SEEA Experimental Ecosystem Accounting:

Towards a definition and classification of ecosystem services for SEEA

12 September 2018

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Discussion paper

Final Report

One page synthesis and preface

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

The paper 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 the definition and classification of ecosystem services, as a basis for discussion.

The authors would like to thank Rocky Harris for providing detailed comments.

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1. Introduction

Background

1.1 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 clear definition and 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.

1.1 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 seen as being determined by an ecosystem (see the SEEA EEA framework for details), although it is recognized 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).

1.2 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 conceptualization and societal framing of the relation between people and nature.

1.3 The added value of the SEEA EEA in relation to other frameworks for analyzing ecosystems and human dependencies on ecosystems, is that the SEEA brings statistical rigor to the analysis of ecosystem services and ecosystem assets and that it allows making a connection between 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 analyze ecosystem services and ecosystem assets, and that changes in ecosystem condition and services can be compared in a consistent manner with economic indicators.

1.4 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 organized, 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. For instance, consideration of long-term, multi-

scale sustainability issues requires consideration of for example complex ecosystem dynamics (e.g. multiple steady states, thresholds, etc.) and potentially also a broader perspective on nature-human relationships as for example offered by IPBES.

1.5 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 within the framework of the System of National Accounts (SNA). 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

1.6 Having a common understanding of the definition of each service as well as a classification of ecosystem services is an important aspect in the further development of the SEEA EEA framework. 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.

1.7 This paper presents selected background information relevant for the definition and classification of ecosystem services for SEEA. 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) and including the outcomes of the Technical Forum. 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 set of recommendations for ecosystem services definition and classification of ecosystem services for SEEA EEA (Chapter 6) – as a basis for discussion. These recommendations emerged out of the various discussions held in the SEEA community including at the 2018 New York Technical Forum – however the set of recommendations only covers a limited subset of the various challenges emerging in this process.

1.8 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 not straightforward (the first classification of ecosystem services including four types of services was published exactly 40 years ago; Van der Maarel and Dauvellier, 1978). It is clearly 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.

1.9 The various proposals included in this note should be seen as a basis for discussing within the SEEA community and with other stakeholders such as IPBES and the Ecosystem Services Partnership. Further testing and evaluation of the definitions and 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.

1.10 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 (US EPA, 2015).

2. Classification systems for ecosystem services

2.1 The Millennium Ecosystem Assessment (MA) published in 2005 (MA, 2005) proposed a typology 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 typology or classification system for ecosystem services. The conceptualization 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 conceptualizations of 'values of nature itself', 'nature's contributions to people (NCPs)' and categories of 'good quality of life', as discussed below.

2.1 The Common International Classification of Ecosystem Services (CICES) developed from the work on environmental accounting undertaken by the European Environment Agency (EEA) and involved extensive consultations. 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. This paper builds upon CICES 5.1 as well as other developments such as NESCS (see below).

2.2 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.

2.3 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.

2.4 The IPBES uses three value dimensions to analyze 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.

2.5 There are both differences and similarities between the various existing typologies / 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 identifies 59 classes of biotic ecosystem services (plus 31 'abiotic' ecosystem services such as providing opportunities to extract geothermal energy). In FEGS-CS, final ecosystem goods and services 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. NESCS defines 'flows of final ecosystem services' by matching together elements from four sub-classifications, one like an ecosystem asset, one the biophysical end-products of nature, one for use types of these end-products, and one for the types of users, for thousands of possible combinations of final ecosystem services. Specific for NESCS is that they include types of users/beneficiaries as discriminatory components within their definition of ecosystem services. NESCS does not include a specific list of ecosystem services (these are defined on the basis of the various interactions between ecosystem assets, end products of nature, use types, and user types).

3. Defining ecosystem services for SEEA EEA

3.1 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, fiber, fuel and water); regulating services (e.g. 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 often resulting in non-material benefits).

3.2 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.

3.2 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). In principle, services can lead to multiple benefits. For instance, stocks of fish and replenishment of these stocks through natural processes may offer opportunities for commercial as well as recreational fishing. Note that these benefits may be both SNA and non-SNA benefits.

3.3 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).

3.4 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.

3.5 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 on their own do not provide information on ecological sustainability of the use of ecosystems – although comparing current use with capacity would shed light on sustainability issues.. However, sustainability of ecosystem management can be inferred from the recording of changes in the condition account as well as in the capacity account.

3.6 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.

3.7 The SEEA EEA TR provides the following clarification of the three types of ES commonly referred to. 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.

3.8 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 might 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).

3.9 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 conceptualized in terms of the benefits that people receive from the engagement with ecosystems. The challenge for ecosystem accounting is often to estimate the contribution of the ecosystem itself to the generation of benefits given that the interactions of people with ecosystems for recreational or cultural practices is not only dependent upon natural features of an ecosystem but also on for instance visitor facilities, walking paths, etc.

4. Challenges in defining ecosystem services

4.1 It is clear from comparing the various classification systems that there are major challenges in coming to a broadly acceptable categorization 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

4.2 Furthermore, it is deemed important to clarify how the ecosystem services classification to be developed relates to the classification systems of CICES, NESCS, IPBES and potentially other typologies or classification systems.

4.3 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 definition and classification system 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.

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

5.1 The following statistical/technical requirements and assumptions underlie the development of clear definitions and 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. These various points have been discussed during the Technical Forum, and the directions obtained from these discussions are included in the text below.

- 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 was discussed during the Forum if and how this distinction needs to be brought forward in the SEEA EEA. A preference seemed to emerge in the discussions in the forum that preferably this distinction is not made, however further discussions and deliberations are required to assess this. This issue needs to be further worked out in an issues paper on ecosystem services definition and classification.
- The classification of ecosystem services must be aligned with the SEEA framework and the SEEA EEA TR. The SEEA EEA framework and the TR provisionally 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. The Forum participants indicated a preference for maintaining the three levels of provisioning, regulating and cultural services, as also distinguished in the SEEA EEA framework and TR.
- 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 <u>one and only one</u> group ('exclusive'), 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. At the same time, the

participants in the Forum indicated that it would be helpful to support their pilots of SEEA EEA to have a list of ecosystem services to consider (as in MA, CICES, IPBES). The system developed in NESCS to identify interactions between ecosystems, uses and users can further assist in developing this list.

- 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). A question for further discussion and consideration in the individual ecosystem services papers is if the core accounting framework, or its associated accounting table needs to be revised in order to record residues in the SEEA EEA framework.

- The concepts of intermediate and final services. 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. The SEEA EEA TR provides guidance on how to differentiate between these two types of services, which could be further elucidated in an issues paper on ecosystem services definition and classification.

- 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. Following the SEEA EEA TR, 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, supporting services can be seen as an intra-ecosystem service, and intermediate services are an inter-ecosystem service. Regulating services can either be intermediate ecosystem services or final ecosystem services (in case they provide a direct benefit to people, for instance in the case of air pollution). This needs to be reflected in the definition of regulating services to be further worked out in an issues paper on ES definition and classification.

- 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 analyzed with the SEEA Central Framework. The participants in the Forum indicated that it would nevertheless be useful to have a list of such abiotic services (as in CICES), even though these would not be 'ecosystem' services. This could include further thinking on the treatment of renewable energy that could be related to ecosystems in the SEEA EEA framework (e.g. waves power, hydro power etc.)

- Following the SNA, accounting does not allow accounting for recording 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. It was considered by the participants in the Forum to have a somewhat lower priority to examine and define disservices.
- The Forum participants very clearly indicated a need to keep the hierarchies in the classification simple with preferably three levels and at most four. It was generally believed that including more levels creates complexity without adding value for the user of the classification system. It was also indicated that each hierarchical level needed to be well defined and consistent at least within the levels of provisioning, regulating and cultural services.
- The participants in the Forum also discussed if water use should be seen as a regulating or provisioning service, or potentially an abiotic service. The tentative conclusion was that water use in some contexts depends upon the regulation of hydrological process by the ecosystem (including its biotic components), in some cases can be seen as a provisioning service, and in other aspects can be seen as an abiotic service (for instance in the case of fossil groundwater, i.e. finite reservoirs of groundwater not affected by any biotic process). A classification may need to consider all of these aspects.

6. Considerations for definition and classification of ecosystem services for SEEA

6.1 Based on the discussions in the Forum, potentially SEEA can maintain a distinction between categories, type of services, and individual ecosystem services. Although CICES as well as NESCS would need to be considered as building blocks for the classification structure, the participants in the Forum indicated a need to simplify, and potentially to better ensure that classes are exhaustive, exclusive and consistent. This structure needs to be further worked out in an issues paper. Annex A1, A2 and A3 present some first 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. However this needs to be worked out in much more detail, in a consultative process and with the whole working group, during the preparation of an issues paper. Some further thoughts on specific key classification challenges are provided below, as a basis for further discussion.

6.2 **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 conceptualization of the connections and dependencies between ecosystem assets. In particular, this allows the ecosystem accounts to recognize the contributions of all ecosystems and associated ecosystem processes wherever the service is delivered and wherever the beneficiary happens to be and to understand the potential impacts of economic production and consumption on ecosystem assets.

6.3 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.

6.4 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.

6.5 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.

6.6 Many if not all regulating services can be either final or intermediate: in some contexts they may have a beneficial effect directly on people (either supporting production and/or consumption) and in other contexts 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.

6.7 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 recognized 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).

6.8 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 could potentially 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.

6.9 The treatment of final and intermediate services needs to be further worked out, based on the principles described above, in an issues paper on ES definition and classification.

6.10 **The treatment of carbon sequestration and carbon storage**. 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).

6.11 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.

6.12 Hence, if carbon storage is valued as a service, it cannot be assumed that all carbon can be released in certain accounting period (e.g. a year). One option is 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 conceptualization 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)[1].

6.13 **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.

6.14 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'. In CICES biodiversity is not a service except where particular properties of biodiversity (e.g. variety/naturalness) are important. CICES 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', and (species) diversity may be an important motivation for attributing bequest or existence value to an ecosystem.

[1] In the UK the policy concern is addressed by reference to extensions of the accounts which record the emissions prevented by the restoration of peatland and the costs of that restoration. Further thoughts to consider in analysing this aspect is that the store of carbon is a stock, but it is not an asset. It may be benign (like a boulder buried beneath the surface of the earth, which has no economic value) or it may be at risk of being released. In the latter case it is a liability. We may put a value on the damage that would be caused if we didn't manage the liability, but this does not represent the value of any positive service. This discussion may need to consider other above or below ground carbon stores in ecosystems that may be released in case of inappropriate ecosystem management.

6.15 A potential proposal for SEEA is to align with TEEB and IPBES, and to be consistent with the concept of cultural services, and to consider human appreciation of habitat or biodiversity also as a service in itself. However this needs to be further worked out and examined in the form of an issues paper. An argument to consider in this paper, and that has been made in the SEEA EEA TR, is 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. However 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).

6.16 **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.

6.17 As pointed out in the SEEA EEA TR, the SEEA EEA recognizes 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.

6.18 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 could be recorded in the flow accounts of the Central Framework (though better conventions for the treatment of LULUCF emissions as anthropogenic or not are needed in the CF). Potentially they could also be considered in the condition account if it is assumed that this account could record both stocks and flows (note that the Netherlands condition account is also including pressures on ecosystems). 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).

6.19 Therefore, considering also the discussions in the Forum, it is proposed to dedicate an issues paper to the topic of ecosystem disservices and externalities. In the case of disservices, this needs to consider 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[2].

6.20 **Ecological production functions**. Ecological production functions (EPFs) characterize relationships between ecosystem condition, management practices, and the delivery of economically valuable ecosystem services (Macpherson, 2009). The concept of EPFs has been used in FEGS-CS and NESCS to indicate the contribution of the ecosystem to production of ecological end-products [EEPs] that may be used in ecosystem service transactions. FEGS-CS and NESCS specify one-to-one relationships such that each EEP may have (a largely overlapping but possibly unique) EPF.

6.21 There appear to somewhat different interpretations of what an EPF actually is and how it can be applied, in the context of identifying ecosystem services and/or the related but different context of modelling ecosystem services. An ecological production function has been defined as: "an ecological production function specifies the output of ecosystem services provided (produced) given its condition and process" (Kareiva et al., 2011). Note that Macpherson explicitly includes management practices as a determining factor in the supply of ecosystem services, whereas Kareiva states: "once an ecological production function is specified, researchers can quantify the impact of landscape change on the level of ecosystem service outputs". It may well be, however, that people will adjust management of ecosystems as a function of changes in landscapes and/or ecosystems, subsequently affecting the flow of ecosystem services (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. This does not need to constrain application of the concepts of EEP and EPF for identifying ecosystem services, as long as the complexities in the dynamic supply of ecosystem services are recognized (as described in US EPA, 2015).

6.22 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. Given the complexities related to interpreting the concept, and the somewhat different perspectives of individual analysists on applicability of the term, it may be recommendable to not use the term 'ecological production function' in the SEEA EEA.

6.23 **Conclusions**. This note can only cover a limited number of challenges related to defining and classifying ecosystem services for SEEA. Nevertheless, by laying out some insights and generic principles emerging from the SEEA discussions to date, it is hoped that this note can contribute to the development of a coherent treatment of ecosystem services for SEEA.

[2] A question is to what extent should the disservices be attributed to the natural world and to what extent are they due to anthropogenic activity and can hence to be recorded in the Central Framework accounts under the appropriate economic sector

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