into the future (Bolt et al., 2016). For example, the role of biodiversity in cycling energy, nutrients and other materials through the environment. Maintaining a diversity of habitat types and communities of species is key to sustaining healthy ecological functioning. In this context the *resilience of ecosystems* to tolerate shocks and disturbance yet maintain the same level of ecological functioning is prime concern (e.g., in the context of climate change). Different habitats and species can contribute to ecological functioning in similar ways, yet respond to differently. As such, maintaining a diversity of habitat types and species is also crucial to maintaining the resilience of ecosystems. We here combine consideration of this perspective with that of another forward-looking perspective on the contribution of biodiversity to maintaining capacity for future service delivery and the provision of an insurance service i.e. "option value". These forward-looking perspectives on the value of biodiversity as an asset are generally missing from the broad assessment of ecosystem services. Part of this stems from the need to focus on final ecosystem services and avoid issues of double counting that may emerge when including the value of this aspect of biodiversity ecosystem service accounts. Nonetheless, biodiversity is clearly a critical asset for maintaining the capacity of ecosystems and ecosystem complexes to deliver goods and services into the future and this should be a fundamental ecosystem accounting concern.



Notes: *There exists an important trade-off to consider in the management of biodiversity for current versus future ecosystem services supply.

Figure 15. Logic chain for biodiversity related cultural ecosystem services

In order to characterise the ecosystem service flow in physical terms a measure is required that tangibly represents the magnitude of the interaction between beneficiaries and biodiversity and habitat stocks (i.e., the level of demand). For direct interactions, this is conceptually reasonably straightforward and can be measured in terms of visit frequency and time spent enjoying the interaction. These types of measure are routinely used in estimating nature based recreation services. They also lend themselves to characterising the cultural ecosystem service flows derived via aesthetic experiences of nature, experiences in cultural landscapes associated with semi-natural ecosystems, ecological knowledge or education services related to biodiversity and habitats captured in Table 1.

- Number of visits to experience the interaction (e.g., national park visitor counts, number of visits to nature sites of cultural significance, number of students on nature based field trips)

- Time engaged experiencing the interaction (e.g., volunteered hours for conservation activities, hours engaged in on-site ecological research, hours engaged in landscape painting)

12.2 Questions and options

A first observation is that King et al. have prepared a very elaborate overview of all cultural services that can be related to biodiversity (as well as an in-depth text on how to measure biodiversity as an asset considering also aspects such as resilience). This is also reflected in the logic chain, where biodiversity is connected to all cultural services. Indeed, it may well be that biodiversity contained within ecosystems (and ecosystem diversity itself) contributes to all cultural services. However for accounting purposes it is important to disentangle the different individual services. This raises the following questions – also considering overlap with the paper by Obst and Barton focussing on one specific cultural service (recreation):

- To what degree can an ecosystem service be defined that reflects human appreciation of biodiversity in a narrow sense and without overlap with other services?

The CICES classification provides an entry point with the service with as descriptor "The things in nature that we think should be conserved" and as ecological and use clause:" The biophysical characteristics or qualities of species or ecosystems (settings/landscapes/cultural spaces)…..which people seek to preserve because of their non-utilitarian qualities". Hence this service reflects some kind of human appreciation of biodiversity independent of any use. In this sense this service is different form services that involve recreational use, use for making pictures, for spiritual or religious experiences, etc. The service could be seen as a flow, since it comprises a human appreciation, by a number of people, over a specific period of time. Note this service provides a value for people, not an intrinsic value, derived from for instance a bequest motive. Valuation of such a service in monetary terms, aligned with SNA conventions, is obviously challenging.

Another perspective might consider the international policy targets that see in habitat maintenance the key for human survival. In this case it would not be strictly an appreciation of individuals but the protection of global society. The role of policy and institutions is an option to explore in identifying the demand for the habitat maintenance service.

A clearer distinction between biodiversity's importance for ecosystem functioning (and for other ES's supply) vs. biodiversity as an ES itself (intrinsic, option, existence, bequest values etc.) is needed. It may be helpful to discuss and potentially consider this service in June 2019, also because it would provide a SEEA a service that expresses that people attach importance to protected areas/specific ecosystems for non-use reasons (which is an important motivation for designating areas as protected area in many countries, and an entry point related to this aspect may be expected by users of the accounts).

13. Conclusions

This section presents some tentative conclusions for the three groups of services recognized in the SEEA EEA framework, noting that potentially other categorizations of ecosystem services are also possible.

Provisioning services

The most critical question to be answered is if there should be a difference in recording ecosystem services in managed and natural ecosystems. It is suggested to take this as the starting point for defining provisioning services, since some other choices partly depend upon this as expressed in Table 1. An obvious advantage of doing so is that further alignment with the SNA is obtained. A disadvantage is that it requires the distinction between managed and natural ecosystems and all possible gradients between these two, which may always be to some degree arbitrary. As depicted in Figure 1, such a distinction may always be somewhat arbitrary given that there is a gradient between managed and natural ecosystems. In the main global ecosystem assessments (MA, TEEB, IPBES), the diversity of ecosystems is considered but there is no structural differentiation between ecosystem services generated in managed or natural ecosystems.

If this distinction is made in SEEA it is recommended that SEEA provides detailed guidelines on which type of ecosystems would be considered managed and which would be considered natural. An aspect requiring specific consideration is for instance what to do with plantations where wood is accumulated over a number of years. In the SNA, the annual accumulation is seen as the benefit. If alignment with the SNA is deemed crucial in this regard, then also the ecosystem service would need to be defined as either the ecological contribution to this annual increment or the annual increment itself. In both cases, there is a need to differentiate between natural and managed ecosystems.

Subsequently, it should be decided if services in (managed) ecosystems should be related to outputs or to ecological processes or characteristics (e.g. processes that maintain soil fertility in a farmer's field). Presumably, this should best be done in a consistent manner across different services (timber, crop, fish, no-timber forest products, etc.). Timber is of particular relevance given that there is a market for the ecosystem service itself (if defined as output), i.e. the standing volume of timber (stumpage) just before harvesting. Potentially this concept can be translated to other provisioning services in all or in natural ecosystems (even though for these other services there may not generally be such a market). In this case, the service related to crop provisioning in natural ecosystems could relate to the physical quantity of blueberries that is harvested, at the point in time that these blueberries are harvested. For managed ecosystems, the corresponding physical unit would potentially be the amount of crops in the field that are harvested, at the point in time they are harvested. The harvested crops are the benefit (in physical terms there may be a small difference because of harvest losses). As mentioned, an alternative is to define the service in managed ecosystems such as intensive croplands as the contribution of the ecosystem to the harvest of crops (with the obvious challenge of defining this contribution given that there is a broad range of processes involved. For example, several dozen processes can be identified that are relevant for maintaining the productive capacity of a farmer's field, ranging from earthworm activity to fungi composition and activity, as well as (often related) properties as soil texture, cation exchange capacity, organic matter content, infiltration capacity, etc.

Note that a question needs to be how policy relevant is every single refinement of the SEEA ecosystem services definition. In this context, it is likely to be complicated and time consuming to define this ecological contribution to crop provisioning in physical terms (and perhaps close to impossible in data poor environments), and every solution will be debatable. Another question is how policy relevant a potentially not very accurate indicator is that specifies the ecological contribution to crop production at high resolution and at national scale. This is also because specific information on for instance soil quality can be included in a condition account if policy relevant.

Next, so once the previous choices have been made, it should be examined how to deal with intermediate services relevant for crop and other provisioning services. These include pollination, water regulation/mitigation of extreme events (including wind erosion), perhaps also water purification and soil retention. A key concern is that double counting should be avoided.

Regulating services

A first key issue is how to define the benefits. This has been done quite differently in the various papers on regulating services (compare the Harris et al. and the LaNotte et al. papers). Often if not always there is a spatial trajectory between the area where the service materialises and the area where the benefit occurs. It needs to be noted that the concept of 'intermediate benefits' as introduced by Harris and that is also relevant for all other regulating services for which individual papers were prepared may NOT be occurring in all regulating services, think of for example pollination.

It seems most appealing to define benefits of regulating services as actual benefits to people, cf. Harris et al. (in line with the principle behind defining benefits for provisioning and cultural services). For some services including air filtration and water purification it is potentially relevant to consider an intermediate step in the analysis, i.e. the reduction in pollution levels to which people are – directly or indirectly - exposed. However it seems potentially confusing to use the term intermediate benefits given the difference in concept with intermediate services (as explained in Chapter 5 on air filtration). A question is if both the term intermediate and the term benefit are appropriate, potentially this aspect relates to 'reduction of environmental pollution levels'. Further discussion on this topic is needed.

Even though the paper on carbon sequestration was particularly well developed, the service still poses some challenges in terms of scope and valuation. A key question for further discussion is if indeed carbon storage can be fully disregarded in the ES supply and use account. Note that also in the current carbon account there is no specific entry for avoided emissions due to interventions in the landscape. A potential option is to distinguish between two type of services related to carbon:

- Carbon sequestration (unmanaged)
- Sequestration and avoided emissions from deliberate interventions in the landscape (these may include projects aimed at generating carbon credits from reforestation and carbon projects (REDD+) aimed at generating carbon credits from reduced emission from deforestation, forest degradation, and fire and oxidation in peatlands)

In principle these two flows can be separated and can therefore be added in a country's carbon balance. An advantage of including the second type of services is that it does justice to the major trend globally to develop carbon credit projects, and that the valuation approach for both types of services is quite different (in the second type there is an actual payment and there are costs for managing the landscape and monitoring and verification, note btw that the payments for REDD and reforestation projects are generally around half the payments for carbon in the ETS).

Cultural services

There remains a need to come to a clear definition of cultural services with as main challenge to avoid overlap between these services. There are clear overlaps between tourism and recreation, between recreational opportunities and amenity services, between the presence and appreciation of biodiversity and tourism and recreation, etc. In the end, it seems a matter of selecting the services and defining them in such a way that overlap is minimized, realizing that completely avoiding overlap may be impossible.

An interesting avenue to explore is to what degree information that is voluntarily shared by people on the internet, in combination with data on the presence of people in ecosystems from mobile phone providers, provides a new entry point to assess interactions of people with nature and thereby cultural services. Since these datasets can be interpreted as depicting flows of information from the ecosystem to people (e.g. the natural beauty of an ecosystem is recorded on a photo which may subsequently be posted on-line). An advantage could be that a data-driven approach could help ensure that there is minimal overlap between services, by connecting one source of data to one service (but it needs to be further explored if this is feasible in a broad range of contexts). An obvious limitation is that it does not work for areas where few people use the internet or a mobile phone including the cultural services provided to remote indigenous people. More discussion is required to assess if these information flows are relevant for analyzing cultural services.

A specific challenge relates to the human appreciation of biodiversity. This is considered a service in CICES, is recognized in the paper by King et al., but there is a need to further sharpen the definition of this service, in such a way that it expresses a 'flow' that can be measured annually, i.e. involving a certain number of people and a certain expression of their appreciation. In the pre-SEEA days, Hein et al. (2006) used actual payments (e.g. annual contributions, legates) to an NGO managing a specific site (a main Ramsar wetland in the Netherlands) for the purpose of nature conservation as an indication of the value of this service (with hindsight in a SEEA conform manner) and surprisingly found that this value exceeded all other values including tourism and recreation. Hence, quantification of this service need not be impossible.

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Annex 1. List of papers on individual ES

	Service (or group of services)	Co-ordinators	Technical expert biophysical modelling	Technical expert: Valuation
1	Biomass provisioning services from agricultural and forestry activity, including input services such as pollination services	Lars Hein (Wageningen University)	Gem Castillo (Resource and Environmental Economics Foundation of the Philippines, Inc. (REAP)) Silvia Cerilli (FAO)	Jane Turpie (Anchor Environmental Consultants)
2	Biomass provisioning services from fisheries activity, including input services such as nursery services	Anthony Dvarskas (Stony Brook University)	Beth Fulton (CSIRO)	Eli Fenichel (Yale)
3	Sediment/soil retention services	Benjamin Burkhard (Leibniz Universität Hannover)	Carlos Guerra (iDiv)	Brynhildur Davidsdottir (University of Iceland)
4	Air filtration services	Rocky Harris (DEFRA, UK)	Stefan Reis (CEH) Laurence Jones (Centre for Ecology and Hydrology, UK) David Nowak (Forest service, US)	Giles Atkinson (LSE) Matthew Agarwala (University of East Anglia)
5	Water purification services	Alessandra La Notte (JRC, EU)	Sergio Vallesi (Durham) Bruna Grizzetti (JRC, EU)	Silvia Ferrini (UEA)
6	Carbon sequestration and storage services	Bram Edens (UNSD)	Emil Ivanov (University of Nottingham)	Peter Elsasser (Thuenen Institute)
7	Water regulation services for mitigating extreme events	Neville Crossman	Stoyan Nedkov (Bulgarian Academy Sciences)	Luke Brander (VU University Amsterdam)
8	Water supply services	Rosimeiry Portela (Conservation International)	Maira Bezerra (CI) Kashif Shaad (CI)	Onil Banerjee (IADB) Mahbubul Alam (CI)
10	Urban and nature-based recreation services	David Barton (NINA, Norway) Carl Obst (UNSD consultant)	Timon McPhearson (New School, NY) Grazia Zulian (JRC) Payam Dadvand (ISGlobal) Thomas Randrup (SLU, Sweden) Ilan Havinga(WUR, NL) Lars Hein(WUR,NL)	Alejandro Caparros (CSIC, Spain) Brett Day (Exeter)
11	Habitat and biodiversity related services	Steven King (UNEP-WCMC)	Simon Ferrier (CSIRO)	Kerry Turner (UEA) Tomas Badura (UEA)

Annex 2. Cross-cutting issues

This Annex lists the cross-cutting issues that were identified during the process of drafting of papers by WG4 and that were discussed at the expert meeting in January 2019, building upon the paper produced by Carl in February 2019 and considering comments provided by rocky on this paper. The issues are listed below. They are the topic of a separate paper.

1. Determining links between ecosystem services
(note that this is partly covered in the current paper)

2. Intermediate versus final services

3. Services that prevent/reduce externalities such as fire or CO2 emissions form drained, degraded peatlands.

4. Treatment of mediated and unmediated pollutants and the description of “sink” services

5. Role of abiotic components of the ecosystem

6. The treatment of use of space

7. Spatial allocation of services to ecosystem assets and the bundling of services

8. Defining the counterfactual for quantification of the ecosystem service flow

9. Distinguishing outputs, outcomes and benefits

10. Treatment of the SNA distinction between cultivated and natural production processes

11. Treatment of recreational and subsistence fishing: two cross-cutting issues but both concerning the harvest of biological resources.

12. Green water