System of Environmental Economic Accounting

Discussion paper on ecosystem services: Towards a classification of ecosystem services for SEEA

for the Forum of Experts in SEEA Experimental Ecosystem Accounting 2018

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SEEA

1 One page synthesis

This paper is prepared to support the discussions on ecosystem services classification for SEEA Experimental Ecosystem Accounting, specifically during the 17 to 20 June 2018 technical meeting in New York. The pursued classification is targeted at supporting the identification and classification of ecosystem services for environmental economic accounting (SEEA).

The paper first provides a background to ecosystem services classification, subsequently it describes the key challenges as identified in the discussions within the SEEA EEA technical committee, it synthesizes some key considerations in designing a classification system for ecosystem services for SEEA, and it sketches a number of very preliminary proposals for classification, as a basis for discussion.

During the New York meeting it is scheduled to discuss the following specific topics in break out group#3 (on services classification):

- What are the general premises / what is a suitable overall classification system for classifying ecosystem services for SEEA EEA?
- Can an agreement be reached on a list of 10 specific ecosystem services, and how these services lead to benefits for economic users? (see Section 6 and Annex 1 as inputs into the discussion)
- Can agreement be reached on specific key concerns in putting together a classification system for ecosystem services in support of SEEA EEA (as described in Section 6 below)
- What further process can be followed to come to a common, agreed classification system? (including further stakeholder consultations)

2 Introduction

Background

1. This note is prepared in order to move forward with the classification of ecosystem services for the purpose of SEEA Experimental Ecosystem Accounting (SEEA EEA), also referred to in this document as ecosystem accounting. In ecosystem accounting it is important to have a comprehensive and consistent classification of ecosystem services (ES), in order to guide the compilation of the physical and monetary ecosystem services use and supply account (these are the terms used in the SEEA EEA). Ecosystem services are central to ecosystem accounting: ecosystems are accounted for in terms of assets (reflected in extent, condition and monetary asset value), and ecosystem services. This dual analysis of ecosystem assets and services provides a comprehensive picture of the relation between ecosystems and human consumption and production dependent upon ecosystems.

2. The relation between ecosystems and people is complex. People depend for their physical well-being on ecosystems (food, products, oxygen), ecosystems contribute to their mental well-being (identity, enjoyment of nature, recreation). Societal views on this relationship vary from economic ('nature delivers services to us') to holistic ('we are part of nature'), as discussed in the next paragraph. A first, related question is if the relation between people and their living environment should be classified in terms of ecosystems or nature. 'Nature' is a broader term that encompasses ecosystems but is less reductionist, i.e. does not imply that nature can be subdivided in specific 'ecosystems'. In accounting, these contributions to people are determined by ecosystem (see the SEEA EEA framework for details), although it is recognised that many of these contributions depend upon an aggregate of interacting ecosystems, e.g. in a landscape (for instance recreation may depend upon the overall landscape rather than specific ecosystems within the landscape).

3. Ecosystem accounting specifically aims at capturing the *flow of contributions to human production, consumption and wellbeing, including both material and non-material contributions, in relation to the condition of these ecosystems*. This is a specific aspect of the broader perspective on interactions between people and nature covered by the Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES). For example, IPBES also specifically captures 'disservices', i.e. negative interactions between people and ecosystems for example those resulting from pest and carnivores eating livestock. By definition, the approach of accounting is reductionist, as 'nature' is divided in ecosystems, and the various contributions of ecosystems are divided into individual services/categories. Therefore, ecosystem accounting covers a specific measurement aspect of the IPBES framework (e.g. Diaz et al., 2017) and these frameworks should be seen as complementary, with ecosystem accounting facilitating a measurement of ecosystem services and ecosystem assets, and the IPBES framework providing a broader conceptualisation and societal framing of the relation between people and nature.

4. The SEEA EEA framework is also complementary to the measurement framework of the Resilience Alliance (see e.g. Walker et al., 2006). The work of the Resilience Alliance is grounded in ecology, but has been broadened to include a range of other disciplines. Its core areas of expertise relate to the complex dynamics of ecosystems, the presence of tipping points in ecosystems (to be

considered in establishing a safe operating space for management of the planet), and there is a specific interest in connecting processes operating across spatial and temporal scales. Often, a long-term perspective is taken. In ecosystem accounting a medium-term perspective is taken in the monetary ecosystem asset account, where the expected flow of ecosystem services during a specific discounting period is considered (often 20 or 25 years, although 50 years has also been applied). Insights from the Resilience Alliance and the safe operating space paradigm are relevant for defining indicators for ecosystem condition (in the condition accounts) and for analysing expected flows of services in the presence of potential thresholds in ecosystem dynamics. However longer term considerations in ecosystem dynamics and ecosystem services supply, and the ecological complexities of ecosystem thresholds and multi-scale processes are not covered well in the SEEA EEA. The SEEA and the safe operating space frameworks should be seen as providing complementary information for environmental management.

5. The added value of the SEEA EEA, also in relation to other frameworks for analysing ecosystems and human dependencies on ecosystems, is that the SEEA brings statistical rigour to the analysis of ecosystem services and ecosystem assets and that it allows connecting part of the ecosystem-human interactions and the national accounting system. The latter has the advantage that data from the national accounts can readily be used to analyse ecosystem services and ecosystem assets, and that changes in ecosystem condition and services can be compared in a consistent manner with economic indicators.

6. Clearly, the SEEA EEA does not intend to provide assessments of 'the total value of nature' – the focus is on measuring the contribution of ecosystems to human consumption and production in a manner that is consistent with national accounts. The information of the SEEA EEA on ecosystem services and ecosystem assets is comprehensive, systematically organised, intended to be made broadly accessible, often new for policy makers and the public alike, but not meant to provide the sole information basis for ecosystem management. Consideration of long-term, multi-scale sustainability issues requires consideration of the various insights from, for instance, the Resilience Alliance, and a broader perspective on nature-human relationships offered by IPBES. The ecosystem services classification of the SEEA EEA should be seen as instrumental to this goal, i.e. to form an international classification system for environmental-economic accounting

7. The ecosystem services classification of the SEEA EEA to be developed is meant to support ecosystem accounting. This means it is developed in such a way that it captures the various services provided by ecosystems while consistency with the System of National Accounts (SNA) is achieved. The SNA has been developed over a period of over 50 years and is the global standard for national economic statistics including indicators such as GDP.

Objectives of the paper

8. The classification of ecosystem services is an important aspect of measurement since classifications can provide important guidance to ensure that an appropriate breadth and depth of measurement is undertaken or, at least, that individual measures are understood within a broader context. A classification can operate as a checklist and be applied in initial discussions by considering

each ecosystem type (ET) and noting those ecosystem services that are considered most likely to be generated from that ET. The resultant "baskets" of services for each ET can aid in discussion of the role of accounting, the structuring of information, the assessment of resources required for compilation and generally communicating the message about the relationship between ecosystems and economic and human activity. In this context, Choices on classifications are normative, as they determine the scope, the boundaries, the resolution and the aggregation effects of data and information. Therefore, the impact of classification choices on the capability to answer to societal questions has to be kept in mind, as these very question provide mandate and relevance to the accounts.

9. This paper presents a first proposal on how to classify ecosystem services for SEEA EEA. The paper starts with a brief overview of existing classification systems (Chapter 2) and a synthesis of earlier discussions held in the context of the SEEA EEA as recorded in the SEEA EEA framework and Technical Recommendations (Chapter 3). Subsequently, key challenges as identified in the previous discussions related to defining and classifying ecosystem services are listed (Chapter 4). Then, the requirements for a classification system for SEEA EEA are explored (Chapter 5). This leads to a preliminary set up of a classification for ecosystem services for SEEA EEA (Chapter 6) – as a basis for discussion. Annex A presents further details including a description of selected provisioning (Table A.1), regulating (Table A.2) and cultural services (Table A.3). The description also includes proposals for indicators for measuring benefits related to each of the listed ecosystem services, and for physical and monetary indicators for these services. Hence, Chapter 6 and Annex A jointly present a tentative set up of a classification system as a basis for discussion.

10. This paper draws from a range of existing classifications, including IPBES, CICES, MAES, FEGS-CS, NESCS, TEEB, and the Millennium Ecosystem Assessment. Differences between these previous classification systems show that classifying ecosystem services is difficult (the first classification of ecosystem services including four types of services was published exactly 40 years ago; Van der Maarel and Dauvellier, 1978). It can be concluded that it is challenging to provide an ecosystem services classification that is suitable for all intents and purposes, however, as mentioned, the currently discussed classification is meant to support the development of ecosystem accounts.

11. The proposal of this note should be seen as a 'first proposal', i.e. as a basis for discussing within the SEEA community and with other stakeholders such as IPBES and the Ecosystem Services Partnership. Following the June 2018 meeting in New York, this draft note will be updated into a final consultation document, based on the discussions to be held. Subsequently, further testing and evaluation of the classification is required, with the aim of producing a tested and generally agreed system for classifying ecosystem services in the context of SEEA by around 2020. This effort is part of the UNSD coordinated program towards developing a standard for SEEA EEA.

12. The paper draws strongly from the SEEA EEA framework, and the SEEA EEA Technical Recommendations (TR), in order to ensure full consistency with these previous documents. The insights presented in the note are based on a review of the relevant scientific literature, the various classification systems proposed in global ecosystem assessments (MA, TEEB, IPBES), the CICES classification, and the various documents produced in the context of the UN SEEA consultation process on ecosystem services classification (e.g. UN et al., 2016; Obst et al., 2017). Where feasible (while

adhering to accounting principles), it is proposed to align with CICES, which represents a framework for ecosystem services classification that has undergone much thinking in the past decade. The US EPA NESCS and FEGS-CS frameworks are also explicitly considered.

13. The paper also discusses some of the key, earlier raised challenges for ecosystem services classification as identified in Obst (2017), and presents a number of first, tentative thoughts on how they could be addressed. To a degree, these thoughts are incorporated in the set-up of an ecosystem services classification system presented in Chapter 6 – first section.

3 Classification systems for ecosystem services

14. The Millennium Ecosystem Assessment (MA) published in 2005 (MA, 2005) proposed a classification based on the four categories of provisioning, regulating, cultural and supporting services. The MA interpreted ecosystem services as the benefits provided by ecosystems, for example, crops harvested or timber produced in either a plantation or a natural forest. Subsequent work in the context of the TEEB (The Economics of Ecosystems and Biodiversity) study (TEEB, 2010), the MAES initiative (Maes, et al., 2014) and the Inter-governmental Platform on Biodiversity and Ecosystem Services (IPBES) have further developed the concept of ecosystem services, and provided further evidence of the potential of the ecosystem services approach in understanding the relationship between humans and the environment. Each of these global or regional assessments has yielded a new classification system for ecosystem services. The conceptualisation of ecosystem services also changed, with TEEB defining ecosystem services as 'the contributions of ecosystems to human well-being'. This idea was broadened in the IPBES, which includes the broader conceptualisations of 'values of nature itself', 'nature's contributions to people (NCPs)' and categories of 'good quality of life', as discussed below.

15. The Common International Classification of Ecosystem Services (CICES) developed from the work on environmental accounting undertaken by the European Environment Agency (EEA). CICES has been updated to Version 5.1 in 2017. CICES has been adopted for mapping work on the European Union's MAES project (Maes, et al., 2014), and the classification included in the SEEA EEA in System of Environmental-Economic Accounting 2012 was an interim version of CICES. The proposals in this document build upon CICES 5.1 as well as other developments such as NESCS (see below). CICES focusses on ecosystem services, and does not explicitly link to (classes of) nature/ecosystems on the one hand or societal/economic benefits or beneficiaries on the other.

16. The United States Environmental Protection Agency (US EPA) developed an alternative classification system for final ecosystem goods and services (FEGS-CS) (Landers and Nahlik, 2013) and the associated National Ecosystem Service Classification System (NESCS) (US EPA, 2015). This work places attention on the links between ecosystem types and the classification of beneficiaries from the final services supplied by those ecosystem types. NESCS is strongly informing the initial development of U.S. ecosystem accounts, and discussions are ongoing on the alignments between CICES, NESCS and SEEA.

17. The classification systems of CICES and NESCS can be seen as complementary. The CICES focuses on defining services following a hierarchical structure based on types of uses, and types of flows. The NESCS provides a systemic approach to classification including nested hierarchical

structures for types of ecosystems, types of ecological endpoints, types of uses and types of beneficiaries. The FEGS-CS provides a systemic approach to classification including types of ecosystems and types of use-beneficiary combinations.

18. The IPBES uses three value dimensions to analyse ecosystem-people interactions. First, the 'values of nature' represent the non-anthropocentric values which can be reflected as ecosystem health, ecosystem condition, diversity as well as intrinsic values. These are the linked to the second category: 'values instrumental to humans as options to provide NCP', much like the supporting service concept in the MEA. Third, the services, or nature contributions to people in IPBES terms, are "*all the contributions, both positive and negative, of living nature to people's quality of life*". NCP include 18 reporting categories in three broad groups of material, non-material and/or regulating NCP. IPBES states that the NCP are provided by particular organisms, by ecosystems, or by particular mixtures of organisms, assembled naturally (e.g. the assemblage of pollinators in a landscape) or artificially (e.g. a planted grove, or a plant mixture on a green roof) (Diaz et al., 2018). NCPs in the IPBES interpretation can be positive or negative according to the cultural and socio-economic context of the stakeholders, or even perceived as benefits or decrements by same stakeholder group according to the spatial or temporal context. IPBES acknowledges the importance of political and cultural context of NCP, which influences the level and way of using the ecosystem, and the (type of) value attached to this use. Finally, the broad socio-economic benefits provide by NCP are categorized in diverse aspects of 'good quality of life', which can serve as a compass to determine quantification and qualification indicators.

19. There are both differences and similarities between the various existing classification systems. A common element is that the various systems differentiate between ecosystem assets, ecosystem services and economic units in SEEA EEA terms. Differences pertain to, in particular, the exact definition of services or NCPs, categories and type of services (/NCPs) included and distinguished. On the service categories, TEEB as well as IPBES include the category of 'habitat services / habitat NCPs'. CICES 5.1 distinguishes not only between broad classes ("sections") of services but also between divisions, groups and classes, with an example of a class being: 'Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes'. CICES is particularly comprehensive, identifying 59 classes of biotic ecosystem services (plus 31 'abiotic' ecosystem services such as providing opportunities to extract geothermal energy). FEGS are defined as the "components of nature, directly enjoyed, consumed or used to yield human well-being" (Landers and Nahlik, 2013), and assume an ecological production function leading to an ecosystem service that is subsequently input into an economic production function. Ecosystem services are identified based on ecosystem or landscape generating the ecological production function, and the stakeholder using the ecosystem services in an economic production function.

4 Defining ecosystem services for SEEA EEA

20. The following paragraphs provide a brief summary of the framing for ecosystem services in the SEEA EEA, drawing from the SEEA EEA TR. In ecosystem accounting following SEEA EEA (UN et al., 2018), each ecosystem asset generates a set or basket of final ecosystem services which are defined as contributions to the production of benefits to economic users including households, firms and the

government. Final ecosystem services encompass a wide range of services provided to economic units (businesses, governments and households) and may be grouped into provisioning services (i.e. those relating to the supply of food, fibre, fuel and water); regulating services (i.e. those relating to actions of filtration, purification, regulation and maintenance of air, water, soil, habitat and climate) and cultural services (i.e. those relating to the activities of individuals in, or associated with, ecosystems resulting in non-material benefits).

21. Note that CICES uses the label 'regulation and maintenance services' rather than 'regulating services/NCPs' (as in MA, TEEB and IPBES)'. This section of services is defined as 'all the ways in which living organisms can mediate or moderate the ambient environment that affects human health, safety or comfort, together with abiotic equivalents'. It is noteworthy that in Haines-Young and Potschin (2018), it is stated that "'Mediation of Flows' and 'Maintenance of physical, chemical and biological conditions' have been merged into a single Division 'Regulation of physical, chemical, biological conditions'; this was done because it was conceptually difficult to conceptually separate the regulation of flows from the mediation of physical conditions.". Hence, given that : (i) it is important that an ecosystem services classification for SEEA builds upon the SEEA EEA framework and technical recommendations; (ii) it is considered useful to align the SEEA ecosystem services classification not only with CICES but also with MA, TEEB and IPBES; (iii) the distinction between maintenance and regulation is not always straightforward as eluded in Haines-Young and Potschin (2018); and (iv) there is no strong argument to use the longer term 'regulation and maintenance' compared to the shorter term 'regulating', it is proposed to maintain the use of the term 'regulating services' in SEEA EEA.

22. Benefits may be either *SNA benefits* - goods or services (products) produced by economic units (e.g. food, water, clothing, shelter, recreation) currently included in the economic production boundary of the SNA; or *non-SNA benefits* – benefits that accrue to individuals, or society generally, that are not produced by economic units (e.g. cleaner air) (UN et al., 2018).

23. In the accounting system, for each supply of final ecosystem services there is a corresponding use that leads to the production of either an SNA or non-SNA benefit. Further, in each sequence of use of ecosystem services and production of benefits there is an associated user or beneficiary being an economic unit – business, government or household. Thus, every final ecosystem service flow represents an exchange between an ecosystem asset (as a producing/supplying unit in the accounting system) and an economic unit (UN et al., 2017).

24. The actual flows of ecosystem services supplied by ecosystem types and used by economic units including households (corresponding to beneficiaries in other systems) during an accounting period (e.g. a year) are recorded in the physical and monetary ecosystem services supply and use account records. The scope does not extend to measuring the broader costs and benefits that may arise from increased or reduced consumption such as health and social outcomes (which appears to be in-scope in the IPBES framework). Thus, ecosystem accounting does not provide a social welfare perspective on the relationship between people and the environment, and consequently does not provide information on social sustainability or equity/justice of the use of ecosystems. As stated in the SEEA EEA framework, the SEEA EEA has not been designed with the aim of being the sole information basis for making decisions on ecosystems.

25. For accounting purposes, the concept of the supply of ecosystem services is that supply is equal to the use or receipt of the services during an accounting period. That is, supply is not recorded if there is no corresponding use. It may be relevant to measure the potential or sustainable level of supply that could be delivered by an ecosystem asset (the corresponding concepts of potential supply and ecosystem capacity are further discussed in the SEEA EEA TR). However, they are not the focus of measurement in the supply and use accounts. The monetary asset account, and the physical and monetary ecosystem services accounts do not provide information on ecological sustainability of the use of ecosystems. However, sustainability of ecosystem management can be inferred from the recording of changes in the condition account as well as in the capacity account.

26. Recording supply as equal to use reflects that, from an accounting perspective, ecosystem services are considered to reflect revealed transactions or exchanges that take place between ecosystem assets on the one hand and economic units (businesses, households, governments) on the other. It is implicitly assumed that each transaction is distinct and hence each ecosystem service is separable.

27. The SEEA EEA TR provides the following clarification of the three categories of ES. In cultivated biological resources, supplying for example crops, plantation timber, and aquaculture fish, benefits (e.g. wheat, timber, shrimps) are produced as a combination of final ecosystem services and human inputs. In semi-natural ecosystems the degree of control of people over the resource is smaller. In the SNA, outputs of cultivated ecosystems are recorded in terms of annual increases in volume (not harvest). Outputs of natural ecosystems are recorded at the time of harvest. The underlying logic is that the growth of cultivated assets such as plantation forests requires inputs over a number of years before harvests can take place – and in these years the accounts can record inputs as well as outputs (in terms of accumulation of volume). A further consideration for SEEA EEA is that in case of cultivated systems all products will be harvested, except in case of losses due to unforeseen circumstances (e.g. fire, storm). In natural systems, part of the product (e.g. timber) may remain in the ecosystem and only part of this may be harvested (however there are also logging systems involving clear felling at regular intervals). Note that in both cultivated and natural biological resources, benefits (i.e. outputs) are a result of the combined use of natural capital and other capital and inputs.

28. For regulating services, there are generally no direct human inputs consumed in the production of benefits (although there may be economic activity associated with managing or altering an ecosystem to support the generation of such services, e.g. in establishing vegetation as part of a carbon capture program). However, note that the description of the service and the benefit will be different. Thus, the description of the service will reflect the action of the ecosystem asset – sequestering carbon or capturing air-borne pollutants, while the benefits should be described in terms of increased stability of climate and cleaner air. Note that there may be costs incurred in establishing or maintaining an ecosystem to support the supply of regulating services (which would be recorded in the SNA as well as potentially, as environmental expenditures, in the SEEA CF). It needs to be discussed if and how such costs can be considered direct inputs to the generation of regulating services in all cases or only in specific cases (e.g. when the costs are made with the specific intention of providing a regulating services such as in the case of reforestation projects for carbon capture).

29. For cultural services, the contribution of ecosystems is relatively passive in that it is commonly the ecosystem providing opportunities for people to engage in activities, learning experiences and the

like. Costs may be incurred to facilitate people benefiting from these services, such as the construction of cycling or hiking paths, visitor facilities, etc. Often, cultural services are conceptualised in terms of the benefits that people receive from the engagement with ecosystems. The challenge for ecosystem accounting is to estimate the contribution of the ecosystem itself to the generation of benefits (UN et al., 2018).

5 Challenges in defining ecosystem services

30. It is clear from comparing the various classification systems that there are major challenges in coming to a broadly acceptable categorisation and list of ecosystem services, even for the specific purpose of ecosystem accounting. As noted above, the purpose of this document is to explore how to best design a classification for the purpose of ecosystem accounting, and to put forward several preliminary proposals for such a classification as a basis for discussion. As much as possible, the note tries to address some of the challenges raised in developing such a classification system, as identified in the SEEA EEA TR, and the note 'Research themes' (see Obst, 2017 for details):

- Clarify the boundary between ecosystem services and benefits, especially in relation to cultivated crops
- Describe approaches to the allocation of ecosystem services to individual ecosystem assets in situations where services are generated in landscapes with a mix of ecosystem types
- Clarify the boundary of non-SNA benefits
- Clarify linkages of ecosystem services to users and beneficiaries
- Clarify definitions of intermediate services and related concepts of intra- and inter- ecosystem flows and ecosystem processes.
- Improve explanation of ecosystem service classifications
- Review selection and description of specific ecosystem services used as examples
- Discuss further ecosystem disservices/ negative NCP
- Clarify the treatment of carbon sequestration and carbon storage as ecosystem services
- Consider explicitly the treatment of sink services and associated unmediated residual flows
- Discuss issues of aggregation and connections between micro and macro scales especially in the context of biophysical modelling
- Clarify discussion of changes in the production boundary implied by ecosystem accounting
- Review / explain further the structure of Table 5.2 of the SEEA EEA TR showing the supply and use of ecosystem services
- Clarify definition and role of ecological production functions

31. Furthermore, is deemed important to clarify how the ecosystem services classification to be developed relates to the classification systems of CICES, IPBES and potentially other classification systems. As much as possible, the note builds upon CICES, which was also developed with the aim of being applicable in ecosystem accounting (as well as for other purposes).

32. This note does not try to respond to each of the research themes in isolation since an integrated approach is needed to tackle these challenges – basically an updated ecosystem services

classification needs to respond to all of these issues in a consistent manner at the same time rather than on a one-by-one basis. Hence, the note presents a first direction towards an updated ecosystem services classification based on the various considerations, challenges and opportunities raised in the scientific literature, the global ecosystem services assessments such as MA, TEEB and IPBES, and the work conducted to date for the SEEA.

6 Requirements and assumption for an ecosystem services classification for SEEA EEA.

33. The following statistical/technical requirements and assumptions underlie the development of an ecosystem services classification system for SEEA EEA. In turn, these requirements are grounded in the general requirements for SEEA as formulated in the SEEA EEA Framework.

- In the SNA, a distinction is made between ecosystem services supplied in a natural and in a cultivated ecosystem. This is not consistent with the manner that ecologists are perceiving ecosystems, which in general involves the acknowledgement that all ecosystems on the planet are to a lower or higher degree influenced by people. It needs to be discussed if and how this distinction is brought forward in the SEEA EEA.
- The classification of ecosystem services must be aligned with the SEEA framework and the SEEA EEA TR. The SEEA EEA framework and the TR distinguish the three categories of provisioning, regulating and cultural services (which is fairly well aligned with other existing systems such as CICES and the classifications of the MA and TEEB). Consequently, a starting point for discussions is that these three types of services need to be distinguished.
- In addition, the definition of ecosystem services as contributions to human benefits provided by ecosystems must be maintained (as postulated in the SEEA EEA and the SEEA EEA TR, and as also applied in the TEEB and IPBES frameworks). It is also critically important that the relation between services and (SNA and non-SNA) benefits is clarified. In principle, every service is connected to one or more benefits. These benefits may either be included in the SNA, or may be outside the boundary of the SNA (the service would in both cases be connected to an economic user)
- Service classification should be such that services belong to one and only one group, class and type of ecosystem service, even though one type of ecosystem service may result in different benefits. This raises an issue with CICES 5.1, where there is a distinction between the class 'Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes' and the class 'Cultivated plants (including fungi, algae) grown as a source of energy'. For example, palm oil is produced both as a source of food and energy and would fall into two classes.
- In SEEA, the ecosystem service comprises an interaction between the ecosystem and an economic unit. The quantity of service extracted from the ecosystem must equal the quantity used by the economic unit, in order to balance the accounts. Harvest losses, in line with the SNA, are therefore seen as part of the ecosystem service supplied by the ecosystem. They are subsequently returned as residues from the economy to the ecosystem. Note that they are

returned as residues (e.g. felling residues) not necessarily as ecosystem elements that existed before the harvest (e.g. trees).

- However, the physical amount of ecosystem service extracted from the ecosystem, e.g. the timber harvested, may or may not be equal to the physical amount of the benefit, e.g. the amount of timber produced by the side of the forest. The difference is composed of harvesting losses and/or felling residues, which are generally returned to the ecosystem (and may serve as mulch or plant nutrients). Note that this logic does not impede that there are further losses of products in the economy (e.g. there may be food losses, or losses of wood when timber is transformed to tables).
- The concepts of intermediate and final services need to be clarified. This is relevant for, in particular, regulating services, that can be both final and/or intermediate ecosystem services depending upon context. For instance, the regulation of water by upstream forests may benefit people directly by reducing flood risks to houses and infrastructure, and it may provide water for irrigation during the dry season. Hence, it is not the type of ecosystem service that determines whether it is final or intermediate but rather the user of the service.
- With regulating services, it is important that 'supporting' services or 'options for NCP' (in the terminology of respectively the MA and IPBES) are differentiated from regulating services. Supporting services are ecological processes that do not have an ex-situ impact. For example, pollination of wild plant species in a forest patch is a supporting service. Where the plants themselves are harvested, the ensemble (ecosystem) of the forest fosters growth of the plant species including by pollination. There is no use singling out pollination as an ecosystem service: when services are aggregated by ecosystem type including both pollination and plant harvests would lead to double counting when valued. Pollination becomes a regulating service where a patch of land provides a (perennial or seasonal e.g. winter) habitat for a pollinator species that pollinates plants in another ecosystem type (e.g. a nearby cropland). In this case, loss of the patch of vegetated land would lead to a decline in crop production in another ecosystem type. The pollination service, in the case of one ET maintaining pollination in a nearby ET, is an intermediate regulating service (a service from one ET to another ET). Hence, regulating services are only relevant for accounting as far as they are not supporting services (in other words: if they provide a beneficial impact on another ecosystem asset in the form of an intermediate service and/or if they provide a final ecosystem service that leads to a benefit for people either in- or ex-situ). This needs to be reflected in the definition of regulating services.
- Based on CICES 5.1, the classification units of category (provisioning, regulating, cultural), group (broad group of services), class (specific group of services with comparable ecological and economic connotations) and ecosystem service type (individual ecosystem service) are distinguished. An example of this hierarchy is shown in the table below. Although there will often be important spatial and temporal variations within ecosystem service types, these have a comparable ecosystem composition (e.g. dominant plant species), ecosystem functioning and ecosystem use. The hierarchy builds upon CICES but aims to provide a simpler classification system that is fully aligned with SEEA EEA. As in CICES, Group level descriptors are framed in a way the ecosystem that are ultimately useful to people (e.g. nutrition), and the class definitions seeks to combine an 'ecological' and a 'use' clause.

- Abiotic services are not included in the SEEA EEA. That is, the SEEA EEA ecosystem services classification only covers services that are at least in part dependent upon biotic components of the ecosystem. For example, the harnessing of geothermal or solar energy is largely independent of the health of the ecosystem, and is therefore not relevant for ecosystem accounting. Note that the mining of abiotic components such as clay or sand can be analysed with the SEEA Central Framework.
- Following the SNA, accounting does not allow accounting for recoding disservices (i.e. services with a negative value) as part of the ecosystem services account. Disservices include, for instance human disease outbreaks originating in ecosystems, or crop damages (e.g. trampling by elephants or grazing by locusts). As with ecosystem services, they depend upon how the ecosystem is managed. This note includes a proposal on how to include disservices in the SEEA ecosystem accounts.

7 Tentative proposals of a set-up of a classification of ES, for discussion

Tentative lay-out of a classification of ecosystem services for SEEA

34. Potentially SEEA can maintain a distinction between categories, groups and classes of services, see Table 1, analogous to CICES 5.1. However, there may be ground to simplify the CICES structure. For example, the unit of 'division' could be excluded since this adds another element of the classification structure without sufficient added value.

Table 1. Classification System for ecosystem services (potential structure based on CICES 5.1)

Category, e.g.:	Group, e.g.	Class, e.g.:	Ecosystem service, e.g.:
Provisioning services	*(Providing a substrate for)*[1] cultivated *annual and perennial* [2] terrestrial plants for nutrition, materials and/or energy	Providing a substrate for growing annual crops including physical, chemical and biological in-situ and ex-situ properties conducive to crop production	Providing a substrate for growing wheat

Notes: 1. CICES does not use the terms 'providing a substrate' in the definition of groups. This may however be a consistent approach. 2. CICES does not explicitly distinguish between annual and perennial crops at this level. It needs to be discussed if this would add value, e.g. because the recording of inputs and outputs may differ between these types in accounting (depending upon how ecosystem services are defined).

35. A tentative lay-out for a classification of ecosystem services based on the principles described in the previous chapters is presented in tables 2 to 4, respectively for provisioning, regulating and cultural services. Annex A1, A2 and A3 present further ideas of how specific ecosystem services in

these three categories of ecosystem services can be defined and how they can be connected to SNA and non-SNA benefits. Note that these are initial proposals only meant to serve the discussion in the working groups.

36. The ecosystem services groups, classes and examples listed in the three tables below are identified on the basis of a review of CICES 5.1, MA, TEEB and IPBES, and grouped in non-overlapping, consistent groups and classes in such a way that alignment with the SEEA EEA framework and TR is achieved. The ambition of the three tables is to have a near-complete list of groups and classes (but not of services), illustrated with examples of ecosystem services in the right hand column. Annex A presents more comprehensive list of ecosystem services in each class, and physical and monetary indicators for these ES.

Note that much further thinking on how to define the groups, classes and services is required – this table is only meant as a basis for discussion in the New York Forum

Table 2. Provisioning services, groups, classes and examples of ecosystem services.

Group	Class	Service **examples**
Cultivated terrestrial plants for nutrition, materials and/or energy	Providing a substrate for the growth of annual crops including physical, chemical and biological in-situ (e.g. soil organic matter) and ex-situ (e.g. presence of pollinators) properties conducive to crop production	Providing a substrate for rice production
	Providing a substrate for the growth of perennial crops including physical, chemical and biological in-situ (e.g. soil organic matter) and ex-situ (e.g. presence of pollinators) properties conducive to crop production	Providing a substrate for oil palm production
	Providing a substrate for plantation forestry including physical, chemical and biological in-situ (e.g. soil organic matter) and ex-situ (e.g. presence of pollinators) properties conducive to timber and biomass production	Providing for timber harvest OR accumulation in accounting period
Wild terrestrial plants and fungi for nutrition, materials and/or energy	Providing harvestable wild plants and fungi for food, energy, materials purposes.	Providing for the harvest of wild mushrooms
Terrestrial animals for nutrition, materials and/or energy	Providing harvestable stocks of wild animals	Providing wild deer for hunting
	Providing space and animal feed for grazing animals	Providing substrate and feed for cattle grazing

Aquatic animals for nutrition, materials or energy	Providing harvestable stocks of fish and other aquatic animal species	Providing salmon for fishing
	Providing a habitat for the rearing of aquatic animals for nutrition, materials or energy	Providing a substrate for salmon aquaculture
Aquatic plants for nutrition, materials or energy	Providing harvestable aquatic plants and fungi for food, energy, materials purposes.	Providing a substrate for growing seaweed
Providing clean(ed) water for drinking water production, irrigation, process water, industrial cooling, etc.	Providing water	Providing water
Genetic material from animals, plants, algae or fungi	Providing genetic materials from animals, plants, algae, fungi.	Providing genetic materials for breeding programs

Table 3. Regulating services, groups, classes and examples of ecosystem services

Group	Class	Service examples
Mediation of nuisances, wastes or toxic substances of anthropogenic origin by living processes	Mediation through breakdown, filtering or storage of air and water pollutants, wastes and/or other toxic substances of anthropogenic origin by micro-organisms, algae, plants and animals	- Denitrification (e.g. of river water flowing through wetlands) - Air filtration by vegetation removing particulate matter from the atmosphere
	Reduction of smell, noise reduction and visual screening	- Visual screening exercised by a forest patch next to a highway
Regulation of water flows and protection from extreme events	Water erosion control: enhanced infiltration leading to reduced extreme run-off events, buffering and attenuation of mass movement (leading to lower overland, rill and gulley erosion and reduced land-slides)	- Control of sedimentation rates in a reservoir due to the presence of upstream forests - Protection form landslides through the stabilising effect of (tree) roots.
	Wind erosion control (wind break): vegetation elements reducing wind speed and thereby reducing wind erosion.	- Protection form wind erosion by a wind break along the borders of a agricultural field

	Water regulation: storage and gradual release of water by upstream forests thereby maintaining baseline flows and reducing peak flows.	- Reduction in peak flows as a function of the buffering capacity of forest vegetation upstream
	Coastal protection resulting from coastal ecosystems such as mangroves, dunes, coral reefs.	- Coastal protection by mangrove ecosystems leading to lower damages from tsunamis, storms and hide tides
Lifecycle maintenance, habitat and gene pool protection	Pollination: providing a habitat for insect pollinators	- Hedgerows providing a habitat during the cold winter period for bees that pollinate various crops in spring.
	Pest and disease control	- Hedgerows providing a habitat for ants and ladybirds that prey upon crop pests in nearby fields
	Nursery service: providing a habitat for nesting, spawning, juveniles,	- Mangrove ecosystem providing a spawning habitat for pelagic fish species
Regulation of marine, lake, rives, and atmospheric composition and conditions	Carbon sequestration and regulation of the emissions of other greenhouse gasses (methane, dinitrogen monoxide).	- Ecosystems sequestering (and storing) carbon
	Regulation of chemical composition of oceans	- Kelp, eelgrass, and other vegetation sequestering carbon in the ocean thereby reducing ocean acidification
	Regulation of rainfall patterns by maintaining hydrological cycles including by regulating local humidity, evaporation rates and temperatures.	- Forests maintaining rainfall patterns in continental interiors by increasing cloud formation, collecting rainfall, and evaporating rainfall for renewed cloud formation
	Regulating micro-level temperatures through shading.	- Shading by trees along city streets reducing urban heat effect.

Table 4. Cultural services, groups, classes and examples of ecosystem services

Group	Class	Service examples
Physical and experiential interactions	Enabling activities promoting health, recuperation or	Providing opportunities for tourism Providing opportunities for recreation

with natural environment	enjoyment through active or immersive interactions	Providing opportunities for eco-tourism Providing opportunities for recreational fishing and hunting Providing opportunities for nature watching (e.g. whale safari)
	Enabling activities promoting health, recuperation or enjoyment through passive or observational interactions	Providing opportunities for the production of nature movies
Intellectual and representative interactions with natural environment	Enabling scientific investigation and/or the creation of traditional ecological knowledge	Providing opportunities for research
	Enabling education and training	Providing opportunities for education
Cultural, nature-conservation, spiritual, symbolic and other interactions with natural environment	Conservation of landscapes of cultural significance	Providing possibilities to enjoy culturally or historically significant landscapes
	Conservation of landscapes of ecological significance	Providing habitat for endemic and/or threatened species
	Conservation of landscapes of religious significance	Providing sacred forests used for customary practices

Key classification challenges

<u>Note that further thinking on these challenges is required – this table is only meant as a basis for discussion in the New York Forum</u>

37. **Final and intermediate services**. The SEEA EEA TR indicates how intermediate services can be recorded in the accounting framework and how this supports a better conceptualisation of the connections and dependencies between ecosystem assets. In particular, this allows the ecosystem accounts to recognise the contributions of all ecosystems and associated ecosystem processes wherever they are located and to understand the potential impacts of economic production and consumption on ecosystem assets.

38. In practice it is not always straightforward to distinguish between intermediate and final services. In general, all provisioning and cultural services are final services – they are directly used by people, supporting production or consumed by people. Consumed, in this case, includes enjoying scenery, or using the various cultural services of an ecosystem.

39. A typical example provided in the SEEA EEA TR is the intermediate services provided by upstream forests in regulating water flows and limiting sediment content in water that is subsequently abstracted downstream (at which point final ecosystem services would be recorded). It is important to understand this intermediate service, since otherwise the importance of the upstream forest for the economy would be underestimated, for instance in spatial planning.

40. An intermediate service always requires a biological or physical interaction between different ecosystem assets (and typically between different ecosystem asset types). For instance, pollination in croplands may depend upon insect pollinators that require shrublands or forest habitat, for instance for shelter. If the shrublands or forests would be converted, the pollination service to the croplands would be diminished or lost. Hence, the ecosystem assets 'cropland' benefit from the biological interaction involving the visitation by insect pollinators, that otherwise depend upon the assets 'shrublands' to provide them with a nesting or winter habitat. In the case of forests regulating water flows, the interaction is of a physical nature, involving modifications of water flows in the landscape.

41. All classes of regulating services grouped in Table 3 can be either final or intermediate: in each of these classes there will be a service that can have a beneficial effect directly on people (either supporting production and/or consumption) and on other nearby or downstream ecosystems providing ecosystem services to people. This beneficial effect can involve for example, the mediation of nuisances, wastes or toxic substances, protection from extreme events, and the regulation of marine and atmospheric composition and conditions.

42. There are two more critical considerations with regards to intermediate services. First, there are so many biological and physical interactions between different ecosystem assets (e.g. migration patterns of birds and other species between ecosystems, hydrological cycles, etc.) that including all of these in an ecosystem account is not possible. This is also not necessary since many of the interactions may not have a significant effect on the condition of the ecosystem asset and on its capacity to supply ecosystem services. Hence, the compiler of the accounts should only select intermediate services that are most relevant for the account. This can be either because they are policy relevant (e.g. loss of insect pollinators is a widespread concern), or because the services play an as yet insufficiently recognised but important role in maintaining the condition of other ecosystem assets (as in the case of upstream forests protecting downstream assets from flood and sedimentation risks).

43. The second consideration is that double counting needs to be avoided. In the case of pollination of agricultural crops, adding pollination services and the biomass accumulation of crops would lead to double counting. Hence, when values are apportioned to individual ecosystem assets or ecosystem types - the value of the intermediate service needs to be appointed to the ecosystem asset playing the largest role in maintaining the service, and the value should be deducted from the ecosystem asset providing the final ecosystem service. It seems appropriate to cap the value of the intermediate service to not more than the value of the final service, in order to avoid negative values and also since the value of an intermediate input cannot be realistically higher, certainly not in the long term, than the value of the final output.

44. **The treatment of carbon sequestration and carbon storage**. In the ecosystem accounting approach, carbon sequestration is considered an ecosystem service. Carbon sequestration is one of the main ways through which ecosystems mitigate climate change. Hence, the corresponding benefit is reducing the impacts of climate change. Carbon sequestration comprises a flow of carbon from the atmosphere to the ecosystem, based on a variety of ecological processes. In this context, it is important to distinguish between short-term flows (e.g. diurnal exchanges of CO_2 between vegetation and the atmosphere) and long-term sequestration. Only the latter should be considered as providing an ecosystem service. Carbon sequestration can also be an intermediate service, in the sense that it supports the functioning and service supply of ecosystems in the future. Particular for the carbon sequestration service that, compared to all other regulating services, the beneficial effect on other ecosystem assets is not only space but also time dependent - including on the long term (note that a time dimension may also occur in the case of other regulating services, e.g. storm protection services are only relevant when there is a storm, which usually is at some point in the future).

45. Carbon storage in forests and peatlands provides a significant benefit as part of reducing the impacts of climate change. If a service was not recorded then the loss of forest and the draining of peatlands would not imply any reduction in benefits. While this seems a clear basis for recording a service of carbon storage, the challenge is that storage constitutes a stock not a flow, and it is therefore difficult to interpret storage as a service. In addition, not all stores of carbon are at risk which reduces the urgency of including such stocks in the assessment of ecosystem services. Finally, the stocks of carbon, per hectare, are sometimes very large. For example, Indonesian peatlands may be up to 20 meters deep. If the amount of carbon locked in a hectare of peat would be released into the atmosphere in a single year this would amount to a massive costs, for any CO_2 price. However it is not physically possible to release this in one year, the maximum that is being achieved is in the order of 5 to 10 cm per year in case of deep drainage and persistent fires.

46. Hence, if carbon storage is valued as a service there is a need to compare values to a baseline trend. This type of valuation depends strongly upon assumptions made on this trend (e.g. what transaction can be identified?) and sits uncomfortably to accounting principles of the SNA. Hence further work is needed to examine if such a conceptualisation of the service (i.e. as avoided emissions in a given time period – for instance in comparison with a trend) leads to realistic and acceptable results. In the meantime, actual storage of carbon and emissions can be included in the carbon account (although the issue remains that carbon storage is not valued in monetary terms in carbon accounts as developed to date).

47. **The treatment of biodiversity**. Biodiversity is a particularly complex concept. It comprises the three fundamentally different levels of genetic, species and ecosystem diversity, it can be measured in many different ways, and its measurement is often hampered by a severe lack of data. Biodiversity nevertheless is highly policy relevant. A consensus in the SEEA community seems to be emerging that species level biodiversity is most relevant for accounting. This because ecosystem diversity is (partly) already covered in the extent account (however it may well be that properly accounting for ecosystem biodiversity requires a more detailed or ecologically refined approach compared to what is proposed for extent accounting – in this light new proposals by IUCN for analysing ecosystem diversity should be considered), and because data are generally lacking for large-area assessments of genetic diversity.

Species diversity, comprising concepts such as diversity, richness, abundance, presence of specific (endemic, rare, red list) species is also highly policy relevant since much of the policy and public debate on biodiversity is about protecting specific species and their habitats.

48. Given that biodiversity can be accounted for in detail in the biodiversity account, a question is if biodiversity is also an ecosystem service. Biodiversity is included as a service in both the TEEB and the IPBES classification, in both cases as the 'habitat service' respectively 'habitat NCP'. CICES is ambivalent, whereas biodiversity as such is not differentiated it includes the cultural service classes 'Characteristics or features of living systems that have an existence value' and 'Characteristics or features of living systems that have an option or bequest value'. Since (species) diversity can be seen as an important motivation for attributing bequest or existence value to an ecosystem, it appears that CICES does not exclude consideration of biodiversity as a service.

49. At the same time, CICES makes explicit that various cultural services provided by an ecosystem can be seen as an ecosystem service. Hence, the proposal for SEEA is to align with TEEB and IPBES, and to be consistent with the concept of cultural services, and to consider habitat or biodiversity also as a service in itself (as in Table 4 above). The argument that has been made in the SEEA EEA TR, that measures of biodiversity are considered to relate primarily to the stocks component in the accounting model, consistent with a view that biodiversity can be degraded or enhanced over time, and that therefore biodiversity has more of a stocks and not a flow character remains valid, but strictly speaking it is the human interaction with biodiversity (in particular, in this case, a value attributed by people, on a continuous basis, to the protection and conservation of certain elements of biodiversity - e.g. a specific habitat and/or specific species) that is the service, and this comprises a flow rather than a stock. This is also aligned better with the notion that ecosystems can provide a cultural service (which is based on properties of the ecosystem that are, by themselves, also a stock, e.g. the presence of specific species or attributes in the ecosystem).

50. **The treatment of ecosystem disservices**. Ecosystem disservices arise in cases where the interaction between ecosystems and humans is considered to be damaging to human well-being. Usually this refers to the effects of things such as pests and diseases that emerge from ecosystems and negatively affect economic production and human life. As with ecosystem services, they depend upon how the ecosystem is managed As pointed out in the IPBES framework, specific ecosystem components can provide services or disservices depending upon context (e.g. an elephant providing opportunities for ecotourism or trampling upon farmers' fields), and specific services can be disservices in other contexts (e.g. visual screening by trees along a highway can on the one hand reduce nuisances for nearby people as well as reduce the view of drivers on scenic locations). Sometimes the disservices are the result of changes in ecosystem management, as in the case of croplands expanding in traditional elephant territory – hence the classification as service or disservice may also change over time.

51. As pointed out in the SEEA EEA TR, the SEEA EEA recognises the frequent discussion on the measurement of ecosystem disservices but does not propose a treatment in accounting terms since, within an accounts-based framing, this would require recording negative production by an ecosystem asset and this not a possible accounting entry.

52. A related matter is the treatment in ecosystem accounting of negative externalities, such as emissions, where economic and human activity leads to declines in the condition of ecosystems and may also affect human health (e.g. through water or air pollution). These externalities are often highly policy relevant (e.g. ambient particulate matter concentration) and they are to be recorded in the condition account. Note that these externalities are often also relevant for the ecosystem services models. First, regulating ecosystem services that comprise a mediating or mitigating effect from anthropogenic (or natural) nuisance or pollution are only relevant where such nuisance or pollution exists, and quantifying their physical impacts and monetary value requires, among others, understanding the level of nuisance or pollution generated. Second, pollution and waste also diminish the supply of ecosystem services either directly (e.g. plastic on beaches) or indirectly (by affecting ecosystem functioning and therefore capacity to supply ecosystem services).

53. Therefore, it is proposed to record ecosystem disservices and externalities in the Condition account. In the case of disservices, this also reflects that disservices are often related to the condition of the ecosystem. Fire in peatlands leading to haze and smoke is a consequence of peat drainage and degradation, and elephant and other wildlife disturbing croplands is often (although not always) related to ecosystem condition (e.g. by human encroachment or modifications of their habitat). Since there are many externalities and potentially also many disservices a selection of pressures (disservices and externalities) is required in ecosystem accounting, based on their policy relevance and the importance for people as well as ecosystem functioning and services supply.

54. **The scope of cultural services within an accounting framework**. The discussion and measurement of cultural services in ecosystem accounting remains the least advanced area of work. For the identification of services, CICES 5.1 provides a good basis. However, challenges lie in articulating the distinction between ecosystem services and benefits and in the associated area of valuation. Where businesses are involved in the delivery of tourism and recreational services the treatment is quite clear and parallels the measurement of provisioning services. However, in other cases the framing is less clear. This is particularly the case for so-called “non-use” interactions where people obtain benefits from nature without any direct interaction, as well as for the spiritual and religious dimensions of cultural services. It is quite plausible for ecosystem services relating to non-use to be considered within scope of ecosystem accounting. In principle, it is possible to record the number of people appreciating a particular service for non-use or spiritual/religious purposes. What is far less clear is whether the value of any non-use services would satisfy the valuation principles required for ecosystem accounting. A potential option is to establish a ‘satellite’ to the ecosystem account including cultural services valued with a broader valuation perspective, for instance following a welfare based perspective where some degree of measurement of consumer surplus is considered. An even broader valuation perspective is proposed by IPBES but it is unclear if and how this can be made to align with the SEEA EEA. Valuation is the topic of another research theme and it is therefore not further treated in this document.

55. **Ecological production functions**. Ecological production functions have been used in FEGS-CS and NESCS to indicate the contribution of the ecosystem to economic production. Ecological production functions characterize relationships between ecosystem condition, management practices,

and the delivery of economically valuable ecosystem services (Macpherson, 2009). A definition of an ecological production function is: "an ecological production function specifies the output of ecosystem services provided (produced) given its condition and process" (Kareiva et al., 2011). In principle, this definition is well aligned with the SEEA interpretation of an ecosystem, i.e. the contribution of an ecosystem to human benefits.

56. A fundamental difference between the definitions of Macpherson and Kareiva is that the first of these explicitly includes management practices as a determining factor in the supply of ecosystem services (presumably Kareiva allows for management influencing the condition and process of ecosystems). Kareiva continues: "once an ecological production function is specified, researchers can quantify the impact of landscape change on the level of ecosystem service outputs". Unfortunately this is a gross oversimplification. In reality, people will adjust management of ecosystems as a function of changes in landscapes and/or ecosystems (see e.g. Hein et al., 2018). A further complication (as acknowledged by Kareiva) is that **the** ecological production function does not exist – the ecosystem provides a range of options to use ecosystem services but increasing the supply of one ecosystem service is likely to reduce the supply of other services. Hence, ecological production functions for different services cannot be determined in isolation of one another.

57. Hence, the basic concept of ecological production function is well aligned with SEEA (in the sense that ecosystem services supply is a function of ecosystem extent and condition, under a given (in SEEA: the current) ecosystem management). However the ecological production function in the interpretation of Kareiva suggests a deterministic relationship between ecosystem extent and condition that is not aligned with the overall conceptualisation of SEEA, and with the focus of SEEA on recording multiple / baskets of ecosystem services, a question is how the concept of ecological production function for single services could be of use[1].

58. Perhaps it is mostly a matter of semantics but strictly speaking there is no need for the SEEA community to take a stand in this debate. The term ecological production function has its uses but it is not defined in the SEEA EEA framework as an essential part of the SEEA EEA. The interconnected concepts of ecosystem service, capacity to generate services, potential to generate services and capability to generate services (see the SEE SEEA TR and Hein et al., 2006) present a potentially more robust and comprehensive framework to analyse the relation between human management and changes in ecosystem services supply. It is proposed to not use the term 'ecological production function' in the SEEA EEA.

8 References

(To be updated)

[1] Of future interest could be to explore developing an ecological production 'matrix' that accommodates trade-offs between services as a function of management, condition and extent, but this is not developed in the literature on ecological production functions.

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9 Annex A. Potential list and classification of ecosystem services for SEEA as input into the discussion

To be further developed as a draft based on discussions with the writing group

Table A.1. Relation between benefits and provisioning services including possible ecosystem service indicators (these will depend in practice upon context and need to be fine-tuned to the local environment and ecosystem uses). Note: for provisioning services: all benefits are SNA benefits.

Benefit	Indicator for the benefit	Description of the ecosystem service class (= contribution of the ecosystem)	Potential ecosystem service physical indicator	Potential ecosystem service monetary indicator
Crops (for food, energy, materials purposes, from either annual or perennial crops)	Amount of crops (including plants, algae and fungi) produced in an accounting period	Providing a substrate for the growth of crops including physical, chemical and biological in-situ (e.g. soil organic matter) and ex-situ (e.g. presence of pollinators) properties conducive to crop production	Amount of harvested crop produced during accounting period	The resource rent generated with crop production (note that in specific cases also information on GVA or NVA may be relevant to policy makers).
Wild plants, algae and fungi for food, energy, materials purposes	Amounts of wild plants, algae and fungi produced in an accounting period	Providing harvestable wild plants, algae and fungi for food, energy, materials purposes.	Amount of harvested wild plants, algae and fungi produced during accounting period	The resource rent generated with harvested wild plants, algae and fungi
Timber and biomass production in cultivated ecosystems (plantations)	Amount of timber or other material produced in accounting period // or // Amount of timber or other material accumulated in accounting period	Providing a substrate for growing plantation crops including physical, chemical and biological in-situ (e.g. soil organic matter) and ex-situ (e.g. presence of pollinators) properties conducive to timber and biomass production	Amount of timber or other material harvested in accounting period // or // Amount of timber or other material accumulated in accounting period	The resource rent generated with timber of other material production // or // accumulation (note that in specific cases also information on GVA or NVA may be relevant to policy makers).
Timber and biomass production in (semi-)	Amount of timber or other material produced in accounting period	Providing a substrate for growing plantation crops including physical, chemical and biological	Amount of timber or other material harvested in accounting period	The resource rent generated with timber of other

natural ecosystems (in particular forests)		in-situ (e.g. soil organic matter) and ex-situ (e.g. presence of pollinators) properties conducive to timber and biomass production		material production (note that in specific cases also information on GVA or NVA may be relevant to policy makers).
Aquaculture production of animals such as fish, clams shrimps.	Amount of aquatic animals produced	Providing a habitat for the rearing of aquatic animals for nutrition, materials or energy	Amount of aquaculture produce harvested	The resource rent generated with harvesting aquatic animals
Fisheries including harvesting of fish, clams, shrimps	Amount of aquatic animals produced	Providing harvestable stocks of fish and other aquatic animal species	Amount of aquatic animals harvested	The resource rent generated with harvesting aquatic animals
Animal husbandry (intensive, ecosystem providing feed and space, farmer controlling production)	Animal feed, animal production	Providing space and animal feed for grazing animals	Amount of animal feed consumed by animals	Potentially: value of replacing animal feed with other sources, alternatively or additionally: price differential products derived from free ranging animals compared to bio-industry animals.
Animal husbandry (extensive, pastures)	Production of animals, including meat, milk and skins			
Hunting of animals	Amount of hunted animals, expressed in numbers of animals or tons of meat	Providing harvestable stocks of wild animals	Amount of harvested animals	Resource rent of production
Genetic materials from animals, plants, algae, fungi.	Amount of genetic materials from animals, plants, algae, fungi. (e.g. number of specimens/samples)	Providing genetic materials from animals, plants, algae, fungi.	Amount of genetic materials from animals, plants, algae, fungi. (e.g. number of specimens/samples)	Potentially quantifiable on the basis of the commercial value of the samples and the resource rent generated.

Note: recreational fishing and hunting are part of the cultural services.

Table A.2. Relation between benefits and regulating services including potential ecosystem service indicators (these will depend in practice upon context and need to be fine-tuned to the local environment and ecosystem uses).

Benefit	Indicator for the benefit	Description of the ecosystem service class (= contribution of the ecosystem)	Potential ecosystem service physical indicator	Potential ecosystem service monetary indicator
Cleaner environment for human activities		Mediation through breakdown, filtering or storage of air and water pollutants, wastes and/or toxic substances of anthropogenic origin by micro-organisms, algae, plants, and animals		
Enhancing environment in which people live by smell or noise reduction and visual screening		Reduction of smell, noise reduction and visual screening		
Reduced loss of fertile soil particles and reduced sedimentation of coastal ecosystems, lakes and reservoirs		Water erosion control: enhanced infiltration leading to reduced extreme run-off events, buffering and attenuation of mass movement (leading to lower overland, rill and gulley erosion and reduced land-slides)		
Reduced loss of fertile soil particles and reduced sedimentation in ecosystems		Wind erosion control (wind break): vegetation elements reducing wind speed and thereby reducing wind erosion.		
Reduced flood risks and enhanced opportunities to use water in the dry season		Water regulation: storage and gradual release of water by upstream forests thereby maintaining baseline flows and reducing peak flows.		
Coastal protection		Coastal protection resulting from coastal ecosystems such as mangroves, dunes, coral reefs.		
		Pollination: providing a habitat for insect pollinators		

		Pest and disease control		
		Nursery service: providing a habitat for nesting, spawning, juveniles,		
		Regulation of chemical composition of atmosphere and oceans		
		Carbon sequestration and regulation of the emissions of other greenhouse gasses (methane, dinitrogen monoxide).		
		Regulation of rainfall patterns by maintaining hydrological cycles including by regulating local humidity, evaporation rates and temperatures.		
		Regulating micro-level temperatures through shading.		

Table A.3. Relation between benefits and cultural services including potential ecosystem service indicators (these will depend in practice upon context and need to be fine-tuned to the local environment and ecosystem uses).

Description of the ecosystem service class (= contribution of the ecosystem)	Example of benefit dependent upon an ecosystem service	Potential ecosystem service physical indicator	Potential ecosystem service monetary indicator
Enabling activities promoting health, recuperation or enjoyment through active or immersive interactions	Tourism	Number of tourists visiting a site	Resource rent generated through tourism on that site
Enabling activities promoting health, recuperation or enjoyment through passive or observational interactions	Nature movie production	Number of movies	Resource rent generated by movie
Enabling scientific investigation and/or the creation of traditional ecological knowledge	Science and innovation	Number of scientific research projects / visiting scientists	Deferred to research group on valuation
Enabling education and training	Education	Number of schoolchildren visiting educational activities	Deferred to research group on valuation
Conservation of landscapes of cultural significance	Landscape and cultural heritage conservation	Active enjoyment captured in services specified above; Passive enjoyment difficult to quantify	Valued at costs spent to maintain area
Conservation of landscapes of ecological significance	Nature conservation		Valued at costs spent to maintain area

Conservation of landscapes of religious significance	Religious activities	Number of visits to site	Valued at costs spent to maintain area

10 Annex B. Differences in recording services and benefits in natural and cultural ecosystems

(from the SEEA EEA TR)

In Table 5.2, note that in all cases the service is defined as the ecosystem's contribution to the benefit. For example, in the case of timber, the ecosystem service pertains to the contribution made by the ecosystem to harvested timber, i.e. the service is the accumulation of woody biomass in the ecosystem that is subsequently harvested. Accumulation of other biomass (e.g. in branches, below ground biomass, or in species that are not harvested) is not relevant for this service. In order to maintain that the physical output from the ecosystem equals the physical input in the economy (in the ecosystem services supply and use accounts), it is necessary that volume of wood/timber recorded is the same for both the service and the benefit - in those cases where it is appropriate to use harvested timber volume as indicator for both the service and the benefit. Felling residues are included in the service and the benefit. The felled timber enters the economy inclusive of felling residue, but these residues return immediately to the environment. These flows are termed natural resource residuals.

For timber harvesting, there is a difference in the time of recording of the ecosystem services depending on whether the growth of the tree is considered cultivated or natural. Cultivated biological resources are, for example, from plantations and natural resources are for example timber stands in natural forests. In reality, there is a grey line between the two, there are many ecosystems where management levels are intermediate (e.g. consider the well-known case of jungle rubber forests, where enrichment planting increases the density of rubber trees). This distinction is based on, among others, ownership and degree of control of the owner on the ecological processes (i.e. planting of seedlings, pruning, fertilizing, etc.). The SEEA Central Framework presents guidance on how to distinguish between these two levels of management for national accounting purposes.

In the case of both cultivated and natural resources, the ecosystem service is defined as the accumulation of woody biomass used for timber harvesting. However, in the case of cultivated resources, the accumulation is recorded progressively on an annual basis, based on the expectation that the total accumulated biomass will be harvested (unless there are natural disasters such as fire, which can be recorded as 'other changes in volume' in timber stock). In the case of natural biological resources, the accumulation is recorded in total at the time of actual harvest of timber in the forest.

The reason for this difference in recording is that in the case of cultivated resources it is expected that all accumulated biomass is harvested at the end of the growing cycle. In the case of natural forest resources, only species of commercial interest are harvested (determined by timber species, age and quality of the individual trees, etc.). Hence it cannot be assessed a priori which parts of the annual accumulation of biomass is harvested in the case of natural resources. This is further

elaborated below. The distinction between cultivated and natural biological resources facilitates integration with the SNA where the same distinction in the time of recording is made.
For annual crops, the distinction between cultivated and natural biological resources effectively disappears. The large majority of crops are grown as cultivated resources, and since they are harvested on an annual basis, the annual accumulation of crop biomass equals the annual harvest, except in case of natural disasters. In the case of annual crops, it is proposed to record the annual harvest as a proxy for the ecosystem service provided. Also in this case, the service equals the benefit, in physical terms.

In the case of provisioning services, in physical terms the service generally equals the benefit. By definition, the service is the *contribution* of the ecosystem to the service. In the case of services from ecosystems that are to a high degree natural, it is clear that the ecosystem's contribution is facilitating growth of the species that is harvested, be it a wild strawberry, medicinal bark, or a fish in the ocean. Since not all individual animals or plants that grow in the ecosystem are harvested, it is only meaningful to record the harvested animals and plants in the ecosystem services supply and use account. In the case of (semi-)-natural ecosystems, therefore, the service equals the benefit – in physical terms (e.g. expressed in cubic meter timber or kg of fish).

In the case of services from cultivated ecosystems, such as a plantation, in line with the SNA and the SEEA Central Framework, the SEEA EEA records the annual increment in biomass. The assumption here is that all biomass grown in a cultivated ecosystem, e.g. an acacia plantation or aquaculture system, is harvested (except for losses e.g. due to natural disasters). In reality, these systems are often intensively managed by people. The contribution of the ecosystem is, in terrestrial ecosystems, a function of the soil and its water and nutrient holding capacity, temperature and rainfall, etc. However, since these processes cannot all be measured in one aggregated indicator, in physical terms it is assumed in the SEEA EEA that, also in all cultivated ecosystems, service equals benefit. Hence, in all cases, for provisioning services (but not for regulating and cultural services), and only in physical units, it is assumed for measurement purposes that service equals benefits. In monetary terms, they are not the same, as explained in the next chapter.

Service (= the contribution of the ecosystem to the benefit)	*Benefit*	*Difference between service and benefit; final or intermediate*
Provisioning Services.		All provisioning services are final ecosystem services
Timber: the accumulation in the ecosystem of timber to be harvested. For natural ecosystems, this is measured in terms of the volume of wood extracted from the forest at the point of time of harvest (i.e. felled biomass), and for timber from cultivated ecosystems (i.e. plantations) this is measured as the	Timber: the amount of wood that is harvested. For natural ecosystems, this is measured in terms of the volume of wood that is harvested (i.e. the felled biomass), and for cultivated ecosystems (i.e. plantations) this is measured as the annual	The service and the benefit are equal in physical terms but not in monetary terms. In monetary terms the service is measured in terms of the resource rent generated by the ecosystem – i.e. on the basis of the revenue of the benefit minus the costs of production and harvesting

annual increment in harvestable timber	increment in the amount of harvestable timber.	including labour costs, user costs of fixed capital and costs of intermediate inputs. The benefit can be analysed in terms of revenue generated or (gross or net) value added.
Crop production: the contribution of the ecosystem to crop production, i.e. the total and combined result of processes taking place in cropland that support crop production such as infiltration of water, the water holding capacity of the soil, the absorption of plant nutrients by soil particles and the resupply of these particles to plants. Since this cannot be currently quantified the amount of crops being harvested can be taken as a proxy for the service in physical terms	Amount of harvested crops	In physical terms, there is no difference between the proxy indicator for service (crops produced) and the indicator for benefits (crops harvested). In monetary terms, the service can be valued in terms of the generated resource rent and the benefit in terms of revenue generated or (gross or net) value added (as explained in the cell above).
Water (e.g. used to produce drinking water): the amount of water extracted from the ecosystem.	The amount of extracted from the ecosystem, to be used for example for drinking water production or for irrigation.	When water is used for irrigation and it is being supplied by a different EA than the EA where the crop is grown, the supply of irrigation water constitutes an intermediate service. Double counting needs to be avoided and the value of the irrigation water should be attributed from the cropland to the EA supplying the water.
Grazed biomass: the amount of grasses, herbs and other biomass grazed by domestic animals in cultivated or natural ecosystems (e.g. pastures, savannah).	The amount of grasses, herbs and other biomass grazed by domestic animals. Domestic animals are 'in the economy', and the service is provided at the time of the interaction between the ecosystem and the economy, i.e. when biomass is grazed.	
Regulating services		
Climate regulation - Carbon sequestration	Ecosystems provide climate regulation services of which the regulation of carbon dioxide through carbon sequestration is one component. Assessments of this service should only consider	As a matter of convention it is proposed to classify this service as a final service, since final and intermediate effects are very hard to disentangle. Revealed market in the purchase of carbon

	carbon stored long-term (i.e. at least several decades) in the ecosystem.	sequestration services by economic units.
Water retention. This may include for example water retention in soils (e.g. in upper watershed forests) and in flood retention basins (e.g. in wetlands)	Regulation of hydrological flow patterns including flood control	The service can be both final and intermediate.
Pollination	Increased crop biomass accumulation	Intermediate service. In some cases, this service is useful to quantify, in particular when ecosystems near croplands provide the pollination service by serving as a habitat for pollinators and when there is a need to specify the contribution of these ecosystems to economic production.
High water flow regulation (e.g. by mangroves, riparian vegetation, coral reefs)	Reduction in risk from floods and related events	Can be both final and intermediate
Water purification	Cleaner water	Can be both final and intermediate
Air filtration	Cleaner air	Can be both final and intermediate
Erosion and sedimentation control	Reduced sediment loads in water and reduced deposition of sediments in downstream water basins	Can be both final and intermediate
Cultural services		All cultural services are final
Enabling/providing opportunities for nature-based tourism	Ecotourism (involving overnight stays)	In physical terms, all services and all benefits can be measured in terms of the number of people engaging in such activities. In monetary terms a resource rent approach can be used to value the service. In this case the costs of providing the service need to be taken into account, for instance in the case of recreation the labour and capital costs related to maintaining walking paths in natural parks.
Enabling nature-based recreation	Nature-based recreation (not involving overnight stays)	
Enabling nature-based education and learning	Nature-based education and learning	
Enabling nature-based religious and spiritual experiences	Nature based religious and spiritual experiences	
Enabling nature-based artistic and other human activities	Nature-based artistic and other human activities	