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Chapter 7: Accounting for ecosystem services in physical terms

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Disclaimer:
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SECTION C: Accounting for Ecosystem services

7 Accounting for ecosystem services in physical terms

7.1 Introduction

7.1 Accounting for ecosystem services in physical terms aims to record, in an accounting structure, the flows of ecosystem services over an accounting period in physical units such as cubic metres and tonnes. Physical quantification commonly focuses on measurement of ecosystem structures, processes and functions; i.e., the supply side of ecosystem service flows but quantification of ecosystem contributions can also take place through a focus on the use of ecosystem services, for example the number of visits to a national park.

7.2 All flows of ecosystem services in the reference list (see Chapter 6) can be measured in physical or quantitative terms. Different ecosystem types will supply different bundles of ecosystem services to different users. The aim in ecosystem accounting is to provide as comprehensive coverage as possible of different ecosystem services within an ecosystem accounting area. With this aim in mind, choices about which ecosystem services should be the focus of measurement will depend in large part on the data and resources available for the compilation of estimates.

7.3 Accounts recording the supply and use of ecosystem services may be compiled for a range of reasons and purposes. These include recording and monitoring the different bundles of ecosystem services supplied by different ecosystem types, who is using these services and how these patterns of supply and use are changing over time. This information can underpin analysis of the relative importance of particular ecosystems, support analysis of trade-offs between different ecosystem services as part of spatial planning and land management and provide information to delineate areas for specific land use including conservation and environmental protection.

7.4 Further, the information on ecosystem services in physical terms can be used to demonstrate the nature of the extension in the SNA production boundary that is applied in ecosystem accounting and, more generally, support engagement and discussion of the wider, non-private, benefits of ecosystems. The data in physical terms will also underpin monetary valuation of ecosystem services (see Chapter 9).

7.2 Ecosystem services supply and use accounts in physical terms

7.2.1 Overall structure of the supply and use accounts

7.5 The structure of the ecosystem services supply and use account is displayed in Table 7.1. The list of ecosystem services reflects the reference list of selected ecosystem services in Chapter 6.

7.6 The top section of Table 7.1 presents the supply table. It records the flows of different ecosystem services supplied by different ecosystem types. The bottom section of Table 7.1 presents the use table. It records the use of different ecosystem services by economic units (final ecosystem services) and by other ecosystems (intermediate services). For each ecosystem service, the total supply recorded in the top section must equal to the total use recorded in the bottom section. Details about the recording principles and specific treatments are described in the following sections.

Table 7.1: Ecosystem services supply and use account in physical terms (physical units) – Supply table

				Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																				
				Terrestrial							Freshwater			Marine				Transitional							
				Tropical-subtropical lowland rainforests	Boreal and temperate montane forests and woodlands	Seasonally dry tropical shrublands	Trophic savannas	Semi-desert steppes	Ice sheets, glaciers and perennial snowfields	Croplands	Permanent upland streams	Large permanent freshwater lakes	Large reservoirs	Seagrass meadows	Epipelagic ocean waters	Continental and island slopes	Submerged artificial structures	Tropical flooded forests and peat forests	Deepwater coastal inlets	Rocky shores	Coastal shrublands and grasslands	Artificial shores	Coastal river deltas	**TOTAL SUPPLY BY RESIDENT ECOSYSTEM ASSETS**	Supply from non-resident ecosystem assets - Imports	**TOTAL SUPPLY**
SUPPLY			**UNITS OF MEASURE**	T1.1	T2.1	T3.1	T4.1	T5.1	T6.1	T7.1	F1.1	F2.1	F3.1	M1.1	M2.1	M3.1	M4.1	TF1.1	FM1.1	MT1.1	MT2.1	MT3.1	MFT1.1			
Selected ecosystem services (reference list)																									
Provisioning services																									
	Biomass provisioning	Crop provisioning																							
		Grazed biomass provisioning																							
		Timber provisioning																							
		Non-timber forest products and other biomass provisioning																							
		Fish and other aquatic products provisioning																							
	Genetic material																								
	Water supply																								
Regulating and maintenance services																									
	Global climate regulation services																								
	Rainfall pattern regulation services																								
	Local (micro and meso) climate regulation services																								
	Air filtration services																								
	Soil quality regulation services																								
	Soil erosion control services																								
	Water purification services																								
	Water regulation services																								
	Flood mitigation services																								
	Storm mitigation services																								
	Noise attentuation services																								
	Pollination services																								
	Pest control services																								
	Nursery population & habitat maintenance services																								
	Soil waste remediation services																								
Cultural services																									
	Tourism recreation related services																								
	Local recreation related services																								
	Amenity services																								
	Education, scientific and research services																								
	Spiritual, symbolic and artistic services																								
	Ecosystem and species appreciation services																								

Table 7.1: Ecosystem services supply and use account in physical terms (Physical units) – Use table

USE			UNITS OF MEASURE	Selected economic units: Intermediate consumption: Agriculture	Forestry	Fisheries	Electricity and gas supply	Water collection, treatment and supply	Manufacturing	Services	Government final consumption	Household final consumption	Non-resident units - Exports	TOTAL FINAL ECOSYSTEM SERVICES					Ecosystem types (realms): Terrestrial ecosystems	Freshwater ecosystems	Marine ecosystems	Transitional ecosystems	TOTAL INTERMEDIATE SERVICES		TOTAL USE
Selected ecosystem services (reference list)																									
Provisioning services																									
	Biomass provisioning	Crop provisioning																							
		Grazed biomass provisioning																							
		Timber provisioning																							
		Non-timber forest products and other biomass provisioning																							
		Fish and other aquatic products provisioning																							
	Genetic material																								
	Water supply																								
Regulating and maintenance services																									
	Global climate regulation services																								
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	Soil erosion control services																								
	Water purification services																								
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Cultural services																									
	Tourism recreation related services																								
	Local recreation related services																								
	Amenity services																								
	Education, scientific and research services																								
	Spiritual, symbolic and artistic services																								
	Ecosystem and species appreciation services																								
	Ecosystem and species appreciation services																								

7.7 The flows for each ecosystem service are recorded using a unit of measure that is appropriate for that ecosystem service. The column titled "Units of measure" provides an example of the type of unit that may be appropriate for each type of service. Common units include tonnes, cubic metres and number of visits. In practice, the unit of measure that is applied will depend on the data available and the measurement method that is used.

7.8 The units used to measure the supply of the service must also be used to measure the use of the service. This is consistent with the accounting principle described in Chapter 6 that the supply of an ecosystem service must equal its use. This applies also where an ecosystem service is supplied by multiple ecosystem types and/or used by multiple economic units. Thus, across a given row (i.e., for a single ecosystem service) the same unit of measure should be applied. This enables a total supply and total use to be estimated for each individual ecosystem service. However, since each ecosystem service will be measured using different units it is not possible to aggregate to provide an estimate of the total supply or use for an ecosystem type or economic unit.

7.9 Each ecosystem service is recorded as being supplied by an ecosystem type. For the purposes of demonstrating the design of a supply table, Table 7.1 shows selected ecosystem types based on selected classes from the Ecosystem Functional Group (EFG) level of the IUCN Global Ecosystem Typology (see Chapter 3 for details). The set of classes shown is not exhaustive for that level. In practice, it is expected that countries will apply a national or regionally applicable classification of ecosystem types. This may show additional detail relative to the EFG level.

7.10 In general, the measurement scope of a supply and use account will be established on the basis of the ecosystem services supplied by all ecosystems within an ecosystem accounting area. However, in some cases, it may be of interest to record the use of ecosystem services from outside of the ecosystem accounting area, for example by non-resident units. The final column of the supply table allows for these flows to be recorded. The recording of import and exports of services may also be of relevance when compiling accounts for regions within a country to account for connections between different regions. Section 7.2.6 provides additional discussion on the recording of imports and exports of ecosystem services.

7.11 The use table shows the use of ecosystem services by economic units – final ecosystem services - and by ecosystem types – intermediate services. Economic units are classified following the general structure of the System of National Accounts (SNA). Seven industry classes are shown in Table 7.1. Selected industry classes may be more detailed to allow for national contexts although it is recommended that the structure of the International Standard Industrial Classification (ISIC) be applied. The columns for Government and Households reflect their final consumption of ecosystem services while the column for non-residents reflects exports of ecosystem services. For analytical purposes, the column for households may be broken down to distinguish different types of households (e.g., by income quintile) to provide further detail on the distribution of use of ecosystem services.

7.12 In the use table, the ecosystem types are shown for the four realms of the IUCN Global Ecosystem Typology that are within scope of ecosystem accounting. This higher-level presentation is used for demonstration purposes only and more detailed classes can be used. The recording of intermediate services by ecosystem type is not applicable for provisioning or cultural services; i.e., all of these services are final ecosystem services and hence cannot be used by an ecosystem type.

7.13 A single supply and use account (SUA) is compiled for one accounting period, usually one year. That is, the entries for supply and use show the total flows in each ecosystem service over that time period. Ideally, a time series of SUA would be compiled to enable analysis of changes

in the patterns of supply and use over time. Where a time series of SUA are compiled, different presentations and arrangements of the components of the SUA may be developed to support showing time as one dimension within the output table.

7.14 There may also be considerable interest in the presentation of data on the supply and use of ecosystem services in the form of maps. Overlaying maps for different ecosystem services can provide a ready source of information on places that might be considered ecosystem services "hot spots". It is quite common, but not essential, for estimates of the supply and use of ecosystem services to be compiled using detailed spatial data such that the flows of ecosystem services can be attributed to specific locations and hence to associated ecosystem types. Where this compilation approach is used, the supply and use account which shows flows by ecosystem type, can be considered an aggregation of data from finer scales and thus the maps and tables are complementary outputs of the same underlying data.

7.15 Where top-down methods are used, for example where ecosystem service flows are based on aggregate visits to national parks or total volumes of timber harvested, the attribution to ecosystem type may be more generic or stylised and there will be no accompanying map outputs.

7.16 In concept, where compilation of ecosystem services is undertaken using fine level spatial data, it would be possible to present information on the supply and use of ecosystem services for each individual ecosystem. However, in practice, there is no requirement for reporting at this level of detail, especially for accounts covering a national scale or large areas within a country. Thus, the SUA shown in Table 7.1 focuses on recording at the level of ecosystem types, regardless of their location.

7.2.2 Applying general supply and use principles in ecosystem accounting

7.17 In concept, ecosystem accounting considers that each ecosystem supplies, or contributes to the supply of, a set or bundle of ecosystem services. The following discussion retains a focus on explaining the principles and treatments of accounting for ecosystem services at the individual ecosystem level although it is recognised that in practice, compilation may take place at the ecosystem type level and, as noted in the previous sub-section, the presentation of data in an SUA is likely to be at the ecosystem type level.

7.18 As described in Chapter 6, ecosystem services are defined as contributions to benefits and encompass a wide range of services provided to economic units (households, businesses and governments) and to other ecosystems. The distinction between services and benefits is meaningful, because:

- It facilitates the explicit recording of the relationship between final ecosystem service flows and existing flows of products (SNA benefits) currently recorded in the SNA
- It allows distinguishing the role of human inputs in the production process and recognising that the contribution of ecosystem services to benefits may change over time (for example, due to changes in the methods of production)
- It helps to identify the appropriate target of monetary valuation, since the final ecosystem services that contribute to marketed products (e.g., crops, timber, fish, tourism services) will represent only a portion of the overall value of the corresponding benefits

7.19 These features also allow clear articulation and attribution of flows between ecosystems and economic units that are represented in accounting terms as supply-use pairs, i.e., transactions. The ecosystem services supply and use account is structured to record the flows

of ecosystem services supplied by ecosystem types and used by economic units during an accounting period.

7.20 A key principle of the supply and use account explained in Chapter 6 is that the supply of ecosystem services is equal to the use of those services during an accounting period. Thus, for example, the supply and the use of air filtration services should be recorded in terms of tonnes of PM2.5 absorbed by vegetation. Note that there is no accumulation of ecosystem services such that supply over an accounting period might be matched with an increase in accumulated ecosystem services available for use in future accounting periods. While measurement of the potential or sustainable level of supply that could be delivered by an ecosystem asset is highly relevant, this is not the focus of recording in the supply and use accounts.[1]

7.21 Recording supply as equal to use means that, from an accounting perspective, ecosystem services are revealed transactions or exchanges that take place between ecosystem assets on the one hand and economic units (households, businesses or governments) on the other. Since, in concept, each recorded exchange is observable, it follows that each ecosystem service is separable.

7.22 In addition to requiring matched supply and use entries, the following key features of supply and use accounting are applied:

- Supply is attributed to an ecosystem type. Where an ecosystem service is jointly supplied by a combination of ecosystems, then it is assumed that, if required, the supply can be allocated/apportioned to individual assets using spatial allocation methods or measurement conventions. This topic is discussed further in section 7.4.
- Use of final ecosystem services is attributed to an economic unit (business, government, household).
- Use of intermediate services is attributed to an ecosystem type.
- For any single transaction of an ecosystem service (i.e., where there is a supply-use pair) the magnitude of the flow will be the same for supply and use in terms of both quantity and monetary value.

7.23 Using these principles allows the data recorded in the supply and use account to support monetary valuation of ecosystem services (described in Chapter 9) and to be considered in an aligned manner with the economic data recorded in the SNA supply and use table (see 2008 SNA, Chapter 14) and the physical data recorded in the physical supply and use tables (PSUT) in the SEEA Central Framework (Chapter 3) (e.g., concerning water). The connections to PSUT are discussed in section 7.5 below.

7.2.3 Ecosystem services and benefits

7.24 Where the flow of ecosystem services is an input to the production of an SNA benefit, a supply and use pair is recorded for the ecosystem service in the ecosystem service supply and use account and a separate supply and use pair will be recorded in the standard, economic supply and use accounts for the transaction in the associated economic good or service, i.e., the SNA benefit.

[1] The corresponding concepts of ecosystem capacity and potential supply will be discussed in other sections.

7.25 For example, the supply of biomass provisioning services for wheat from a farmland will be recorded as a use by the farmer of that ecosystem service in the ecosystem service supply and use account. Stylized entries for these flows are shown in Table 7.2.

Table 7.2: Basic Ecosystem services physical supply and use account #1

	Unit of measure	Economic unit (selected)			Ecosystem asset (selected types)		
		Farmer	Government	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (wheat)	Tonnes					100	
USE							
ES #1: Biomass provisioning services (wheat)	Tonnes	100					

7.26 Separately, supply-use pairs for the harvested wheat and other transformed goods (such as flour and bread) will be recorded in the economic supply and use accounts reflecting a series of transactions between a farmer and a flour mill, a baker and households. This recording allows the supply and use of ecosystem services to be seamlessly connected to entries for the supply and use of goods and services currently recorded in standard economic SU tables. The compilation of extended supply and use accounts is described in Chapter 11.

7.27 Where the flow of ecosystem services is an input to the production of a non-SNA benefit, for example the contribution of air filtration services to cleaner air, a supply and use pair is recorded for the ecosystem service in the ecosystem service supply and use account by adding a row. Stylized entries showing flows for both air filtration and biomass provisioning services are shown in Table 7.3.

Table 7.3: Basic Ecosystem services physical supply and use account #2

	Unit of measure	Economic unit (selected)			Ecosystem asset (selected types)		
		Farmer	Government	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (wheat)	Tonnes					100	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
USE							
ES #1: Biomass provisioning services (wheat)	Tonnes	100					
ES #2: Air filtration services (PM2.5)	Tonnes			50			

7.28 For most ecosystem services that contribute to non-SNA benefits, the use of the ecosystem service is attributed to the receiver of the non-SNA benefit. In this example for air filtration services this is households. In cases where a single ecosystem service is used by a number of economic units – e.g., in the case of water regulation for mitigation of extreme events – this will mean that the supply of the service will be partitioned across multiple economic units in the use table.

7.29 However, where the ecosystem service contributes to a non-SNA benefit that is considered "collective", the use of the ecosystem service is attributed to government which is considered

to use the service on behalf of society as a whole. Following the SNA, "*a collective consumption service is a service provided simultaneously to all members of the community or to all members of a particular section of the community, such as all households living in a particular region. … Collective services are the "public goods" of economic theory*." (SNA2008, 9.4). Collective services will thus be both non-rival and non-excludable. The primary example of such an ecosystem service is global climate regulation, the benefits of which are obtained by all members of the community.

7.2.4 Recording intermediate services

7.30 Where there is a sequence of intermediate services and final ecosystem services, recording the supply and use of each service ensures that the appropriate net effect is shown. Using an example involving the ecosystem services of pollination and biomass provisioning services (in this example changed to melons), the supply and use of pollination services from one ecosystem (natural grassland where the pollinators are assumed to live) to another (farmland where the melons are pollinated) is recorded as a supply and use of an intermediate service. Thus, the supply of the intermediate service of pollination is attributed to the grassland and there is a use of pollination services by the farmland (as an input to its supply of final ecosystem services) and supply of biomass provisioning services. The relevant entries are shown in Table 7.4.

Table 7.4: Basic Ecosystem services physical supply and use account #3

	Unit of measure	**Economic unit (selected)**			**Ecosystem asset (selected types)**		
		Farmer	Government	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (melons)	Tonnes					80	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
IS: Pollination services	# visits						2000
USE							
ES #1: Biomass provisioning services (wheat)	Tonnes	80					
ES #2: Air filtration services (PM2.5)	Tonnes			50			
IS: Pollination services	# visits					2000	

ES: Final ecosystem services; IS: Intermediate services

7.31 By ensuring that a sequence of supply and use entries are recorded for each type of ecosystem service, the overall contribution of each ecosystem can be determined. Thus, for example, by considering the column for farmland the output of biomass provisioning services can be seen to require the input of pollination services from grassland ecosystems.

7.32 A specific context in which intermediate services may be recorded concerns flows associated with water supply as discussed in Section 6.4. Following the advice of that section, where water supply is treated as a final ecosystem service, it may be appropriate to record flows of related ecosystem services such as water regulation of base flows and water purification as intermediate services. Alternatively, these input services may be treated as final ecosystem services and water supply treated as an abiotic flow. In any selected approach, care is required such that the links between ecosystem services are recorded once and that double counting is avoided.

7.33 Potentially, quite complex interlinkages between different ecosystems can be recorded within a supply and use accounting structure. However, the focus of ecosystem accounting should remain on recording final ecosystem services and entries for intermediate services should concern only those flows that can be clearly connected to a final ecosystem service – as in the example above. It is not the ambition in ecosystem accounting to provide a full documentation of all ecological processes or connections.

7.2.5 Exports and imports of ecosystem services

7.34 The measurement scope for ecosystem accounts is set by the ecosystem accounting area, for example a country including its exclusive economic zone. As noted above, for ecosystem services supply and use accounts this implies a focus on the ecosystem services supplied by all ecosystems within the ecosystem accounting area (EAA). There will be a range of situations in which the supply of ecosystem services will not be used by economic units resident[2] in the EAA. To ensure a balance between supply and use, the use of services by non-residents are recorded as exports.[3]

7.35 The general framing of exports and imports provided here will be commonly understood to apply at national level. Conceptually, and often in practice, the same framing can be applied at sub-national scales, for example for large administrative regions or catchments. In this case, the measurement barrier for identifying imports of ecosystem services will be reduced in cases where accounts for multiple areas within a country are being compiled at the same time.

7.36 Four cases need consideration. First, there are people visiting from outside of an EAA, for example tourists, who will commonly be users of recreation-related services supplied by ecosystems within the EAA. In this case, measurement requires an allocation of the total supply of the service to that group of people as non-residents (i.e., exports).

7.37 Second, there are commonly exports of biomass and related products (e.g., wheat, timber, fish) between countries. In ecosystem accounting these flows of products are not considered flows of ecosystem services and hence are not recorded as exports in the ecosystem service supply and use account. Rather the ecosystem services can be seen to be embodied in the traded products with the flows of products recorded in the standard economic supply and use accounts and related balance of payments statistics. Analysis of the extent to which traded products have embodied ecosystem services can be undertaken and this may be an important part of understanding how consumption in one country may have impacts on other countries' ecosystems. (This topic will be discussed further in Chapter 12)

7.38 Third, there are commonly situations, particularly for regulating and maintenance services, where the users of the ecosystem service are located outside of the ecosystem supplying the service. For example, users of air filtration services provided by forests will usually not live in the forest but in neighbouring communities. Where both the supplying ecosystem and the location of use are in the same EAA, then the accounting entries described above will apply. However, where the location of use is outside the EEA an export of an ecosystem service should be recorded to ensure a balance between supply and use.

[2] The concept of residency of economic units is applied based on the definitions and principles of the SNA and the Balance of Payments.

[3] Conceptually, there may be flows of intermediate services between EAA but these should only be recorded in very specific circumstances of analytical interest where the flow into an EAA (i.e., an import of an ecosystem services) can be clearly linked to a final ecosystem service supplied by an ecosystem within the EAA.

7.39 Fourth, a sub-set of the ecosystem services considered in the previous paragraph concern ecosystem services that are collective services that are not attributable to individuals or households but rather are treated as being used by the government on behalf of the community. The primary example concerns global climate regulation services and, indeed, this service can be considered to be of benefit to all people globally rather than only in a more local, landscape setting. By convention, collective services are recorded as being used by the government that has jurisdiction over the supplying ecosystems – i.e., jurisdiction over the EAA – and no exports of collective services are recorded in the system.

7.40 Given that the measurement scope of an ecosystem supply and use account is determined by the set of supplying ecosystems within an EAA, there is less focus on imports of ecosystem services which, by definition, are supplied by ecosystems outside of the EAA. Indeed, this reality implies there will likely be a larger measurement challenge in quantifying imports of ecosystem services. In concept, the treatments described above for exports apply equally to imports since, following accounting principles, each export entry must have a matching import.

7.41 In ecosystem accounting, the measurement scope of imports should be determined by identifying flows of ecosystem services that are of particular interest, for example in establishing a more complete picture of the use of ecosystem services by resident economic units. For example, the use of recreation-related services by residents who visit locations outside of the EAA may be of interest. Where imports are recorded, they are entered in the supply table and a corresponding use is recorded by type of economic unit in the use table. Specific note is made of the appropriate treatment for fish caught by resident operators fishing in areas outside their national exclusive economic zone. In line with standard practice of the SNA and the SEEA Central Framework, these services should be treated as an import of an ecosystem service in the accounts of the country undertaking the fishing.

7.42 In all cases, appropriate allocation and recording of exports and imports of ecosystem services will require an understanding of the location of supply and use and the residency of the economic units involved. This will be particularly relevant when an ecosystem service is supplied from a combination of ecosystems within a landscape context in which the ecosystems involved are located on different sides of an administrative boundary (e.g., on opposite sides of a river). Further discussion on the spatial allocation of the supply and use of ecosystem services is provided in section 7.4.

7.2.6 Recording cultural services

7.43 All cultural services involve an interaction between people and ecosystems. Consequently, the quantification of these services generally reflects measurement of the type, number and/or quality of the interaction. For example, recreation-related services are commonly quantified using the number of visits to a specific natural location. While these measures are not a direct quantification of the ecosystem contribution, they are considered a suitable proxy which can be improved by taking into consideration as far as possible the number and length of time of interactions with specific features and characteristics of the ecosystems concerned.

7.44 At the same time, for many cultural services, but primarily for recreation-related services, there are businesses involved in facilitating and supporting interaction between people and ecosystems. Broadly, the types of businesses are involved supply access to the ecosystem, facilitate activities/experiences within the ecosystem (e.g., covering entry fees, guides, tour operators, etc.) or supply goods and services to visitors to support their travel to and time at an ecosystem (e.g., hotels, restaurants, transport companies, fuel suppliers).

7.45 To varying degrees, all of these businesses can be seen to have a connection to the ecosystem and may be considered to have an input of ecosystem services. This interpretation is most appropriate in the context of the first type of business, for which it seems likely that, where payments are made by visitors to those businesses, (i.e., reflecting an economic transaction between visitors and the businesses), there is an inherent ecosystem service contribution. For transactions involving the second type of business, any ecosystem service contribution is likely to be much smaller. For accounting purposes, challenges lie in appropriately distinguishing the ecosystem service contributions to transactions already recorded in the standard economic accounts and identifying the additional contribution of the ecosystem to the overall benefits that arise from people's interactions with ecosystems.

7.46 The recommended treatment for the ecosystem services supply and use account in physical terms is to record a supply and corresponding use for each interaction, with the supply shown from the relevant ecosystem type and households as users of the service. This flow should be recorded irrespective of the degree to which there is involvement of businesses in facilitating or supporting the activity.

7.47 In addition, a supplementary row to the use of ecosystem services should be recorded showing the connection between the ecosystem and relevant businesses. This entry does not add additional supply but provides complementary data on the use of ecosystem services. Further, whether recorded as use by households or businesses, the flows still reflect final ecosystem services. The required entries for the monetary supply and use account are described in Chapter 9.

7.2.7 Recording abiotic flows

7.48 Chapter 6 identified a range of environmental flows, e.g., concerning the supply of energy, that do not meet the definition of ecosystem services and hence are considered abiotic flows. These abiotic flows may be relevant in the assessment of ecosystem services and the use of specific ecosystems. For example, in the production of solar energy it will be common to install solar panels which will reduce the potential to use the location for the generation of ecosystem services. Thus, recording abiotic flows and attributing their supply to individual locations can help to provide a more comprehensive picture on the use of the environment.

7.49 Where the incorporation of abiotic flows is desired, additional rows may be added to the supply and use account (Table 7.1) showing the supply of the abiotic flow from the relevant ecosystem type (e.g., electricity generated from wind turbines on farmland) and the use of that abiotic flow by economic units (e.g., electricity generators). Table 7.5 shows how such flows can be incorporated in the supply and use framing assuming an example where an electricity generator uses wind turbines on farmland to generate electricity.

Table 7.5: Basic Ecosystem services physical supply and use account #4

	Unit of measure	Economic units(selected)			Ecosystems (selected types)		
		Farmer	Electricity generator	Households	Forest	Farmland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (melons)	Tonnes					80	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
IS: Pollination services	# visits						2000
AB: Energy from wind power	kWh					10000	
USE							
ES #1: Biomass provisioning services (wheat)	Tonnes	80					
ES #2: Air filtration services (PM2.5)	Tonnes			50			
IS: Pollination services	# visits					2000	
AB: Energy from wind power	kWh		10000				

ES: Final ecosystem services; IS: Intermediate services; AB: Abiotic flows

7.2.8 Linking the supply of ecosystem services to economic units

7.50 *<< **Note to reviewers**. Pending advances on the description of ecosystem services, this section will present complementary tables showing supply of ecosystem services in terms of the economic units that own or manage the relevant ecosystems. This will also be linked to discussion of the link between ecosystem types and economic units (e.g., by ownership) in Chapter 4 (extent accounts).>>*

7.3 Considerations in accounting for ecosystem services in physical terms

7.3.1 Spatial allocation of ecosystem services to ecosystem assets

7.51 A number of ecosystem services, particularly regulating and maintenance services but also some cultural services, are generated at landscape scale in the sense of involving a range of ecosystems of different types. Examples include the contributions of different ecosystems to the regulation of water flows and soil erosion control services which are commonly measured and modelled at a catchment scale rather than for individual ecosystems types within the catchment.

7.52 For ecosystem accounting, it is appropriate for the measurement of the total supply of an individual ecosystem services to be undertaken at a larger, multi-ecosystem scale in order to get the best estimate of supply. However, the logic of ecosystem accounting further implies the allocation of total supply to specific ecosystem types and conceptually, to individual ecosystems. This allocation can in turn would support, for example, understanding the critical ecosystems within a catchment.

7.53 In addition to allocation to specific ecosystem types there is a general interest in mapping the supply and use of ecosystem services; i.e., in linking the supply and use of ecosystem services to the location of ecosystems as reflected in the measurement of ecosystem extent. Spatial allocation is conceptually feasible since ecosystem services are spatial phenomena.

7.54 Considerations in the allocation of ecosystem services to ecosystem types vary by type of ecosystem service. Provisioning services are treated as supplied and used in the same ecosystem since, in accounting terms, the exchange between ecosystem and economic unit takes place at the point of harvest which must take place *in situ*. Subsequent transactions involving the processing, transportation and sale of harvested materials are the subject of standard economic accounting and are not the focus of ecosystem accounting.

7.55 Regulating and maintenance services are commonly supplied by ecosystems, or combinations of ecosystems, in one location and used by economic units in other locations. Further there are a range of cases where a single service is supplied to a range of different economic units who are present in a single area. Specific examples here concern the services of ecosystems in mitigating the effects of extreme events.

7.56 Many cultural services are supplied and used in situ since they are based on direct interactions between people and ecosystems. Recreation-related services are the clearest example. At the same time, there are a range of cultural services in which there are indirect connections and hence the locations of supply and use will be different.

7.57 For the purposes of compiling a supply and use account, following Table 7.1, it is necessary to allocate the supply of ecosystem services to ecosystem types but it is not required to (i) allocate that supply to individual ecosystem asset in specific locations; or (ii) record the location of the economic units using the ecosystem services. However, for a range of purposes, especially to support spatial planning and assessment, attribution of ecosystem services supply and use to locations is likely to be of considerable power. Further, for many ecosystem services, particularly regulating and maintenance services, the compilation methods are likely to involve the use of detailed spatial data in which case allocation to locations can be seen as a by-product.

7.58 The discipline of allocating ecosystem services to locations is known as ecosystem services mapping. Key concepts of relevance for ecosystem accounting are service providing areas (SPA) and service benefitting areas (SBA). For each ecosystem service, the delineation of SPA and SBA provides the location and spatial boundary that will reflect the location of supply and use, respectively. For accounting purposes, it will be appropriate to link SPA with maps of ecosystem extent classified by ecosystem type and to link SBA with information on the location of different types of economic units (businesses, government, households) for example using cadastral information. Guidance on ecosystem service mapping is available in Burkhard & Maes (2017).

7.3.2 Determining ecosystem service measurement baselines

7.59 Ecosystem service measurement baselines (baselines), also referred to as counterfactuals, are needed in ecosystem accounting to ensure consistent quantification of ecosystem service flows in different contexts. They are especially relevant in the measurement of regulating and maintenance services but are implicit in the measurement of all ecosystem services.

7.60 Where it is possible to observe a direct interaction between people and ecosystems, that is for provisioning services and cultural services, the implicit baseline is zero – i.e., no harvest or interaction. The quantification of the ecosystem services is therefore appropriately focused on measuring the number and type of interaction or harvest.

7.61 Quantification of regulating and maintenance services, on the other hand, involves a focus on the extent to which ecological processes contribute to environmental conditions that are favourable to people and their activities. These processes may involve mediation or mitigation of a potentially negative impact. For example, air filtration reduces ambient air pollution

concentrations. The negative impacts may be caused by human activities (e.g., most forms of air pollution, greenhouse gas emissions), may be natural events (e.g., due to storm surges), or they may be natural events but with an increased likelihood because of human activities (e.g., increased landslides because of deforestation activity). Not all regulating and maintenance services involve mediating a negative impact. For example, the nursery service involves maintaining a favorable habitat for species reproduction and pollination involves the transfer of pollen to enable fruit development and reproduction.

7.62 The quantification of the supply of regulating and maintenance services generally depends directly and strongly upon knowledge of the ecosystem type and its key characteristics since the role of the ecosystem in supplying services will vary as the type and characteristics change. Thus, in assessing the extent to which a particular ecosystem provides regulating and maintenance services, it is normal to make an assumption as to what services would be supplied if the ecosystem type or its characteristics were different. This comparison of two different ecosystem contexts, one being the baseline or counterfactual, provides a basis for quantifying the role of the ecosystem in supplying a given service.

7.63 For example, forests are better at capturing air pollutants than grasslands, and forests with a well-developed soil (with a high infiltration rate) are better in storing and regulating water flows compared to forests with degraded soils. In these examples the contribution of forests can be quantified using as baselines grasslands in the first case and forests with degraded soil in the second. ***An ecosystem service measurement baseline is thus defined as the level of service supply with which a regulating or maintenance service provided by an ecosystem is compared in order to quantify the service.***

7.64 For ecosystem accounting, the use of a common baseline is required to ensure comparability across ecosystem types and across different services. For this purpose, the default baseline is zero, i.e., assuming no supply of the regulating service. In cases where a zero level of service supply cannot be modelled or meaningfully identified, the baseline should be the amount of service supplied by bare land or alternative worst-case ecosystem scenario. The application of this default baseline varies by type of service as shown in Table 7.6.

7.65 For air filtration, it is possible to define more directly a 'no' or 'zero' air filtration level, and the differentiation is meaningful from a modelling perspective. In this case it can simply be stated that the baseline is when there is zero air filtration, i.e., zero capture of ambient air pollutant by an ecosystem. Thus, the supply of the ecosystem service is equal to the quantity of pollutant deposited in the ecosystem.

7.66 In other cases, determining the baseline of no service supply independent of any land cover is difficult. For instance, the soil erosion control service is usually quantified using the Revised Universal Soil Loss Equation (RUSLE). This approach compares actual erosion rates to those for bare land where the erosion rate in bare land is the maximum potential erosion rate (a worst-case scenario) in a given ecosystem, allowing for soil type and erosivity, slope characteristics, rainfall characteristics and land management factors. Thus, in this case, service supply is defined as the reduction in erosion rates compared to bare land and the baseline reference level needs to be bare land since it represents the situation in which there is no ecosystem service supply.

7.67 In general, for services where the focus is on the regulation of flows (e.g., of water, soil) it is not generally possible to assess the service compared to a zero service baseline. This is because the flows will occur regardless of whether a service is being provided by an ecosystem or not. Further, while the biotic components of ecosystems modify and affect the flows (of water, soil), the flows themselves cannot be conceptualized or modelled without there being land over which the flow occurs. In these cases, the baseline needs to be bare land.

7.68 In some cases, the use of bare land as baseline may not be considered to be conceptually very strong, may be counterintuitive, or cannot be meaningfully modelled. The recommendation therefore is to differentiate in a systematic way, between services for which the baseline is bare land and services for which the baseline is zero service supply. Clear communication and explanation of the chosen methods will be required.

Table 7.6: Baselines for selected regulating and maintenance services*

Type of service	Baseline (proposed)	Comments
Global climate regulation services	No/zero carbon retention	
Air filtration services	No/zero air filtration	
Water regulation services	Bare land	Overland and groundwater flows cannot be zero, and the effect of vegetation can only be compared to a situation without vegetation i.e., bare land.
Flood mitigation services	Bare land	Flood risks are influenced by geomorphology and can be reduced by tree cover (e.g., dunes, riparian forests or mangroves along a coast). There is no such a thing as no flood risk in coastal areas and the flood risk of the vegetation can be compared with a situation without vegetation.
Soil erosion control services	Bare land	The service can be quantified by comparing the erosion rate of the current vegetation cover to that in bare land, the difference is the amount of erosion control/sediment retained.
Water purification services	No purification (i.e., no breakdown of water pollutants in the ecosystem)	
Pollination services	No/zero pollination	
Rainfall patten regulation services	Bare land	It is not possible to model rainfall patterns without assuming any rainfall and evapotranspiration across all components of the landscape. The role of vegetation therefore needs to be compared to a situation with no vegetation, i.e., bare land.
Nursery population and habitat maintenance services	No/zero nursery service	

NB: For descriptions of each service refer to Chapter 6, Table 6.2

7.4 Connections to the SEEA Central Framework

7.69 The basic structure of the ecosystem services supply and use account is derived from the design of physical supply and use tables (PSUT) in the SEEA Central Framework. There are three principle alterations. First, unlike the Central Framework PSUT, which contains just one column representing the environment, the ecosystem services supply and use account contains multiple columns, each representing a different ecosystem type.

7.70 Second, the PSUT presented in the SEEA Central Framework covers three types of flows: natural inputs, products and residuals. While in general concept ecosystem services align to natural inputs as defined in the Central Framework, the coverage of natural inputs is limited

to provisioning services and regulating and maintenance services and cultural services are excluded from the Central Framework. At the same time, flows of some regulating services are related to flows of residuals recorded in the Central Framework (e.g., emissions, pollution, waste). For example, there will be a connection between residual flows of air pollutants and air filtration services. Conceptually, however, these are different flows (this is discussed further below).

7.71 Third, the SEEA Central Framework does not consider the ways in which different stocks and flows assets may be connected spatially (i.e., it incorporates an individual-resource perspective) and it describes accounting at national scale rather than allowing for the location of ecosystems and their services to be reflected in the accounts. In contrast, the ecosystem services supply and use account has the capacity to record intermediate services reflecting the dependencies existing between ecosystem assets and there is the potential to directly incorporate the results from ecosystem services mapping. These features are unique to ecosystem accounting.

7.72 In line with the SEEA Central Framework, ecosystem services are recorded before deducting any natural resource residuals[4]. Thus, in the case of timber harvesting, for example, the biomass that is felled represents the quantity of the ecosystem service, just as the biomass felled is regarded as the flow of natural inputs in the SEEA Central Framework. However, further work is needed to determine how to define and record flows of natural resource residuals within an ecosystem accounting context.

7.73 As noted above, the SEEA Central Framework records flows of residuals (e.g., emissions, pollution, waste). Residual flows are not ecosystem services: rather, they are physical flows from economic units into the environment. While from a conceptual standpoint, residual flows and ecosystem services are different, there are important relationships between them. Specifically, several regulating services affect the breakdown or absorption of the substances present in residual flows.

7.74 From an accounting perspective, the measurement of ecosystem services is limited by two factors. First, there must be a related use for the service, i.e., a human must benefit from the breakdown of the residual substances. For example, when water undergoes purification through dilution of excess nutrients discharged by various economic sectors, a service is supplied only if the water is used by people (for various reasons such as water supply, swimming, fishing, etc.), at which point the removal of those nutrients would provide a benefit (e.g., a reduced need for water purification treatment). Second, it may not be possible for the entire quantity of residual substances to be broken down in ecosystem processes, in which case the extent of the ecosystem service would be limited, reflecting the quantity of the residual substances that are absorbed.

7.75 On the other hand, the quantities of residual substances that are not broken down or absorbed may be of particular interest with respect to the measurement of environmental pressures, as they are related to changes in ecosystem condition. Indeed, since flows of residuals are likely to affect the condition of ecosystems and hence the capacity of ecosystem to supply ecosystem services, the potential to quantify this type of feedback loop is an important aspect in considering the linkages between ecosystem accounting and the accounts of the SEEA Central Framework. Overall, information on residuals is related to but different from information on ecosystem services. Given these differences, entries for residual flows and entries for ecosystem services should not be recorded in a single table.

[4] These residual flows are additional to the residuals related to emissions, pollution and waste.