DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
STATISTICS DIVISION
UNITED NATIONS

System of Environmental Economic Accounting

# System of Environmental-Economic Accounting 2012 - Experimental Ecosystem Accounting Revision

## Chapter Draft prepared Global Consultation

## Chapter 6: Ecosystem services concepts for accounting

**July 2020**

*Disclaimer:*
*This draft chapter has been prepared under the guidance of the SEEA Experimental Ecosystem Accounting Technical Committee under the auspices of the UN Committee of Experts on Environmental Accounting. It is part of the work on the SEEA EEA Revision being coordinated by the United Nations Statistics Division. The views expressed in this paper do not necessarily represent the views of the United Nations.*

# Opening note to the chapters on ecosystem services

In 2013, the United Nations Statistical Commission endorsed the System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA EEA) as the initial version of statistical framework on the integration of data on ecosystems and the economy. A process to revise the SEEA EEA began in 2017 with the aim of harmonizing and standardizing relevant definitions and concepts in the SEEA's approach to ecosystem accounting. The central framing of the SEEA EEA, referred here as "ecosystem accounting", is to use national accounting principles to integrate ecosystem and economic data.

Ecosystem accounting organizes data in a series of accounts as shown in the table below.

**The core ecosystem accounts**

| | |
|---|---|
| 1 | Ecosystem extent account – physical terms |
| 2 | Ecosystem condition account – physical terms |
| 3 | Ecosystem services supply and use account– physical terms |
| 4 | Ecosystem services supply and use account – monetary terms |
| 5 | Ecosystem monetary asset account – monetary terms |

An important principle of ecosystem accounting is that both physical and monetary data are relevant in the description and assessment of the relationship between ecosystem and the economy. In this context, the three core accounts expressed in physical terms should be considered together with the monetary accounts as part of the broad discussion of the value of ecosystems given that the concept of value can be extended beyond those expressed in monetary terms.

Chapter 2 "Overview of ecosystem accounting" will provide a more complete overview of the accounting framework and will also discuss the ways in which ecosystem accounts can support the discussion of different perspectives on value. Chapters 3-5 concerning the measurement of ecosystem extent and condition and Chapters 8-11 on the valuation of ecosystem services and assets in monetary terms and integration of the ecosystem accounts with the standard national accounts have been released for global consultation and are available on the SEEA EEA Revision website (https://seea.un.org/content/seea-experimental-ecosystem-accounting-revision).

Chapters 6 and 7 on "Accounting for Ecosystem Services" are now being circulated for global consultation and concern the ecosystem services supply and use account in physical terms.

- Chapter 6 provides definitions for ecosystem services and related concepts, describes a reference list of ecosystem services and treatments for recording selected ecosystem services and other flows in an ecosystem accounting context.
- Chapter 7 describes the ecosystem services supply and use accounts in physical terms, outlines the appropriate recording for various flows and summarises some specific issues in measurement such as the spatial allocation of flows of ecosystem services.

The glossary including terms and definitions in Chapters 8-11 has been updated to reflect terms and definitions in Chapters 6 and 7. Consistency of terminology and coherence of concepts across chapters will be further analysed when drafting and reviewing the whole document.

# Contents

# SECTION C: Accounting for Ecosystem services

# 6 Ecosystem services concepts for accounting

## 6.1 The purpose in accounting for ecosystem services

6.1 In the ecosystem accounting framework, ecosystem services serve as the connector between ecosystem assets and the production and consumption activity of businesses, households and governments. The measurement of ecosystem services is thus central to achieving the goal of an integrated set of ecosystem accounts.

6.2 Since the release of *Ecosystems and Human Well-being* (Millennium Ecosystem Assessment, 2005), there has been a significant increase in the number of studies focused on ecosystem services. These studies, involving more than 1300 researchers from a range of disciplines and from all over the world, have focused on many aspects of definition and measurement. The potential of an ecosystem services approach to foster an understanding of the relationship between humans and the environment has then been strengthened through subsequent work within the context of The Economics of Ecosystems and Biodiversity initiative (TEEB, 2010), the Mapping and Assessment of Ecosystems and their Services (MAES) framework (Maes et al., 2013) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015). The approach to accounting for ecosystem services presented here builds on all of this research.

6.3 The measurement of ecosystem services is of particular interest in explaining the variety of contributions that ecosystems make to people and the economy. These contributions extend well beyond marketed goods, such as timber and fish, and include services such as air filtration, water purification, climate regulation and amenity services. Commonly these types of services are supplied to communities outside market institutions. The focus of accounting for ecosystem services is to provide a clear structure by which information on the range of services can be readily compared, connected to information on the different ecosystems that supply the services and linked to the different users who receive the services.

6.4 Further, an important part of the rationale for accounting for ecosystem services is that while much economic production (for example, in agriculture, forestry and fisheries) uses inputs directly taken from ecosystems, those inputs (and any associated costs of capital) are not explicitly recorded in the standard national accounting framework. In ecosystem accounting, ecosystem services are clearly differentiated from the goods and services that are produced, i.e., the ecosystem services are recorded as the contributions of ecosystem assets to the production of those goods and services. In effect, this extends the input-output or supply chain to include ecosystems as suppliers.

6.5 This chapter provides descriptions and definitions of the various concepts and principles that are applied in accounting for the supply and use of ecosystem services. Using these concepts and principles, the chapter outlines a reference list of selected ecosystem services and associated definitions to support account compilation and comparison of methods and findings. The chapter also provides additional explanation on the treatment of specific services and associated environmental flows thus describing the measurement scope that is appropriate for ecosystem accounting.

## 6.2 Concepts and principles in accounting for ecosystem services

### *6.2.1 Ecosystem services*

6.6 The key concepts of the ecosystem accounting framework related to ecosystem services concern (i) the supply of ecosystem services to users and (ii) the contribution of ecosystem services to benefits. The following paragraphs place these concepts in context for ecosystem accounting purposes.

6.7 Following the general framework of ecosystem accounting, each ecosystem asset supplies a set or bundle of ecosystem services. In this framing, ***ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity***. Ecosystem services are recorded as flows between ecosystem assets and economic units; where ecosystem assets are defined as contiguous spaces of a specific ecosystem types (see Chapter 3), such as a forest or wetland; and economic units encompasses the various institutional types included in the national accounts, such as businesses, governments and households.

6.8 Following the cascade model describing flows of ecosystem services,[1] the supply of an ecosystem service will be associated with an ecosystem process or an ecosystem characteristic or a combination of ecosystem processes and characteristics that reflect the biological, chemical and physical interactions among ecosystem components. These processes and characteristics are observable and measurable but are not themselves flows of ecosystem services as defined in ecosystem accounting since this requires a connection to be made to users.

6.9 For accounting purposes, ecosystem assets can also be considered as complex and interacting producing units ("factories") who supply outputs of ecosystem services to various users. Thus, ecosystem services can be considered to be transacted between ecosystem assets on the one hand and economic units on the other. The nature of transactions implies existence of a matching supply and use – i.e., in a single transaction of ecosystem services the amount supplied by the ecosystem must equal the amount used by the economic unit. This equality between supply and use is a foundational accounting concept (see SEEA Central Framework Section 3.2) and holds in both biophysical and monetary terms.[2] The recording of ecosystem services will pertain to total flows over an accounting period (e.g., one year) and thus an entry will reflect a rate or total flow per unit of time.

6.10 The recognition of ecosystems as units that transact directly with economic units also supports the integration of flows of ecosystem services with flows of goods and services (products) transacted between economic units as recorded in the standard national accounting system. The measurement scope of products is defined by the SNA production boundary which explicitly excludes ecosystem services by considering that "*a purely natural process without any human involvement or direction is not production in an economic sense*" (2008 SNA, 6.24). Recording ecosystem services as transactions supplied by ecosystems as

[1] This framing reflects the general framing of the well-recognised cascade model (Haines-Young & Potschin-Young, 2010) and the framing provided by Boyd & Banzhaf (2007). Central to these framings is that ecosystem services are "contributions to benefits" rather than being "equivalent to benefits" which was the framing applied in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005). The language of contributions is also present in the approach of IPBES (Díaz et al., 2015) which adopts the term "nature's contributions to people" although this is a concept very closely related to ecosystem services as generally applied in the ecosystem services literature. The focus on contributions and transactions also directly suits the accounting approach of the SEEA and the application of supply-use principles.

[2] It is recognised that in much ecosystem services literature the term supply is used to refer to an ecosystem's potential or capacity to supply services irrespective of use and the term use is applied to refer to the actual flow to people. Here, the amount of ecosystem service transacted will be equivalent to the actual flow.

additional producing units thus supports an extension of the SNA production boundary, i.e., the total output of the extended system is increased.

### *6.2.2 Benefits*

6.11 ***Benefits are the goods and services that are ultimately used and enjoyed by people and which contribute to individual and societal well-being***. The use of the term benefit in ecosystem accounting derives from the SNA definition of an economic benefit, namely "*an economic benefit is defined as denoting a gain or positive utility arising from an action*" (2008 SNA, 3.19) where an action or activity concerns production, consumption or accumulation and utility concerns the satisfaction of a human need or an improvement in well-being.[3] Thus, in ecosystem accounting, a benefit will reflect a gain or positive contribution to well-being arising from the consumption of ecosystem services.

6.12 Benefits are classified as either SNA benefits or non-SNA benefits. ***SNA benefits are goods or services produced by economic units currently included in the economic production boundary of the SNA.*** Examples of SNA benefits include food, water, energy, clothing, shelter and recreation. Following SNA principles, goods and services produced through subsistence production are included in the set of SNA benefits and hence ecosystem services that contribute to the supply of these benefits are in scope of ecosystem accounting.

6.13 As contributions to SNA benefits, ecosystem services are readily seen as inputs into an existing production process and consequently SNA benefits can be seen as resulting from a joint production process involving ecosystems and various economic inputs including produced assets and labour. It will often be useful to distinguish between economic inputs involved in the supply of ecosystem services (e.g., the use of fertilizers in the growing of crops) and those involved in accessing or using ecosystem services (e.g., use of vehicles to drive to parks for recreation). In both contexts, the aim in ecosystem accounting is to isolate and record the ecosystem's contribution to the benefits received.

6.14 ***Non-SNA benefits are benefits that accrue to individuals, or society generally, that are not produced by economic units.*** Examples of non-SNA benefits include clear air and flood protection. By convention, the scope of non-SNA benefits for ecosystem accounting purposes is limited to the contributions of ecosystem services with an identifiable link to human well-being. While ecosystem accounting does not require the recording of non-SNA benefits, their description is needed such that the relevant ecosystem contributions can be defined and measured.

6.15 In addition to distinguishing benefits as being either SNA or non-SNA benefits, a complementary view is to consider the private and public nature of the benefits. Three situations can be described.

i. There are ecosystem services that contribute to benefits received by owners and managers of ecosystems (e.g., in the case of agricultural production).

ii. There are ecosystem services that contribute to benefits received by individual economic units, including households, that do not own or manage the ecosystem (e.g., benefits from air filtration to a local community from a privately-owned forest).

[3] As in the SNA, the term utility is used here in the sense of providing a conceptual reference point rather than a measurement objective.

iii. There are ecosystem services that contribute to benefits received by society or communities at large and satisfy the economic definition of public goods (e.g., benefits from global climate regulation services).

6.16 An application of these distinctions is that those ecosystem services that contribute to public goods can be treated analogously to those services treated in the SNA as collective consumption. These distinctions are relevant in the allocation of ecosystem services to users (as discussed further in Chapter 7) and in the integration of ecosystem services and ecosystem assets in the extended sequence of sector accounts described in Chapter 11.

### *6.2.3 Well-being*

6.17 Ultimately, the measurement of ecosystem services is linked to the concept of individual and societal well-being. In an economic framing, well-being is commonly described in terms of welfare and utility which in turn may be linked to the consumption of goods and services[4] and the receipt of benefits. The System of National Accounts, for example, defines an economic benefit as "*denoting a gain or positive utility arising from an action*" (2008 SNA, 3.19). More widely in economics, the assessment of changes in welfare and well-being, will consider both positive and negative effects on utility.

6.18 In bridging among these perspectives on well-being from an accounting perspective, a useful framing concerns the distinction between outputs and outcomes (OECD, 2008). In that discussion, it is generally agreed that the focus of measurement for accounting purposes should be on outputs produced by economic units (e.g., medical care) rather than on outcomes which reflect a particular state or condition to which people attach utility or value (e.g., health). It will generally be the case that the measurement of outcomes will reflect the measurement of well-being. There is much merit in measuring outcomes and associated concepts concerning well-being (e.g., OECD work on well-being measures).

6.19 For ecosystem accounting, the focus is on recording flows of ecosystem services as contributions to benefits. Thus, the definition and measurement of the level of individual and societal well-being is outside the scope of measurement for the ecosystem accounting framework. At the same time, as summarized in Annex 8.1, it is possible, under various assumptions, to make inferences about changes in well-being using information about changes in flows of ecosystem services. Further, data from the core ecosystem accounts may support the derivation of complementary measures such as those described in Chapter 12.

### *6.2.4 Users and beneficiaries*

6.20 In accounting, the supply and use of ecosystem services in the production of benefits can be considered, in many contexts, as the first step in a longer economic "supply" chain. For example, a water supply company's use of water purification services will be an initial step in the abstraction and distribution of water to a wide range of economic units, including businesses, governments and households. For clarity of expression, all of these economic units may be referred to as beneficiaries of ecosystem services but the economic unit that has the direct connection to the ecosystem, i.e., the unit that is the counterparty in the transaction with the ecosystem, is labelled the user of the ecosystem service. In this example, the user of water purification services is the water supply company while the other economic units would

[4] In this context, "consumption" includes both the transformation of materials (e.g., use of timber to build houses or for energy) and the passive receipt of non-material ecosystem services (e.g., the amenity of viewing landscapes).

be beneficiaries. This approach is consistent with the recording of the use of goods and services in the SNA.

6.21 In recording flows of ecosystem services to various users and beneficiaries, it will be relevant to consider the location of use relative to the location of the supplying ecosystem. This will extend to consideration of imports and exports of ecosystem services and the associated benefits. The mapping of ecosystem service flows to users and beneficiaries is discussed further in Chapter 7.

### *6.2.5 Final and intermediate services*

6.22 The primary focus of ecosystem accounting is on the measurement of final ecosystem services. ***Final ecosystem services are those ecosystem services in which the user of the service is an economic unit – i.e., business, government or household***. Thus, every final ecosystem service flow represents a transaction between an ecosystem asset (as a producing unit) and an economic unit.

6.23 To support integration with the SNA, the measurement scope of ecosystem services is set such that transactions in ecosystem services do not overlap with the transactions in goods and services recorded in the SNA (i.e., SNA benefits). The measurement scope of goods and services recorded in the SNA is defined by the SNA production boundary. In ecosystem accounting, ecosystem services are recorded as additions to the SNA production boundary.

6.24 The focus on accounting for final ecosystem services is sufficient for recording, in a comprehensive manner, the connection between people and ecosystems. However, the ecosystem processes associated with flows of final ecosystem services involve many connections within and between ecosystem assets that will be relevant in determining the supply of final ecosystem services. For example, populations of wild fish may be caught at sea while the associated nurseries are located in seagrass meadows closer to shore. The overall contribution of ecosystems will be embodied in the catch of wild fish (a final ecosystem service) but this recording will not reveal the contribution of the seagrass meadows.

6.25 Conceptually, the ecosystem accounting framework allows the contributions of ecosystem processes taking place within and between ecosystems to be recorded as intermediate services. As for final ecosystem services, intermediate services are transactions and represent contributions to benefits. However, they are recorded as transactions between and within ecosystems rather than involving an economic unit as the user.

6.26 For ecosystem accounting purposes, measurement of intermediate services is limited to those flows that are part of an observable chain of flows to a final ecosystem service. It is expected that only a limited number of intermediate services would be recorded in a set of ecosystem accounts, primarily to recognize connections of high analytical or policy interest, for example concerning the role of wild pollinators in supporting the production of crop biomass. Thus, ***intermediate services are those ecosystem services in which the user of the ecosystem services is an ecosystem that is connected to the supply of final ecosystem services.***

6.27 It is not intended that the concept of intermediate services is used as a basis for recording the wide array of biophysical flows within and between ecosystems that reflect the ongoing operation of ecological processes. There is no doubt that these processes are fundamental to the supply of ecosystem services but a complete mapping of intra- and inter ecosystem flows is beyond the scope of ecosystem accounting. Nonetheless, there will be interest in understanding the extent to which the various ecological processes are well-functioning, for example in understanding the ability of an ecosystem to provide ecosystem services into the future. In ecosystem accounting, the maintenance of well-functioning ecosystems is

considered in the measurement of ecosystem condition and capacity. It is also a key focus in the measurement of biodiversity.

### *6.2.6 Abiotic flows*

6.28 Not all flows from the environment to people are considered ecosystem services. For example, flows of mineral resources that are extracted by economic units are not considered ecosystem services. Generically, these flows are considered abiotic flows and are distinguished from ecosystem services by considering the relative importance of current ecological processes in their supply. There is a range of boundary cases that are considered in section 6.4.

### *6.2.7 Identifying flows of ecosystem services*

6.29 To support consistent application of the boundary between ecosystem services and benefits a tool referred to as a "logic chain" is applied. The intent is to provide a standard framing for recording information relevant to the description and measurement of individual ecosystem services. A logic chain reflects a sequence in which an ecosystem asset supplies an ecosystem service to an economic unit who uses that ecosystem service as an input to a production or consumption activity which subsequently leads to an SNA or non-SNA benefit. Logic chains can be shown graphically but may also be shown in a table as shown in Table 6.1.

**Table 6.1: Generic logic chain (with example of air filtration services)**

| **Ecosystem type/s** | **Factors determining supply** | | **Ecosystem Service** | | **Factors determining use** | **Benefit** | **Users** |
|---|---|---|---|---|---|---|---|
| | **Ecological** | **Human** | **Description** | **Physical metric/s** | | | |
| Mainly forest and woodland | Type and condition of vegetation; Ambient pollutant concentrations; | Ecosystem management; Release of air pollutants | **Air filtration services (air pollutant mediation)** | Tonnes of pollutants absorbed by type of pollutant (e.g., PM10; PM2.5) | Behavioural responses and location of people and buildings affected by pollution | Reduced concentrations of air pollutants providing improved health outcomes and reduced damage to buildings (non-SNA benefit) | Individuals and households |

6.30 As shown in Table 6.1, each logic chain for a given ecosystem service has a number of components: (i) the ecosystem types; (ii) factors determining supply; (iii) the ecosystem service and the common metric for measurement; (iv) factors determining use; (v) the associated benefit/s and (iv) the users. The following points are highlighted in respect of each component:

- *Ecosystem assets:* All ecosystem services are treated as being supplied by ecosystems, either individually (e.g., forest providing air filtration services to a neighbouring town) or in combination (e.g., ecosystems within a catchment providing water regulation services). Where relevant for description and measurement purposes, it may be useful to highlight

particular ecological characteristics of the ecosystems that are relevant to the supply of ecosystem services, for example the presence of particular species, or soil type.

- *Factors determining supply*: In most cases, but particularly for regulating services, there are certain factors, that are present which determine the supply of an ecosystem service. For example, the service of air filtration requires that there is some release of air pollutants and some level of atmospheric pollutant concentrations. Both ecological and human factors should be considered in describing those factors determining supply. Where there are cases of joint production of benefits, for example in the growing of crops, it will be relevant to recognise the human inputs such as labour, produced assets (e.g., tractors) and intermediate consumption of goods and services (e.g., fuel, fertilizer).
- *Ecosystem services*: A logic chain should revolve around a single ecosystem service recognising that it may be supplied by a combination of ecosystem assets and may contribute to a number of benefits. A physical metric needs to be specified that gives a clear focus for measurement recognising that this metric may be a proxy for the ecosystem service and will vary depending on the data availability. For example, for air filtration a suitable metric will be the tonnes of pollutant absorbed by type of pollutant (e.g., PM2.5, PM10).
- *Factors determining use*: In addition to describing the factors involved in supply it will be relevant to describe how people and economic units engage with the ecosystem in order to use the ecosystem service. In the case of air filtration, the relevant factors concerning use will be the number of people in proximity to the relevant forest or other type of ecosystem.
- *Benefits*: While the focus of ecosystem accounting is on identifying the contribution of ecosystems reflected in ecosystem services, commonly it will be through the observation of the benefits that the identification of the role of ecosystems can be described. For air filtration, the benefit of reduced concentrations of air pollutants will be received by both individuals with respect to their health and building owners in terms of damage to property.
- *Users:* Different economic units will use the ecosystem services, in some cases the same service may be used by different types of economic units. For example, air filtration services will be used by both households and businesses.

*<<**Note to reviewers**: Additional examples of logic chains for a small selection of ecosystem services are presented in Annex 6.1. It is intended that logic chains for other ecosystem services in the reference list (see section 6.3) will be developed. >>*

### *6.2.8 Potential supply and ecosystem capacity*

*<<**Note to reviewers**: There are a number of relevant concepts to be discussed in this section. They are linked to ongoing discussion on the topic of ecosystem capacity which has also emerged in the context of Chapter 5 on ecosystem condition and Chapter 10 on the monetary valuation of ecosystem assets. Relevant text for all relevant sections will be included for the second round of global consultation.>>*

### *6.2.9 The link between biodiversity and ecosystem services*

6.31 The SEEA adopts the Convention on Biological Diversity's (CBD's) definition of biodiversity as: ***"the variability among living organisms from all sources including, inter alia, terrestrial,***

***marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".***

6.32 The CBD definition highlights ecosystem, species and genetic diversity (i.e., within species) as the broad components of biodiversity. While these components of biodiversity are not considered ecosystem services in themselves, there are distinct elements within these components that can be directly linked to ecosystem service supply. For example, specific genes (DNA sequences) can be a provisioning service to the pharmaceutical industry; pollinator species can provide important pollinating services to the agricultural sector; and ecosystems, such as forests and beaches, can provide places for recreation.

6.33 However, the interactions between different components of biodiversity are essential for cycling energy, nutrients and other materials through the environment (Mori et al., 2013). This is fundamental for maintaining the various ecosystem processes and functions that underpin ecosystem service supply (Bolt et al., 2016). Further, as biodiversity is lost, these ecosystem processes are impacted. For example, as different ecosystems are lost, landscape processes are altered; and as species and their populations are lost from ecosystems, so are the different functional roles they perform (e.g., decomposing, pollinating, dispersing seeds). Consequently, biodiversity loss directly threatens ecosystem processes and the supply of many ecosystem services across multiple scales.

6.34 Biodiversity also plays a fundamental role in maintaining the capacity of ecosystem assets to continue to generate ecosystem services into the future. The presence of a diversity of organisms (e.g., multiple species, the genetic diversity within them) performing a given function within an ecosystem boosts the capacity of that ecosystem to maintain functionality and supply ecosystem services. This is because different environmental changes or shocks will affect individual elements of this diversity in different ways. This ability of ecosystems to tolerate shocks and disturbance while maintaining the same level of functioning is often referred to as 'ecosystem resilience' (Mori et al., 2013)and may be considered to have an 'insurance value' (Baumgärtner, 2007).

6.35 Elements of biodiversity that do not provide ecosystem services at present may also provide valuable ecosystem service in the future. For example, a tropical tree species might prove to be the only source of a drug capable of combating a major new human disease. This role of biodiversity can be linked to the concept of an "option value" (Faith, 2018; Weitzman, 1992).

6.36 Further, while biodiversity underpins the supply of ecosystem services, the maintenance of biodiversity itself will be impact on the types of ecosystem services used by people and the extent of that use. Thus harvesting of timber and fish will have implications for biodiversity in the relevant ecosystems and biodiversity will be affected in ecosystems with high levels of tourism activity. Choices in restoration and protection will also have impacts on biodiversity. The connections between biodiversity and human activity thus operate in two directions.

6.37 It is important to identify there still remains considerable uncertainty around the specifics of the current relationships between biodiversity itself and ecosystem service supply (Harrison et al., 2014; Mace et al., 2012). In particular, where 'tipping points' for biodiversity loss may lie with respect to ecosystem service supply (Mace et al., 2015). This should encourage a precautionary approach to the management of biodiversity for sustainable ecosystem service supply.

6.38 The strong emphasis on biological "variability" or "diversity" is clear in the CBD definition. In the context of ecosystem accounting, biodiversity can then be viewed as an emergent property of a set of ecosystem assets and the community assemblages within them. These interact and support multiple ecosystem processes that underpin the capacity for current and future ecosystem service supply. As such, the link between biodiversity and ecosystem service

supply should consider the roles played by diversity across all three of its components (ecosystems, species and genes) and across scales. Options on how this can be accounted for are explored further in Chapter 13.

### *6.2.10 The treatment of ecosystem disservices*

*<<**Note to reviewers**: Material concerning ecosystem disservices will be developed as part of a wider discussion on the links between ecosystem accounting and the assessment of externalities.>>*

## 6.3 The reference list of selected ecosystem services

### *6.3.1 Principles of the reference list of selected ecosystem services*

6.39 Within the conceptual scope of the ecosystem services production boundary there are a wide range of different ecosystem services. Notwithstanding strong advances in the development of classifications of ecosystem services, in particular the Common International Classification of Ecosystem Services (CICES)[5] and the National Ecosystem Service Classification System (NESCS)[6], an internationally agreed classification of ecosystem services has not been finalized. In its absence, a reference list of selected ecosystem services has been developed by combining the findings from the CICES, NESCS and other work (e.g., MA, TEEB and IPBES- NCP) on the typology and classification of ecosystem services with the outcomes of the consultation on the revised SEEA EEA. The primary criterion for inclusion in the reference list of selected ecosystem services is that the service is considered to constitute a relevant and material ecosystem service in many countries and contexts.

6.40 The reference list of selected ecosystem services provides labels and descriptions for a set of key ecosystem services relevant for ecosystem accounting. The reference list will support discussion among ecosystem accounts compilers, the comparison of measurement and valuation techniques and the comparison of accounting results.

6.41 The reference list is not intended to provide a full ecosystem service classification system. It is intended that a complete and internationally agreed classification system for ecosystem services will be developed. To support this development and to allow those using those classification systems to link to the reference list, correspondences to CICES and NESCS are presented in Annex 6.1. *<<NB: These correspondences will be developed on finalization of the reference list>>*

6.42 Each ecosystem service in the reference list is defined such that it can be measured in a mutually exclusive and separable way such that there is no double-counting of the ecosystem contributions of individual ecosystem services in the reference list. The focus in applying this principle will vary by type of ecosystem service. For provisioning services, the mutual exclusivity will be connected with using a classification of biomass outputs such as of agricultural products. For regulating services, the focus is on distinguishing the roles of different ecological processes. For cultural services, the focus is on the description of the types of interactions that individual have with ecosystems, for example whether they take place within ecosystems or outside.

[5] https://cices.eu/resources/

[6] https://www.epa.gov/eco-research/national-ecosystem-services-classification-system-framework-design-and-policy

6.43 Since it contains only selected ecosystem services, the reference list is not exhaustive. It is therefore appropriate for ecosystem services not included in the reference list to be included in a set of ecosystem accounts subject to them satisfying the definition of ecosystem services and being within the scope of the ecosystem services production boundary. Where additional ecosystem services are included in a set of ecosystem accounts it is important that the definition, labelling and measurement of those ecosystem services is done in a mutually exclusive and separable way to facilitate comparison to those ecosystem services included in the reference list.

6.44 Following the requirements of ecosystem accounting, the reference list does not incorporate a distinction based on the type of supplying ecosystem asset or a distinction based on the nature of the use of the ecosystem service (e.g., whether for use by households or business, for nutrition or energy, etc). The information on the supplying ecosystem assets and the using economic units will be evident from the column in the supply and use account where the transaction is recorded. Thus, for example, the supply and use account will use existing classifications of ecosystem types and economic units to organize information on each ecosystem service flow.

6.45 Further, the reference list includes both final ecosystem services (i.e., used by economic units) and intermediate services (i.e., used by ecosystem assets). The distinction between final and intermediate is not a reflection on the type of ecosystem service but instead is a reflection of the user of the service (and hence affects where it is recorded in the supply and use account).

### *6.3.2 The reference list of selected ecosystem services*

6.46 The reference list of selected ecosystem services and associated descriptions is shown in Table 6.2. The list is structured at the highest level into three broad categories: provisioning services; regulating and maintenance services and cultural services.

- ***Provisioning services are those ecosystem services representing the material contributions supplied by an ecosystem.***
- ***Regulating and maintenance services are those ecosystem services resulting from the capacity of ecosystems to regulate and maintain climate, hydrological and biochemical cycles, Earth surface processes and a variety of biological and geological processes.***
- ***Cultural services are the perceived or realized qualities of ecosystems whose existence and functioning enables a range of cultural benefits to be derived by individuals.***

6.47 Within each of these broad groups a number of ecosystem service types are included with some sub-types also listed.

6.48 To ensure that the coverage of the ecosystem accounts is as comprehensive as possible, compilers are encouraged to include as many types of ecosystem services as possible. A progressive expansion in scope of measurement over time may be appropriate, considering data and resource availability and relative significance of the ecosystem services.

**Table 6.2: Reference list of selected ecosystem services**

| ECOSYSTEM SERVICE | | DESCRIPTION |
|---|---|---|
| **Provisioning services** | | |
| Biomass provisioning services | Crop provisioning services | Biomass provisioning services are the ecosystem contributions to the growth of plant, animal and other biomass (e.g., fungi) that are subsequently harvested by economic units for various uses. These uses include the production of food, fibre, energy, medicines and cosmetics. These services may be provided in cultivated and natural production contexts and will reflect final ecosystem services. |
| | Grazed biomass provisioning services | |
| | Timber provisioning services | |
| | Non-timber forest products (NTFP) and other biomass provisioning services (incl those related to hunting and trapping and bio-prospecting activities) | |
| | Fish and other aquatic products provisioning services | |
| Water supply | | Water supply services reflect the combined ecosystem contributions of water purification and water regulation to the supply of water to economic units for various uses including domestic consumption, irrigation and hydropower. It is a final ecosystem service. |
| Genetic material services | | Genetic material services are the ecosystem contributions from all biota (including seed, spore or gamete production) that are used by economic units (i) to maintain or establish a new population, (ii) to develop new varieties or (iii) in gene synthesis. It is a final ecosystem service. |
| | | |
| **Regulating and maintenance services** | | |
| Global climate regulation services | | Global climate regulation services are the ecosystem contributions to the regulation of the concentrations of gases in the atmosphere that impact on global climate, primarily through the retention of carbon in ecosystems. It is a final ecosystem service collectively consumed by governments on behalf of society. |
| Rainfall pattern regulation services (at sub-continental scale) | | Rainfall pattern regulation services are the ecosystem contributions of vegetation at the sub-continental scale, in particular forests, in maintaining rainfall patterns through evapotranspiration. It is a final ecosystem service. |
| Local (micro and meso) climate regulation services | | Local climate regulation services are the ecosystem contributions to the regulation of ambient atmospheric conditions (including micro and mesoscale climates through the presence of plants that improves the living conditions for people and supports economic production. Examples include the evaporative cooling provided by urban trees and the contribution of trees in providing shade for livestock. It is a final ecosystem service. |
| Air filtration services | | Air filtration services are the ecosystem contributions to the filtering of air borne pollutants through the fixing and storage of pollutants by ecosystem components, particularly plants, that mitigates the harmful effects of the pollutants. It is a final ecosystem service. |
| Soil quality regulation services | | Soil quality regulation services are the ecosystem contributions to the decomposition of biological materials that maintains the fertility and characteristics of soil for human use. It is an intermediate service. |
| Soil erosion control services (includes also sediment retention services) | | Soil erosion control services are the ecosystem contributions, particularly the stabilising effects of plants, that reduce the loss of soil (and sediment) and mitigate or prevent potential damage to human use of the environment or human health and safety. It is generally an intermediate service (contributing to biomass |

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| | | provisioning services) but it can also be a final ecosystem service (preventing damaging effects to houses and buildings from mass movement of soil). |
| Water purification services (water quality amelioration) | Retention and breakdown of organic pollutants including excess nutrients | Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the dilution, breakdown and storage of pollutants by ecosystem components that mitigates the harmful effects of the pollutants on human use or health. It can be a final or intermediate ecosystem service. |
| | Retention and breakdown of inorganic pollutants | |
| Water regulation services | Baseline flow maintenance | Water regulation services are the ecosystem contributions to the regulation of river and groundwater flows. They are derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods.<br>Services concerning baseline flows may be final or intermediate, while those concerning extreme events are generally final ecosystem services. |
| | Peak flow mitigation | |
| Flood mitigation services | Seawater (Tidal) surge mitigation (Coastal protection services) | Seawater surge mitigation services are the ecosystem contributions of linear elements in the landscape, for instance dunes or mangrove ecosystems along the shore, in protecting the shore and thus mitigating the impacts of tidal surges or storms on local communities. This is a final ecosystem service. |
| | River flood mitigation | River flood mitigation services are the ecosystem contributions of riparian forests and other riparian ecosystems in protecting the banks of rivers from floods by providing structure and a physical barrier to high water levels and thus mitigating the impacts of floods on local communities. This service complements the peak flow mitigation service in which ecosystems regulate water levels. River flood mitigation is a final ecosystem service. |
| Storm mitigation services | | Storm mitigation services are the ecosystem contributions of vegetation, especially linear elements in the landscape, in mitigating the impacts of wind, sand and other storms (other than water related events) on local communities. This is a final ecosystem service. |
| Noise attenuation services | | Noise attenuation services are the ecosystem contributions to the reduction in the impact of noise on people that mitigates its harmful or stressful effects. It is a final ecosystem service. |
| Pollination services | | Pollination services (or gamete dispersal in marine contexts) are the ecosystem contributions by wild pollinators to the fertilization of crops that maintains or increases the abundance and/or diversity of other species that economic units use or enjoy. It is generally an intermediate service, especially in the context of biomass provisioning services. |
| Pest control services | | Pest control services are the ecosystem contributions to the reduction in biological interactions of the incidence of species that prevent or reduce the output of biomass from ecosystems. It is generally an intermediate service, commonly in the context of biomass provisioning services. |
| Nursery population and habitat maintenance services | | Nursery population and habitat maintenance services (including gene pool protection) are the ecosystem contributions to the presence of ecological conditions (usually habitats) necessary for sustaining populations of species that economic units use or enjoy. It is generally an intermediate service, for example in the context of biomass provisioning services (fish provisioning services) and in the context of ecosystem and species appreciation services. |
| Solid waste remediation | | Solid waste remediation services are the ecosystem contributions to the transformation of an organic or inorganic substance that mitigates its harmful effects. It can be a final or intermediate ecosystem service. |

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| **Cultural services** | | |
| Recreation-related services | Tourism recreation-related services | Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through physical and experiential interactions with the environment. They are final ecosystem services. A distinction is made between local and tourism related services to reflect the type of visitor engaging with ecosystems. |
| | Local recreation-related services | |
| Amenity services | | Amenity services are the ecosystem contributions to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems, that provide benefits including recreational opportunities, visual aesthetics and lower levels of air and noise pollution. They are final ecosystem services. |
| Education, scientific and research services | | Education, scientific and research services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through intellectual and representative interactions with the environment. They are final ecosystem services. |
| Spiritual, symbolic and artistic services | | Spiritual, symbolic and artistic services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that are recognised by people for their cultural, historical, sacred or religious significance. They are final ecosystem services. |
| Ecosystem and species appreciation services | | Ecosystem and species appreciation services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that people seek to preserve because of their non-utilitarian qualities. They are final ecosystem services. |

## 6.4 The treatment of specific ecosystem services and other environmental flows

### *6.4.1 The treatment of biomass provisioning services*

6.49 There is clear recognition that people source and use biomass from ecosystems in a wide variety of ways and for different purposes, including for food, fibre and energy. Sometimes the biomass is harvested directly by a final consumer (e.g., household picking berries in a forest) but the vast majority of biomass is grown, harvested or accessed by farmers, foresters and fishers (economic units both small and large) that supply it to other economic units. Determining the appropriate treatment of these biomass provisioning services is complicated by the variety of biomass types and the range of ways in which people grow and harvest biomass from the environment.

6.50 Biomass provisioning services are ecological contributions to SNA benefits in the form of food, fibre and energy outputs produced by economic units. In line with treatments in the SNA, all biomass provisioning that is input to subsistence production of agriculture, forestry and fisheries should be included in the scope of ecosystem accounts. This includes for example the collection and harvest of non-timber forest products and the growing of vegetables in backyard gardens. While all biomass harvested can be considered an SNA benefit, the SNA makes a distinction between cultivated and natural (non-cultivated) production processes with the differentiation based on the extent to which an economic unit manages or controls the growth of the biomass.

6.51 In natural production processes, all of the biomass that is harvested is considered the ecosystem contribution. Examples include harvesting of timber from natural forests, capture

fishing from wild fish stocks and wild animals trapped and hunted (including bush meat). The measurement of the ecosystem service should be aligned with the gross quantity of biomass that is harvested, i.e., the gross natural input. This will be different from the total stock of biomass available for harvest and from the biomass that is subsequently removed from the ecosystem and sold or otherwise used. Thus, for example, felling residues and discarded catch should be considered as part of the ecosystem service flow.[7] This definition will apply irrespective of (i) the length of time over which the biomass has been growing; and (ii) the derivative nature of the product, (e.g., honey from wild bees). Thus, focus is solely on the quantity of the biomass that is harvested or accessed.

6.52 In cultivated production processes, joint production is considered to occur in which the role of the ecosystem in supplying the biomass intersects with the activity (and associated human inputs) of people and economic units. The activities of economic units in this joint production process can be separated into those concerning the growth of the biomass (e.g., the application of fertilizers and pesticides) and those concerning the harvest of the biomass. The contribution of the ecosystem is evident up to the point of harvest.

6.53 There is a very wide range of cultivated production contexts. Thus, the extent of human activity in the management of biomass growth can be very high (e.g., for hydroponically grown strawberries) or very low (e.g., for lightly managed timber plantations). Further, depending on the type of biomass and the related product, the timing and context of the growth and harvest can vary significantly. Further, within each production context there is a wide variety of management practices and there may be more than one benefit that is generated. For example, corn production may produce food as well as biomass for the production of energy; and cattle production will supply food as well as hides for leather and bones for fertilizer.

6.54 Notwithstanding this diversity of cultivated production contexts, the conceptual intent for ecosystem accounting is to identify the ecological contribution, i.e., to recognize that in different production contexts the relative role of ecosystem services will vary. This intent can be aligned with a framing in which there is a focus on the individual inputs such as nutrients, water, soil retention, pollination etc. which will be used in different combinations in different contexts.

6.55 In practice, there is a considerable measurement challenge in either identifying all of the relevant individual inputs or accurately measuring the ecosystem contribution to the gross biomass that is harvested that takes into account the diversity of cultivated production contexts. Thus, a suitable proxy for the measurement of the flow of biomass provisioning services in cultivated production contexts is the gross biomass harvested.

6.56 For cultivated plants, the measurement of gross biomass harvested is applied directly such that the proxy measure of ecosystem services is the quantity harvested, for example quantities of corn, timber or apples. This flow is recorded as supplied by the relevant ecosystem and used by the economic unit managing the cultivation (e.g., farmer).[8]

6.57 For cultivated livestock, the measurement of the gross biomass harvested may focus on the livestock products (e.g., meat, milk, eggs); the growth of the livestock (i.e., change in number and weight of livestock) or on the provision of feed (i.e., grazed biomass). For ecosystem accounting, the focus is on the extent of the connection between livestock and relevant

[7] This treatment aligns with the recording of natural inputs in the SEEA Central Framework – see Section 3.2.2

[8] The subsequent sale of harvested outputs by the economic unit along the supply chain is recorded in the standard SNA production accounts. Double counting is avoided by ensuring that there are entries for both the supply and use of the ecosystem service and hence the net effect with respect to the farmer's value-added is unchanged but the contribution of the ecosystem is recognised.

ecosystem assets, primarily natural and cultivated pastures. Hence, the supply of biomass provisioning services related to livestock is focused on the quantity of grazed biomass which may be extended to include other ecosystem services provided by relevant ecosystems such as water supply and local climate regulation (e.g., trees providing shade and wind protection).

6.58 Consequently, for ecosystem accounting, where livestock production takes place and the animals are not in direct connection with an ecosystem, as commonly occurs, for example, in the raising of chickens and pigs, no ecosystem services should be recorded. In these cases, the associated ecosystem services are limited to the ecosystem contribution to the production of feed and supplements (e.g., hay, pellets, etc.) that may be supplied on-farm, by neighbouring producers or may be imported. In these instances, the ecosystem contribution should be attributed to the location where the feed is grown not to where it is used.

6.59 By extension, this same treatment applies to animals (mainly fish) raised in aquaculture facilities whose cultivation involves the provision of feed inputs. Thus, the gross biomass harvested from aquaculture should not be used as a proxy for the ecosystem contribution. An exception arises where no feed or other inputs are provided (e.g., the farming of oysters). In these cases, the ecosystem service can be proxied using the gross biomass harvested.

6.60 To support analysis, it may be appropriate to present data on the gross biomass harvested by different broad production contexts, for example in terms of intensive and extensive production or organic farming. Further, measurement by biomass type and by relevant ecosystem characteristic (e.g., by soil type, climatic zone) is likely to assist in understanding the relative ecological contribution.

- To complete the description of the treatment of biomass provisioning services, four other commonly considered issues are noted. There are many instances, especially with regard to fishing, where people catch wild animals as part of their recreational activities and sometimes as part of a paid service. From a national accounts perspective, if the catch is retained for consumption then it should be included within the production boundary of the SNA and hence the quantity and value of the associated biomass should be included as part of biomass provisioning services. At the same time, there will be a clear connection to the measurement of recreation-related ecosystem services, including hunting, trapping and fishing. In these instances, cultural services may be recorded in addition to biomass provisioning services.

- *Intermediate services in biomass production.* For cultivated biomass provisioning it should be straightforward to attribute the service to a specific ecosystem asset since there will be a distinct location where the biomass is grown and harvested. For uncultivated biomass provisioning this may be more challenging, especially for fish biomass. In concept, for non-aquaculture fish biomass, the relevant supply location is the place at which the transaction in ecosystem services takes place – i.e., the place where the catch occurs. However, it is well recognized that there may be multiple ecosystems that are important in the growth of wild fish. To record their relative importance, intermediate services can be recorded reflecting the connections between ecosystem assets. This would include, for example, recording nursery services from seagrass meadows for certain species. The extent to which this measurement is possible will depend on the data available and levels of ecological knowledge.

- *Trade in biomass products.* Given the extent of international trade in agricultural, forestry and fisheries products, there will commonly be a large spatial disconnect between the location of harvest (where the ecosystem service is recorded), the location of subsequent processing and manufacturing and the location of final household consumption. As explained further in Chapter 7, following accounting principles, the supply and use pair for ecosystem services is recorded in the location of harvest rather than recording the

supply of ecosystem services in one location and use (albeit embodied in another product) in another location. Thus, there is no international trade in biomass provisioning services. Rather, using input-output techniques it is possible to trace the flow of associated/derivative products within the international economy.

- *Losses in biomass production.* A common feature in the harvesting of biomass is that not all of the captured biomass is retained and used in the subsequent production process. These are referred to in the SEEA Central Framework as losses and include felling residues, discarded catch and harvest losses. For the SNA, the focus is on the output ultimately sold by the producer and thus, in physical terms, the measure of output will be net of these losses. In the SEEA Central Framework, compilers are encouraged to record the flows of biomass in gross terms since this reflects the actual flow of inputs from the environment. For ecosystem accounting, it is recommended that the principles of the SEEA Central Framework should be applied such that quantity of biomass provisioning services should be equal to the harvest in gross terms, i.e., before harvest losses, felling residues and discarded catch are deducted.

### *6.4.2 The measurement of global climate regulation services*

6.61 The measurement and analysis of climate change has commonly focused on the release of greenhouse gases (GHG) as a result of economic and human activity and the associated changes in concentration of these gases in the atmosphere. From an ecosystem accounting perspective, the focus of measurement is on the role of ecosystems in helping to regulate the changes in the climate by virtue, primarily, of their capacity to capture (i.e., remove from the atmosphere) and store carbon.

6.62 There are several ways in which the supply of global climate regulation services can be envisioned in an accounting context. All approaches are based on the comprehensive recording of stocks and changes in stocks of carbon (i.e., a physical carbon stock account). Ideally, this will encompass measurement of the opening and closing stocks of carbon stored in biomass (both above and below ground) and in soil, across the full range of ecosystem types within an ecosystem accounting area, including marine ecosystems as appropriate. This scope may be broader than required following IPCC guidelines. Changes in the carbon stock will reflect the capture and release of carbon from these stocks for all reasons, including for example, reforestation activity, conversion of peatlands to agricultural production, natural regeneration of vegetation and the effects of bushfires.

6.63 For ecosystem accounting purposes, measurement of all stocks and changes in stocks of carbon is not required, for example concerning deposits of fossil fuels, releases of carbon through the consumption of fossil fuel, or the concentration of carbon in the atmosphere. Nonetheless, a complete accounting for all carbon stocks and flows is highly recommended to support coherence in measurement and wider discussion on climate change and associated policy issues.

6.64 For ecosystem accounting, the ecological contribution of global climate regulation reflects the ability of ecosystems to retain the stock of carbon – i.e., ecosystems supply a carbon retention service through the avoided release of carbon to the atmosphere. Thus, to the extent that the carbon stock increases over time, for example through carbon capture, then the quantity of services provided will have increased. The reverse also holds. For a single ecosystem, the minimum service that can be supplied is zero when the stock of carbon is zero.

6.65 The service is quantified by recording the stock of carbon retained in ecosystems over an accounting period. This is a proxy indicator for the flow of the service, analogous to the

quantification of the services supplied by a storage company in terms of the volume of goods stored. As required, changes in the supply of global climate regulation services can be attributed to either capture or removal from the stock of carbon of ecosystems based on analysis of the changes in the stocks of carbon.

6.66 The carbon stored in sub-soil fossil fuel deposits should not be considered an ecosystem service since these deposits are not ecosystems. Similarly, the storage of carbon in harvested wood products should not be considered an ecosystem service since this carbon is no longer stored as part of an ecosystem asset, but rather within products (e.g., houses, furniture) that are considered part of the economy.

### *6.4.3 The identification of cultural services*

6.67 There are important connections between people and ecosystems that are not provisioning or regulating in nature. The label cultural services is used to encompass many of these connections. There are two key aspects in the identification of cultural services for ecosystem accounting purposes. First, it is necessary to determine the set of benefits since these services can only be defined from a user perspective. Second, flows of cultural services, representing the contribution of the ecosystem to the benefits, will reflect the characteristics and qualities of ecosystems. For many cultural services, recognizing the richness and functionality of the space provided by ecosystems, for example to support recreation, is fundamental.

6.68 For ecosystem accounting, the cultural benefits to which cultural ecosystem services should contribute comprise (i) benefits from undertaking activity (including recreation) within ecosystems (i.e., in situ) and (ii) benefits from having a cultural, spiritual or similar relational connection to an ecosystem or the biodiversity it contains. The first type of cultural benefits in which people experience nature directly is considered to encompass a contribution from the ecosystem while accepting that there must also be human inputs of time and potentially resources (e.g., equipment, travel). Both of these types of benefits will encompass associated benefits to people's physical and mental health.

6.69 The second type of cultural benefits covers the things in nature that we think should be conserved for a wide variety of motivations and reflects a direct experience to which the characteristics and qualities of an ecosystem asset contribute. This type of benefit includes cultural and spiritual connections and the maintenance of ecosystem services for future generations in the form of bequest, insurance and options values. This set of benefits may commonly be a focus of economic transactions such as donations to non-profit groups that are motivated to protect and conserve ecosystems.

6.70 Cultural benefits arising from the remote experience of ecosystems (including via various media – e.g., television, music, photos, etc.) are not considered to be within scope of ecosystem accounting, aside from the limited set of benefits enjoyed by the producers of the relevant content (e.g., artists, movie producers, etc.) who directly use the characteristics and qualities of the ecosystems and who, in some instances, may be required to pay for access or similar rights to complete the production process. In this case the cultural benefits are SNA benefits.

6.71 Given this scope of cultural benefits, cultural services are defined as the perceived or realized qualities of ecosystems whose existence and functioning enables a range of cultural benefits to be derived. Within this definition, cultural ecosystem services (i) reflect the ecosystem contribution in terms of providing places and opportunities for activity by people; (ii) are linked to flows from ecosystems to people that may be considered "experiential"; and (iii) are able to contribute to multiple benefits, i.e., one ecosystem and its characteristics/qualities

can contribute to different cultural benefits and can be linked to varying motivations of different users.

6.72 Using this definition of cultural services, six cultural services are included in the reference list, namely: recreation-related services; amenity services; education, scientific and research services; spiritual / religious services; ecosystem and species appreciation services and maintenance of ecosystem service options. A description of these services is provided Table 6.2 above.

6.73 Cultural ecosystem services contribute to processes involving different combinations of ecosystem assets, produced assets (e.g., access roads, on-site facilities, walking trails, residential location) and human capital (including people's time, experience and knowledge, capabilities (physical and perceptional)). Generally, human inputs will reflect the inputs required to use or access the cultural benefits, but some human inputs, for example concerning activities to restore or maintain ecosystem condition, will concern the supply of cultural benefits.

6.74 People undertake a range of activities in the environment for a range of purposes. Generally, the focus of cultural services is on activities of a recreational or personal purpose. However, for those people working outdoors – such as farmers, tour guides, landscapers and others that have a relatively direct connection with the environment in their jobs – they will likely derive some benefit from being outdoors that is similar to a recreation-related service. The potential ecosystem contributions to these benefits are not recorded explicitly in the ecosystem accounts but, as appropriate, can be implicitly included in measures of ecosystem and species appreciation services.

6.75 Where payments are made by people to economic units who manage ecosystems, e.g., managers of national parks, for access to ecosystems; or where payments are made to economic units who support activities in ecosystems (e.g., canoe rental businesses), connections can be made to entries in the standard national accounts and hence SNA benefits. The appropriate recording of these flows is described in Chapter 7.

### *6.4.4 The treatment of water supply*

6.76 The treatment of the abstraction of water by economic units, including households, for use in production processes (e.g., irrigation) or for consumption, lies on the ecosystem service measurement boundary. There is no doubt that flows of water are highly relevant in both ecological and economic contexts, with the volume of water supply being largely determined by hydrological cycles. At the same time, the availability and quality of water in any given location is directly affected, to varying degrees, by ecosystem structures and processes. Consistent with the general definition of ecosystem services, it is this ecological contribution that is the focus of measurement in ecosystem accounting.

6.77 In ecological terms, there is a range of factors that contribute to the availability and quality of water. Two primary processes are (i) those related to the regulation of base flows of water including precipitation, runoff, infiltration and evapotranspiration leading to water absorption and release; and (ii) those related to the purification of water. In a catchment context, these and other relevant ecological processes are likely to involve multiple ecosystem assets of varying types, e.g., forests, agricultural land, wetlands and rivers. These two primary processes can be considered inputs to water supply.

6.78 In compiling ecosystem accounts there are two complementary approaches that may be adopted. The first approach is to measure the contribution of each ecosystem process to the availability and quality of water that is ultimately abstracted (abstracted water is the benefit

in this logic chain). In this case each ecosystem process, i.e., water purification and water regulation of base flows, will represent a final ecosystem service. The second approach is to measure the aggregate ecosystem contribution by using the volume of water abstracted (by quality of water) as a proxy. In this case the water supply represents a final ecosystem service. An option under this second approach, if relevant for analytical purposes, is for the relevant contributions of water purification and water regulation of base flows to water supply to be recorded as intermediate services.

6.79 In many contexts, the volume of water abstracted may be more readily measured and hence the second approach may be commonly applied. This being the case, care is needed to ensure appropriate recognition of the connection to other ecosystem services and benefits that will be observable in water abstraction contexts. For example, the services of water purification and water regulation of base flows will be relevant in the supply of recreation-related cultural services, for instance when people swim in a lake or river that is also used for water supply. Thus, under the first approach the measurement of water regulation of base flows and water purification services as they pertain to water supply may not provide a complete measurement of the ecosystem contribution of these services. Further discussion on the appropriate recording of these combinations of flows is presented in Chapter 7.

6.80 A significant volume of water is abstracted from groundwater sources from both deep and shallow aquifers.[9] By convention, no ecosystem services are associated with the volume of water abstracted from deep aquifers while for water abstracted from shallow aquifers the two approaches described above for surface water can be applied. Water abstracted from marine ecosystems, for example for desalination or use as cooling water, should be treated as an abiotic flow.

6.81 Following the SEEA Central Framework, water used for the generation of energy through hydropower plants is treated as abstracted – i.e., it is removed from the environment into the economy, notwithstanding its immediate return and potential to affect water quality. Water abstracted for hydropower is treated as an abiotic flow. In some contexts, surrounding landscapes may provide ecosystem services that support hydropower production, for example, forests retaining sediment. These should be recorded as final ecosystem services as appropriate.

### *6.4.5 The treatment of abiotic flows*

6.82 As noted in section 6.2.6, there is a range of flows between the environment and the economy in which there may be discussion as to whether there is a material ecosystem contribution that should be recorded as an ecosystem service. In general terms, if there is a clear contribution of ecosystem structures and processes then the flow can be treated as an ecosystem service. However, if there is no distinct role of ecosystem structures and processes the flow is treated as an abiotic flow. This distinction is clear in many cases but there are also many boundary cases.

6.83 The treatments described here are intended to give guidance to compilers as to the appropriate treatment to support comparability. However, it is not possible to conceive all possible contexts. Thus, in principle, compilers should return to the core definition of ecosystem services and ensure that the focus of measurement is on the ecosystem contribution to benefits. Further, in identifying ecosystem contributions the focus should be

[9] The distinction between deep and shallow aquifers should be made consistently with the delineation of ecosystem assets described in Chapter 3.

on the nature of the ecological processes rather than on whether the ecosystem is more or less dominated by biotic or abiotic characteristics, i.e., recognizing that deserts, with comparably little biota, and rainforests, with much biota, are both ecosystem types. Since ecosystems by definition are a combination of both biotic and abiotic characteristics, and involve interactions across various scales, this variation should not be a key factor in determining whether an ecosystem service is supplied and used.

6.84 Flows related to the generation of energy. For flows of energy from non-renewable sources, such as fossil fuels and uranium, it is considered that these are abiotic flows. This treatment also applies to peat used as an energy source because time for peat to regenerate is considered to be too long to feed into near-future economic activities.[10] For flows of energy from renewable sources, three types can be distinguished:

- Energy from biomass, including timber, maize used for ethanol, etc. Here the flow involves an ecological contribution that should be captured as part of estimating the flow of biomass provisioning services.
- Energy from sources such as wind, solar, geothermal and tidal energy. Here the flows do not involve, or rely on, ecological processes and hence they are considered abiotic flows.
- Energy from hydropower. For ecosystem accounting, it is considered that the source of the energy is related most strongly to the landscape structure and geomorphology (for example the fall in the river). Thus, while ecosystem services supplied by the surrounding landscape such as water regulation of base flows and water purification (in terms of sediment retention) are important final ecosystem services to be recorded, the supply of hydropower itself is considered an abiotic flow.

6.85 Flows related to the use of ecosystem extent (use of space) for undertaking economic and other activities. These flows relate primarily to the fact that all activities take place in a location. While ecosystems will, by definition, be present in those locations, there is no ecological process reflecting a contribution to those activities that should be recorded as an ecosystem service. This implies that the benefits from land supporting buildings, houses, roads, railways and other structures and associated values related to location are not considered to incorporate ecosystem services. A unique case concerns navigation on rivers where the flow of water supports transportation of people and goods. In this case there may be a contribution of ecosystem processes, primarily concerning water regulation of base flows, that may be recorded as an ecosystem service.

6.86 Flows related to abiotic components of ecosystems in the supply of regulating and maintenance services. Since, ecosystems are a combination of biotic and abiotic components, the following cases are treated as ecosystem services, notwithstanding that there may be a dominant role of abiotic components in some ecosystem types.

- Air filtration services (capture of air pollutants) by abiotic components (such as bare and rocky surfaces) – here pollutants are absorbed and stored but not by active biotic components
- Coastal protection services provided by unvegetated shingle or sand dunes – while recognizing the predominant role of the landscape form, these landscapes incorporate biotic components that influence the supply of services (e.g., sand dunes are influenced in their role in coastal protection by the associated vegetation).

[10] Note that peatlands may supply ecosystem services, such as global climate regulation and water purification. These should be recorded as for other ecosystem types.

- Water purification and regulation services from bare but unsealed soil – here water permeating through the soil may be improved in quality through water purification services and may also provide a more continuous supply of water to groundwater sources.

6.87 Flows related to residuals from economic activity. There is a range of residuals that are released through economic activity including emissions to air, soil and water and the generation of solid waste. In many cases, ecosystems act as sinks or receivers of these residuals. Three cases are considered here:

- Where residuals are stored in specific areas, such as with landfill or mining overburden. This is considered a case of using the ecosystem's location and no ecological contribution is involved and no ecosystem service should be recorded.
- Where residuals are actively mediated, broken down or otherwise processed via ecological processes, examples in this case include air filtration, water purification and solid waste remediation. In this case, the ecosystem contribution is considered an ecosystem service equivalent to the quantity of residual that is processed.
- Where residuals are passed through an ecosystem, for example where contaminants from effluent flow into freshwater ecosystems and are subsequently deposited within the sediment or passed on to the marine environment, including in cases where the flow of residuals exceeds the capacity of the ecosystem to mediate or process the residual. In this case, the storage of pollutants is not considered to reflect an ecosystem contribution.

6.88 In this third case, increasing concentrations of some residuals will be a significant factor in the decline of the condition of ecosystems – e.g., excess nitrogen leading to eutrophication of lakes and bays. These declines should be recorded in the condition account and may be reflected in the decline in future flows of ecosystem services supplied by the affected ecosystem. However, the presence of residuals in an ecosystem is not, of itself, considered to imply the supply of an ecosystem service.

6.89 The ability of ecosystems to capture and dilute pollutants (e.g., excess nitrogen) may be regarded as providing a benefit to the polluter since they do not need to store the residuals. This is commonly described as the ecosystem providing a "sink" service. While the use of the relevant ecosystem services, e.g., water purification, may be assigned to the polluter, the convention in ecosystem accounting is to assign the use of ecosystem services to those economic units who subsequently use the ecosystem and hence benefits arising from cleaner water, air and soil.

6.90 Flows related to the use of the atmosphere. Two specific cases are identified. The first concerns the use of the atmosphere for transport. This is considered to reflect an abiotic flow as for other transport services. The second case concerns the use of the atmosphere as a sink for emissions of greenhouse gases (GHG). Consistent with the treatment of residuals from economic activity, while the atmosphere can be considered to contribute to a benefit received by the economy in terms of storing excess GHG, the contribution of the atmosphere does not reflect an ecological process and hence no ecosystem service should be recorded. An abiotic flow may be recorded to reflect the contribution.

## Annex 6.1: Initial logic chains for selected ecosystem services

| Ecosystem type/s | Factors determining supply | | Ecosystem Service | Physical metric(s) | Factors determining use | Benefit | Users | Potential beneficiaries |
|---|---|---|---|---|---|---|---|---|
| | **Ecological** | **Human** | | | | | | |
| Cropland | Soil fertility; Water supply; Pollination | Farm management at different stages of production process | **Crop provisioning services** | Gross tonnes of crop biomass harvested – e.g., wheat (proxy measure) | Harvesting practices, Demand for biomass (e.g., for food) | Crop products – e.g., harvested wheat (SNA benefit) | Agricultural producers, include household and subsistence production | Food processors, transport and retail;<br>Households as final consumers |
| Forests | Soil fertility; Climate and water supply | Forest management practices | **Timber provisioning services** | Gross tonnes of timber biomass harvested | Harvesting practices, Demand for timber | Harvested timber (SNA benefit) | Forestry producers, Households | Forest product manufacturers;<br>Households as final consumers |
| Primarily woody biomes, also marine | Ecosystem type and condition (e.g., density and age); Atmospheric carbon concentrations | Ecosystem management;<br>GHG emissions | **Global climate regulation services (carbon retention)** | Tonnes of carbon retained (captured & stored) | na | Reduced concentrations of GHG in the atmosphere leading to more stable (cooler) global climate (non-SNA benefit) | Collectively consumed by government on behalf of society | Individuals, households and businesses globally |
| Mainly forest and woodland | Type and condition of vegetation; Ambient pollutant concentrations; | Ecosystem management;<br>Release of air pollutants | **Air filtration services (air pollutant mediation)** | Tonnes of pollutants absorbed by type of pollutant (e.g., PM10; PM2.5) | Behavioural responses and location of people and buildings affected by pollution | Reduced concentrations of air pollutants providing improved health outcomes and reduced damage to buildings (non-SNA benefit) | Individuals and households; | Business (through improved workforce participation/ reduced sick days) |
| Riparian ecosystems, Coastal margins | Extent and condition of vegetation | Ecosystem management | **Flood mitigation services** | Number of properties/ km of coast protected; change in degree of risk | Extent of existing produced assets (e.g., flood barriers, dykes); location of properties | Reduced impact of flood events (non-SNA benefit) | Property owners – Households, business, government | Local communities |
| Many ecosystem types | Extent and condition;<br>Presence of iconic landmarks or species | Ecosystem management including facilities to support access | **Recreation-related services** | Number and length of visits; | Expenditure on access to recreation sites; Location of users relative to ecosystem | Physical and mental health; Enjoyment | Households;<br>Tourism and Outdoor Leisure sectors | |

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