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SEEA Experimental Ecosystem Accounts

Chapter 3: Accounting for ecosystem services in physical terms

(for discussion)

REVISION OF THE SYSTEM OF ENVIRONMENTAL - ECONOMIC ACCOUNTING (SEEA)

SEEA Experimental Ecosystem Accounts

Draft material prepared for the 7th Meeting of the Committee of Experts on Environmental-Economic Accounting (UNCEEA)

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DRAFT

Chapter 3: Accounting for ecosystem services in physical terms

Material prepared in consultation with the Editorial Board for the SEEA Experimental Ecosystem Accounts and following discussions at the Expert Meetings on Ecosystem Accounts.

The following text has been drafted for discussion among UNCEEA members as part of the process of developing the SEEA Experimental Ecosystem Accounts. The material should not be considered definitive and should not be quoted.

Status of Chapter 3

The material around the definition of ecosystem services and the examples of ecosystem services has developed well and provides a sound base for the measurement of ecosystem services in physical terms. At the same time further work is required in two specific areas.

First, a draft of the Common International Classification of Ecosystem Services (CICES) is needed to support work in this area. As part of drafting CICES clarification is needed on the treatment of abiotic resources (such as mineral and energy resources) and on the appropriate time and point of recording of ecosystem services for cultivated resources such as livestock and crops. A process to finalise a draft CICES has commenced as a first round of feedback has been completed. Finalisation of this work will also be used to confirm the set of examples of ecosystem services included in Section 3.4.

Second, proposals for accounting tables need to be finalised. These proposals rely on developments in CICES and on the discussion on statistical units discussed in Chapter 2. Also, some further discussion is needed among those more closely involved in ecosystem accounting as to the type of information that should be included in ecosystem services related tables.

Chapter 3: Accounting for ecosystem services in physical terms

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Chapter 3: Accounting for ecosystem services in physical terms

3.1 General concepts and principles in measuring ecosystem services

3.1 Ecosystem services have become a central concept in connecting biophysical information on ecosystem processes and ecosystem capital with the benefits received from ecosystems by society. As described in the core ecosystem accounting model in Chapter 2, ***ecosystem services are the contributions of ecosystems to benefits used or enjoyed by society.***

3.2 The measurement of ecosystem services needs to consider a range of factors to appropriately define the object of measurement. First, there may often be a series of ecosystem processes that take place within ecosystems before the ecosystem services are captured and benefits arise. For instance, forest patches support bee populations which in turn pollinate fruit trees which are, in the final step, harvested. Recording the flows associated with each step would overstate the total flow of ecosystem services as contributions to society. Further, it is often very difficult to disentangle the specific contribution of different steps.

3.3 Recognising these multiple interactions, the SEEA, in order to record only the contribution of ecosystems to benefits used or enjoyed by society, adopts a measurement scope of ecosystem services that only includes what might be termed the 'final ecological output' from ecosystems. As explained in Chapter 2, these final ecosystem services may be used by households, enterprises or government to produce goods and services. Consequently, the internal flows of ecosystem processes, often referred to as intermediate or supporting services, are excluded from the measurement scope of ecosystem services.

3.4 Second, it is considered that ecosystem services are generated as a result of bio-physical, geo-chemical, and other physical processes and interactions within an ecosystem. Consequently, flows from the environment such as extractions of mineral and energy resources and the capture of energy from renewable sources, such as wind and solar energy, are not considered ecosystem services in the SEEA.[1]

3.5 Third, the distinction between ecosystem services and the benefits to which they contribute is an important one that recognises that, in many situations, the contribution of the ecosystem is just one of the inputs required in order for society to receive the benefits from an ecosystem. Often, though not always, the service provided by an ecosystem is combined with inputs of labour, produced assets and intermediate consumption (e.g. fuel) in order to generate a benefit. For example, a tree must be cut down using labour and a chainsaw before the benefit of using it for timber can be realised. These benefits are considered material benefits which, by definition, arise from a production process as defined in the SNA.

3.6 At the same time, there are also important benefits which are received without the use of any production processes – for example the benefit of clean air that arises from the air filtration

[1] At the same time it is recommended that data on these flows be compiled in conjunction with ecosystem accounts.

services from trees. In these cases the ecosystem services and the benefits are considered equivalent. These benefits are defined as non-material benefits.

3.7 There are also a broader range of conditions and factors that must be considered in the measurement of ecosystem services. Since ecosystem services are measured only when benefits can be identified, the conditions and factors that influence the receipt of benefits are relevant. For example, the receipt of benefits from the air filtration processes of trees is dependent upon the number of people in sufficiently close proximity to the relevant patch of trees. The consideration of these conditions and factors is particularly important in the measurement of ecosystem services that result in non-material benefits.

3.8 Following standard practice in economic accounting, the flow of ecosystem services into economic activity is necessarily an intermediate flow into the generation of material benefits. Then, depending on how the material benefit is used, it may be recorded as part of intermediate consumption (e.g. the use of wood in the manufacture of furniture) or as part of final consumption (e.g. the collection of wood by households for heating, benefits of recreation from visiting a forest).

3.9 Material benefits that are generated using, in part, contributions from ecosystem services are already in scope of the production boundary of standard measures of economic activity as defined in the SNA and as used in the SEEA Central Framework. Examples include the benefits from the commercial supply of wood, crops etc. This boundary also includes the products produced by subsistence agriculture and fishing, and all own-account activity of household (such as the collection of fuelwood, water and forest products for own-use).

3.10 However, non-material benefits are not within scope of the standard production boundary and the recognition of these benefits and the associated ecosystem services is an important part of ecosystem accounting. Often non-material benefits are characterised as being in the form of avoided costs e.g. the benefits of air filtration arise in the form of reduced health care costs and improved quality of life. However, in the SEEA, this characterisation is considered a link to outcomes rather than outputs and is not the focus of the accounting model. Rather non-material benefits are described in a manner analogous to goods and services produced in the economy – e.g. clean air from air filtration services.

3.11 From a societal perspective there may often be outcomes from ecosystem processes that are seen as negatives (e.g. pests and diseases). These ecosystem disservices often originate from a combination of ecological processes and adverse human management. In part, these disservices are included in the ecosystem accounts in an indirect manner, for example when agricultural pests lead to declines in ecosystem capital and a reduced supply of ecosystem services. However, other disservices that directly enter the production or consumption functions of households, enterprises and governments (e.g. natural pathogens having an impact on health) are not accounted for. The relationship between these disservices and benefits as defined in the SEEA may be difficult to establish and, in addition, for many of these effects, there is only a weak correlation between consumption of ecosystem capital and the management of the disservice.

3.12 It is recognised that the vast majority of the world's ecosystems have been modified by people, often with the purpose of enhancing the production of one or more specific ecosystem services, and often having offsetting effects on the availability of non-material benefits. These

modifications by people (which include efforts to restore ecosystems) impact on the capacity of ecosystems to provide ecosystem services and are accounted for as part of assessments of ecosystem capital described in Chapter 4.

3.13 The ecosystem accounting relationships described in Chapter 2 also consider the returns to the ecosystem. For instance, when trees are felled, there are logging residues that remain in the ecosystem. In addition, economic activity may lead to pollution or other pressures on the ecosystem, or on nearby ecosystems. These pressures are highly relevant for ecosystem management, but are site and case-specific and not further described in this section. They are however, included in the SEEA to the degree that they lead to consumption of ecosystem capital, i.e. a decrease in the capacity of ecosystems to supply ecosystem services.

3.2 Scope and classification of ecosystem services

3.14 At the broadest level three different categories of ecosystem services are distinguished in the SEEA: (i) provisioning services; (ii) regulating services; and (iii) cultural services.

3.15 *Provisioning services* reflect contributions to the goods and services produced by or in the ecosystem, for example a piece of fruit or a plant with pharmaceutical properties. These goods and services may be provided by agricultural systems (arable land, permanent crops, pastures), as well as by semi-natural and natural ecosystems.

3.16 *Regulating services* result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes. These services often have an important spatial aspect. For instance, the flood control service of an upper watershed forest is only relevant in the flood zone downstream of the forest. The nursery service can also be classified as a regulation service. It reflects that some ecosystems provide a particularly suitable location for reproduction and involves a regulating impact of an ecosystem on the populations of other ecosystems.

3.17 *Cultural services* relate to the intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation, and spiritual reflection. This may involve actual visits to an area, indirectly enjoying the ecosystem (e.g. through nature movies), or gaining satisfaction from the knowledge that an ecosystem containing important biodiversity or cultural monuments will be preserved. The latter may occur without having the intention of ever visiting the area. The category cultural services also includes the biodiversity conservation service that represents the benefits that people obtain from the existence of biodiversity and nature and the passing of it on to subsequent generations (not because biodiversity provides a number of services, but because people believe its conservation is important in itself).

3.18 These three types of ecosystem service form the highest level of the *Common International Classification of Ecosystem Services* (CICES). The next levels in the hierarchy are shown in Table 3.1. The annex to SEEA Experimental Ecosystem Accounts contains some additional detail showing examples of services that might be included in the different classes. Experience to date suggests that at a broad level the structure of CICES can be used in a range of situations. However, the CICES presented in the SEEA is provisional and it is anticipated that it will be refined over time as ecosystem accounting develops further.

Table 3. 1 Higher levels of CICES

(To be finalised)

3.19 There are two significant boundary issues in relation to CICES. The first relates to the so-called intermediate or supporting services. These flows relate to all of the underpinning ecosystem processes within an ecosystem that reflect the ongoing operation of ecosystems including things such as soil formation, nutrient cycling, etc. There is little doubt that these flows are central to the operation of ecosystems. However, in the ecosystem accounting model they are not considered contributions to benefits received by society – i.e. they are not final ecological output. In an accounting sense they are embodied in the provisioning, regulating and cultural services which they underpin. While they are not considered ecosystem services, these flows are an important part of accounting for ecosystem capital, in particular for the changes in ecosystem capital over an accounting period.

3.20 The second issue concerns flows related to abiotic materials. Society takes significant advantage of abiotic materials found in the environment (such as underground mineral and energy resources) and also captures many abiotic flows for various purposes (particularly the capture of energy from solar and wind sources). However, since these materials and flows do not arise as a result of interactions within ecosystems and because the availability of these materials and flows cannot be managed on human time scales, they are not considered ecosystem services.

3.21 At the same time it is recognised that the assessment of ecosystems necessarily requires consideration of these flows. Ecosystem capital is likely to be impacted by decisions to capture and extract these materials and flows, and the residuals that result from the use these materials also impacts on ecosystems. Therefore, although these flows are not included as part of ecosystem services, these flows are grouped in a fourth section of CICES titled "Other environmental flows". It is recommended that relevant information relating to these flows be compiled in the context of ecosystem accounting to permit assessment of tradeoffs between alternative uses of land and ecosystems. The measurement of these flows is discussed in some detail in the SEEA Central Framework Chapters 3 and 5.

3.22 In the same way as internal flows of an ecosystem are excluded from the measurement scope of ecosystem services, flows between ecosystems are also excluded, including flows between ecosystems in other countries. At the same time imports and exports of ecosystem services may arise, for example, when visitors to a country enjoy a walk in a forest, the associated ecosystem service is a contribution to a produced benefit that is recorded as an export.

3.23 Section 3.4 describes a range of approaches that might be considered in the measurement of ecosystem services in physical terms.

3.3 Accounting structures for ecosystem services

3.24 The aim of ecosystem service flow accounts is to organise information on the flows of ecosystem services by type of service, by statistical unit, and by economic units considered responsible for utilising the service. In addition it will be relevant to identify the recipients of both material and non-material benefits that arise from using the contributions of ecosystem services.

Tables proposed for inclusion but yet to be finalised:

Table 3.2 Ecosystem service flows by ecosystem accounting unit (EAU)

Table 3.3 Ecosystem service flows by ecosystem accounting unit and responsible economic unit

Table 3.4 Ecosystem service flows by ecosystem accounting unit and benefit recipient

3.4 Measurement approaches for selected ecosystem services

3.25 The following section describes potential approaches to the measurement of a range of ecosystem services in physical terms in order to assist compilers in commencing work on the measurement of ecosystem services and to better explain the measurement concepts. It is not possible to identify and define all ecosystem services and hence the intent here is to highlight relevant issues in the measurement of the most commonly recognised ecosystem services. Section 3.5 discusses considerations that might be taken into account in determining the set of ecosystem services that should be measured.

3.26 The approach taken to describe the measurement approaches is to describe individual ecosystem services. It is recognised that presenting the information in this de-constructed way may give the impression that ecosystem services are easily separable flows. In reality, the measurement of ecosystem services must start from a more holistic sense of an overall ecosystem and the range of different services that effectively emerge from the ecosystem as a bundle of services. However, as a matter of statistical and scientific approach, direct measurement of this bundle is not possible and hence a decomposition must be adopted.

3.27 Table 3.5 presents the list of ecosystem services that are described in more detail in this section. The table includes a brief description and some potential indicators.

Table 3.5 List of selected ecosystem services described in Section 3.4

Name of ecosystem service	Description of ecosystem service	Corresponding benefit
Provisioning Services		
Crops	Crops from intensive and extensive agriculture including shifting cultivation	Crops can be consumed directly or further processed.
Fodder for livestock	Rangelands provide fodder (grass, herbs, leaves from trees) for livestock	Livestock products (including animals, meat, leather, milk)
Raw materials including wood and non-timber forest products	Ecosystems, in particular forests, generate stocks of wood and non-timber forest products that may be harvested. Non-timber forest products include for instance rattan, various food products, genetic materials, ornamentals, and pharmaceutics.	Firewood, logged timber, non-timber forest products.
Fish and other aquatic and marine species from marine and inland waters	Marine and other aquatic ecosystems provide stocks of fish and other species that can be harvested.	Fish and other species can be consumed or further processed.
Fish from aquaculture	Aquaculture systems are used to cultivate a variety of fish and other aquatic and marine species.	Fish and other species can be consumed or further processed.
Water	Ecosystems filter and store water that can be used as raw material for drinking water production	Drinking water
Regulating Services		
Carbon sequestration	Ecosystem sequester and store carbon	Climate regulation
Air filtration	Trees can filter particulate matter from ambient air	Cleaner air
Flood protection	Ecosystems regulate river flows and can provide a barrier to floods	Protection of properties and lives
Cultural services		
Providing opportunities for tourism and recreation	Ecosystems present physical space and landscape features people enjoy, to watch or undertake activities in (hiking, cycling)	Recreational benefits

3.4.1 Provisioning Services

3.28 Provisioning services should be the most amenable to measurement as they are within the production boundary of the SNA and the SEEA Central Framework and hence flows of these services can be directly related to relevant measures of production (e.g. cubic metres of timber, tonnes of fish, etc).

3.29 The scope of provisioning services covers outputs from both cultivated and natural biological resources. Cultivated and natural biological resources are distinguished in the SNA and in the SEEA Central Framework to recognise that the growth of biological resources is managed to a greater extent in some cases compared to others. Thus, for example, the rearing of livestock and fish, the growing of crops, and the farming of orchards, vineyards and plantations, are all considered to result in the production of cultivated biological resources. Conversely, the harvesting of fish on the high seas, the felling of timber in naturally regenerated forests, and the hunting of wild animals are all considered to be the extraction of natural biological resources.

3.30 The distinction between cultivated and natural biological resources impacts on the accounting in the SNA by altering the time at which the production of the resources is recorded. For natural biological resources the production is recorded at the point of extraction or harvest, whereas for cultivated biological resources the production is recorded on an ongoing basis as the resources grow.

3.31 More significantly, there are also large differences in the production functions of the different resources with many more inputs being recorded in the case of cultivated biological resources. But this is a difference in terms of extent rather than a difference in conceptual treatment of the production activity.

3.32 From the perspective of ecosystem services it is the case that, whether the biological resource is cultivated or natural, the broad set of relevant ecosystem processes will be the same. Put differently, nature makes no distinction in terms of its contribution to growing a tree in a plantation as distinct from a naturally regenerated forest. However, the point in the production process at which the contribution of the ecosystem is recognised will vary depending on the degree of cultivation that is undertaken. Thus, the final ecosystem service in a case of completely natural growth will be the tree or animal that is harvested. Conversely, in a heavily cultivated situation, the final ecosystem service will relate to the grass that is eaten by livestock or the nutrient uptake by plants.

3.33 Unfortunately, there are no neat boundaries around degrees of cultivation and there is a limited ability to distinguish between varying production process to determine the extent to which different ecosystem processes are final. Thus various conventions are adopted to enable ecosystem accounting to be completed. It is recognised that at the scales at which ecosystem accounting for the SEEA is undertaken (i.e. at regional and national levels) these conventions are unlikely to have a significant impact on the overall measures. However, for more detailed studies in specific sites a more fulsome articulation of ecosystem service flows linking final and intermediate services may be useful.

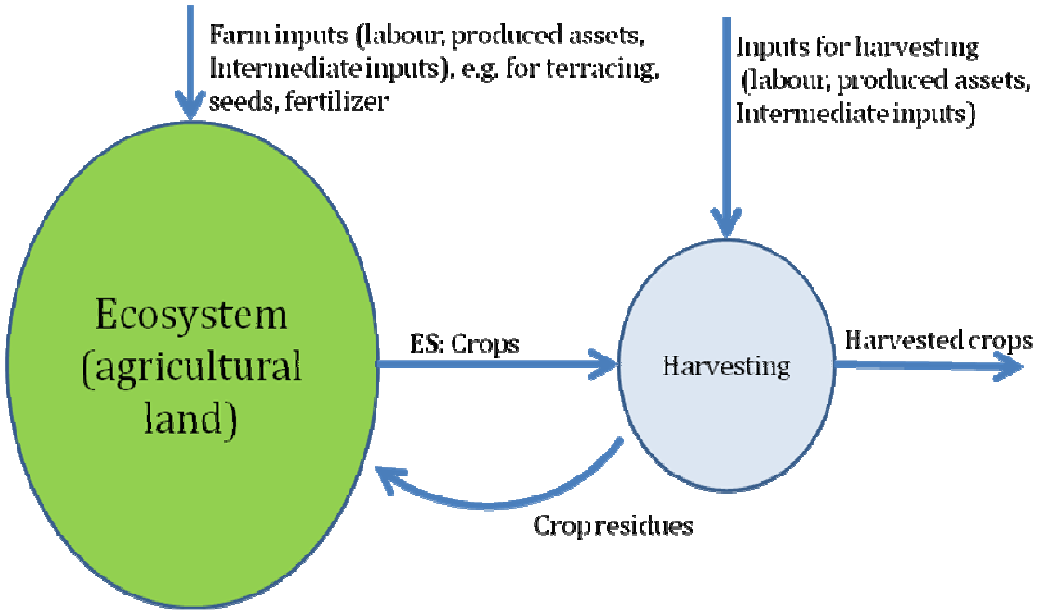
3.34 In the following paragraphs, common ecosystem services are elaborated on the basis of a short description and an illustration. The figures present the ecosystem, the flow of ecosystem services (i.e. the goods that are extracted from the ecosystem), the activity required to extract the ecosystem service, and examples of the subsequent benefits. In reality, an ecosystem service may generate a cascade of different benefits (e.g. timber may be converted into a table) and only one or a few illustrative benefits are shown in the figures.

3.35 The figures below also depict the inputs of labour and produced assets required to (i) mange the ecosystem,; and (ii) harvest or extract the ecosystem service. The distinction between these two types of inputs is made for the following reason. For any provisioning service, there are always costs related to extracting the service, be it harvesting a crop, felling timber, or catching fish. These costs are paid at a specific point in time and they may rise when stocks become depleted or ecosystems degrade. However, the costs for managing the ecosystem vary substantially between different ecosystems and vary with the degree of human modification of the ecosystem. These costs may be made on an ongoing basis in order to maintain the productive capacity of the ecosystem.

Provisioning of crops

3.36 Agricultural production includes the production of annual and perennial crops in cultivated land including plantations, see Figure 3.1. The ecosystem service comprises the harvest of crops and other products from the ecosystem. The farmer or land manager is (i) managing the overall production environment, i.e. the farm or plantation, for instance by constructing a wind break or an irrigation reservoir; and (ii) harvesting crops using labour and machinery. In practice, it may not always be easy to distinguish between these different inputs at an individual farm level. Crop residues are recorded as remaining in the field, and returned to the ecosystem.

Figure 3.1. Agricultural production

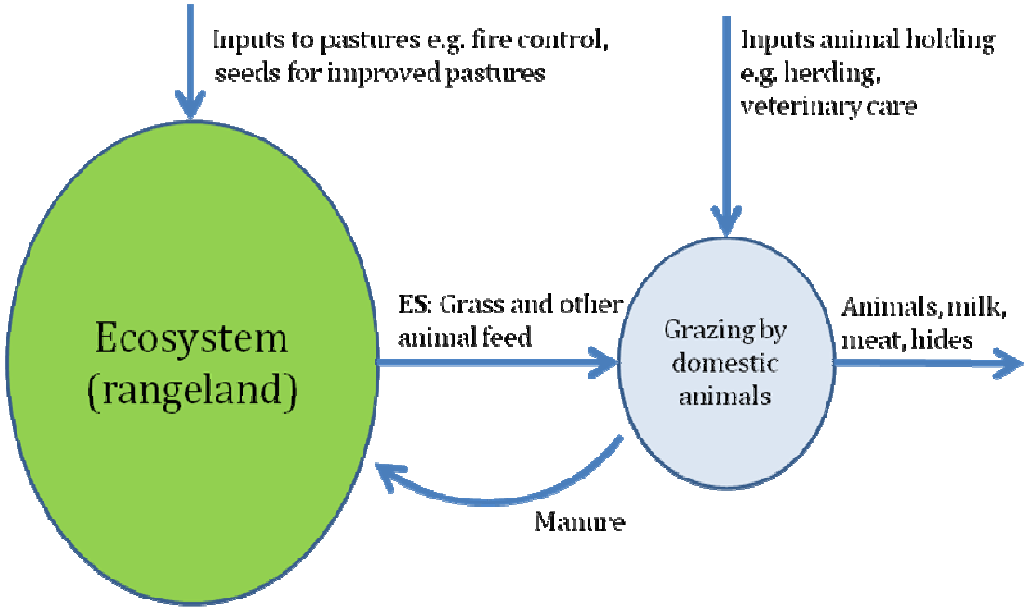


Provisioning of fodder for livestock

3.37 In livestock grazing, the service supplied by the ecosystem relates to the amount of animal fodder produced in the ecosystem, as it is grazed by livestock. This animal fodder comprises annual and perennial grasses and herbs, leaves from trees, etc. The livestock holding system may be more or less intensive, for instance free ranging cattle grazing large stretches of semi-arid rangeland, or dairy cattle grazing confined pastures. The land manager may invest in managing the overall ecosystem, for instance by sowing improved pasture varieties, or by building fences or firebreaks. Livestock holding is the activity undertaken by the land manager in the ecosystem, involving all aspects related to animal production and resulting in outputs of animals, wool, milk, meat, hides, etc.

3.38 The ecosystem service can be measured in physical terms in terms of amount of fodder grazed by animals on an annual basis. Fodder will normally comprise different types of quality (palatability, nutrient contents, etc.). A part or all of the manure is normally returned to the field, contributing to maintaining soil fertility in the ecosystem, see Figure 3.2

Figure 3.2. Provisioning of fodder for livestock



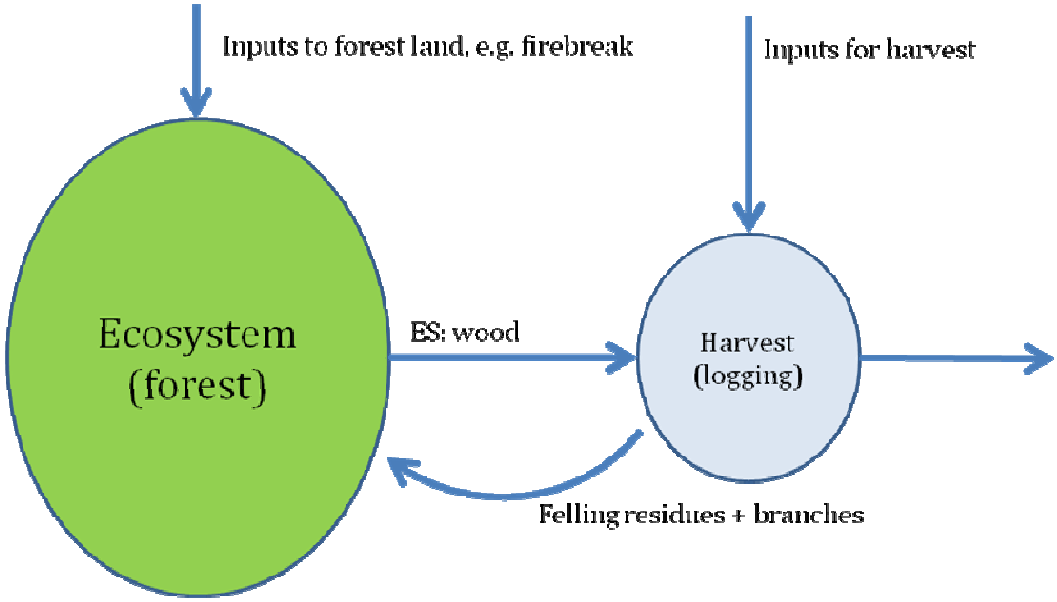
Provisioning of wood and non-timber forest products

3.39 Wood production includes the production of timber and firewood in natural, semi-natural or plantation forests. Non-timber forest products (NTFPs) include a broad range of products that can be harvested in a forest, such as fibres (e.g. rattan), fruits, mushrooms and pharmaceutical products. Plantation forests are considered cultivated biological resources and are evidenced by relatively significant levels of economic activity in the growing process including the construction of fire breaks, reforestation with specific species, the spraying of pesticides, and the thinning of branches to promote growth.

3.40 While the management practices may differ, the underlying ecosystem provisioning service is the same: the growing of the 'wood' or 'NTFP' that enters the production function of the logging company or individual. Figure 3.3 presents this service, focusing for illustrative purposes on the supply of wood.

3.41 For logging, a number of inputs are required such as labour, a saw and a truck. The product resulting from the logging is logged wood, with felling residues returned to the ecosystem. Wood can have a wide range of different qualities. Both the product (logged wood) and the ecosystem services (wood) can be measured in terms of kg/ecosystem/year. The difference between the two is that the ecosystem service represents standing wood at the moment immediately before it is felled, the product represents logged wood. For harvesting of NTFPs, only labour may be required, and the ecosystem service (i.e. NTFP immediately prior to collection) may be equivalent to the product (i.e. the harvested NTFPs).

Figure 3.3 Provisioning of wood

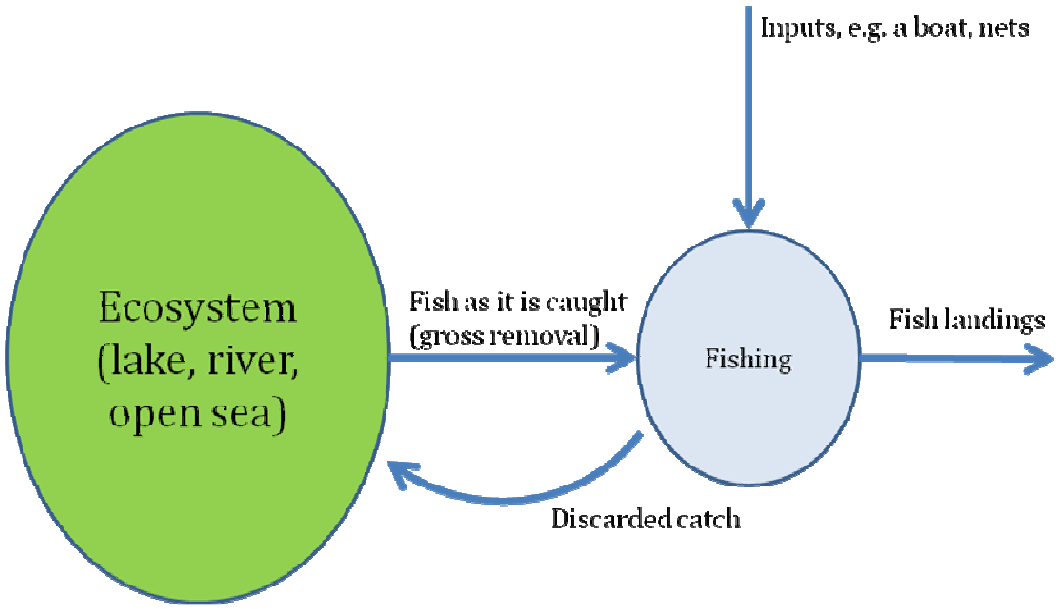


Provisioning of fish and other aquatic and marine species

3.42 Marine or inland waters (lakes, rivers) supply fish and other species (shrimps, shellfish, seaweed, etc.). There is generally little investment in maintaining the state of the ecosystem, even though monitoring or law enforcement activities may be undertaken, and on specific occasions also restocking of specific lakes may be carried out. However, inputs are required for the harvesting of fish and other species, involving boats, nets, labour, etc. The ecosystem service is the fish as it is harvested (corresponding to the 'gross removal'). The product resulting from the activity fishing is fish, most commonly expressed as landed fish.

3.43 The ecosystem service may be measured in physical terms in terms of the amount of fish caught (i.e. the gross removal from the ecosystem), accounting for differences in species, see Figure 3.4. Discarded catch is usually returned to the ecosystem. Often the discarded catch consists mainly of dead specimens that do not lead to a restocking of the ecosystem.

Figure 3.4. Provisioning of fish

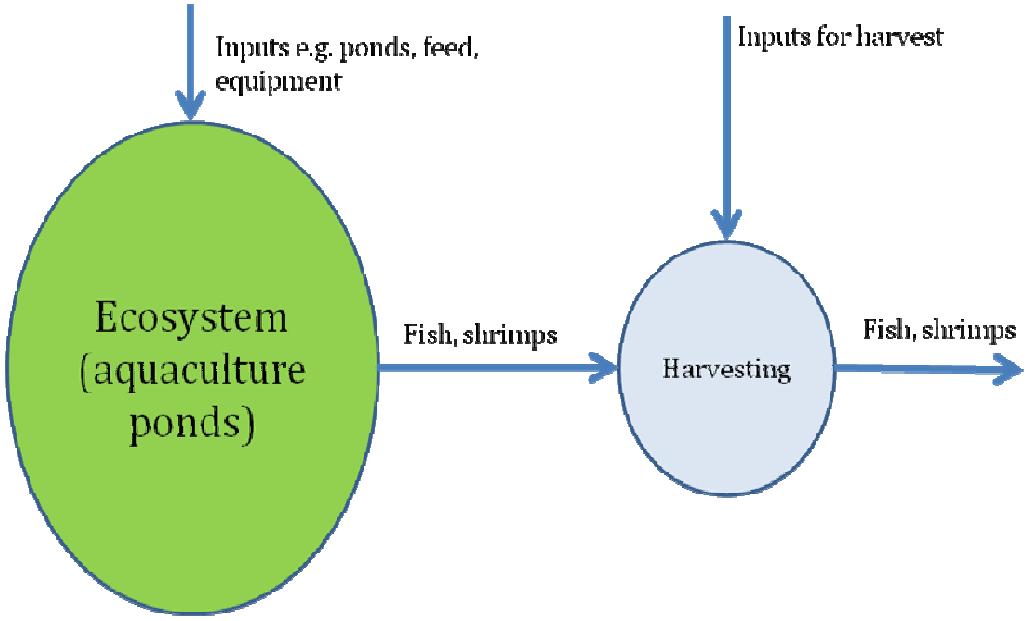


Provisioning of fish from aquaculture

3.44 Aquaculture systems range from highly extensive (blocked water bodies with some stocking of commercial varieties) to highly intensive (e.g. intensive shrimp ponds with controlled stocking, feeding, use of pesticides and other chemicals). As in the case of farming, in aquaculture there are investment required to shape the productive environment required for growing fish or crustacean production, for instance in ponds and infrastructure. In addition, inputs are required to harvest the crops, even though these may be small compared to the investment required for developing the aquaculture facility. In the case of aquaculture, there may not be any return of discarded fish to the ponds, and the harvested 'ecosystem service' may equal the product. Figure 3.5 shows the overall model for this ecosystem service.

3.45 The ecosystem service can be measured in terms of fish produced. In the case of aquaculture, there is a need to examine if harvesting systems can be classified as ecosystems (which may be appropriate for the extensive systems where natural processes including predation are important in regulating the ecosystem dynamics) or as purely produced systems (akin to greenhouses (as may be more appropriate for the most intensively aquaculture systems).

Figure 3.5 Fish and crustacean production from aquaculture



Provisioning of water

3.46 Freshwater can be extracted from deep or shallow aquifers, and from surface water including lakes, rivers or man-made reservoirs. The supply of water from deep aquifers is not strongly linked to ecosystem functioning since these reservoirs tend to depend on geological water resources. The extraction of water from deep aquifers storing water that is not replenished on human time scales should therefore be interpreted as extraction of sub-soil assets.

3.47 For both surface water and water extracted from renewable, shallow aquifers, both the quantity and the quality of water generally depend on ecosystem functioning. Water from rivers, lakes or other reservoirs may be purified by ecosystems, in particular if it has passed through a wetland that has the capacity to break down organic pollutants, and absorb inorganic pollutants. Water pumped up from aquifers or other subsurface groundwater sources is often less polluted than surface water because of the capacity of ecosystems to breakdown or bind pollutants and filter micro-organisms harmful to human health. Often, headwaters or complete watersheds important for drinking water production are protected and managed as drinking water extraction area.

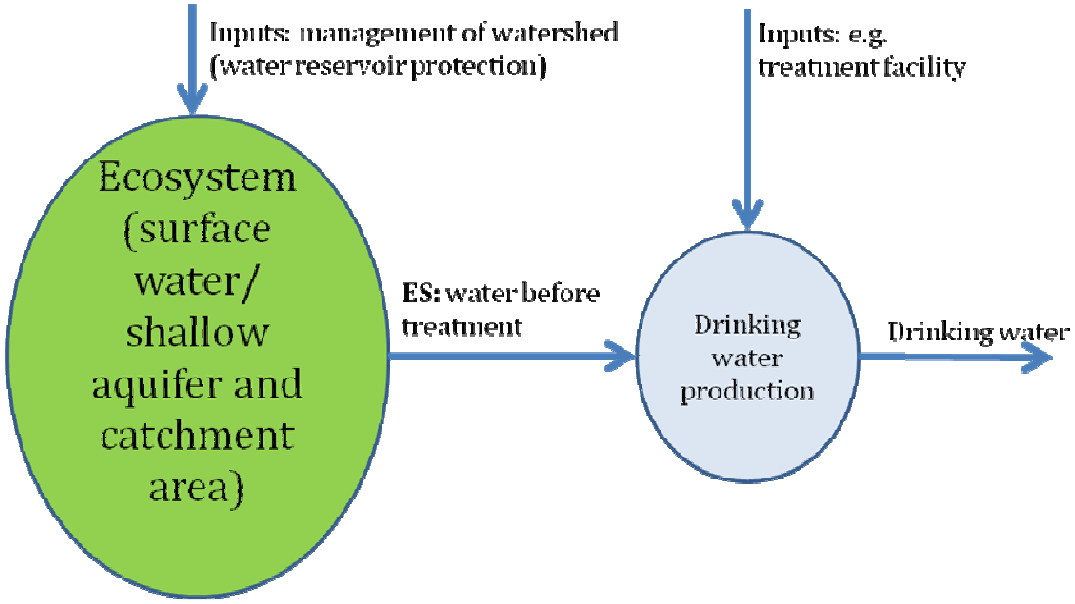
3.48 Water supply therefore combines elements of a provisioning and a regulating service. It is a provisioning service in the sense that the extraction of water involves the flow of a good from the ecosystem to society, however underlying the presence of the water are a number of regulating processes such as water storage (inter or intra-annual) and water purification.

3.49 The water accounts presented in the SEEA Central Framework and in SEEA-Water detail the methods for accounting for water resources including deep aquifers. In contrast, in SEEA Experimental Ecosystem Accounts, the focus is on ecosystems' capacity to support water extraction. The approach taken is to analyse the provisioning of water as an ecosystem service

is illustrated in Figure 3.6 below. The ecosystem service is the amount of water (before treatment) extracted from the surface water source or the shallow aquifer.

3.50 Investments may be made in order to protect the ecosystem (generally a watershed) supplying the water (e.g. adjusted land management, monitoring of water quality, creation of retention basins) as well as for the transformation of extracted water into drinking water. The extracted, untreated water enters the production function of the drinking water company, or of the household consuming the water. The household may either consume this water directly, or filter it before consumption.

Figure 3.6 Provisioning of water



3.4.2 Regulating services

3.51 Typical for regulating services that they involve a process regulated by the ecosystem that provides a non-material benefit to society in the form of lowering the risks of certain negative outcomes (such as polluted air). However, typical for this category of services is that a range of conditions and factors need to be in place before a benefit is received. Thus, the processes regulated by the ecosystem only constitute a benefit - and therefore an ecosystem service - in situations where the ecosystem processes affects people. For instance, air filtration by vegetation only materialises as an ecosystem service if there is air pollution in the atmosphere that the vegetation is absorbing and if there are people living nearby that benefit from a lower concentration of air pollutants.

3.52 These other conditions and factors have been called, for the purpose of SEEA Experimental Ecosystem Accounts, 'enabling factors'. These enabling factors differ for the various regulating services, and are described below for three regulating services. Note that these enabling factors are typically not an attribute of the ecosystem, and they are not reflected in

the stock of ecosystem capital. Nevertheless, these factors need to be understood, quantified and recorded before physical and monetary quantification of the ecosystem service can take place.

3.53 The delivery of regulating services is commonly and increasingly affected by land use choices made by producers and society generally. At a local level the delivery of regulating services may be affected negatively by the removal of vegetation, for example. Equivalently, the delivery of regulating services may be enhanced by the planting of vegetation or the protection of existing vegetation. Thus, while the regulating services themselves are very much natural processes, the extent of their delivery can be materially affected by human activity.

3.54 The paragraphs below present a brief description of selected regulating services. They also contain a figure that illustrates the supply of ecosystem services by the ecosystem, as well as the role of other inputs (such as labour and produced assets) and the subsequent benefits. In the case of regulating services, there are no activities required to produce the service.

Sequestering of carbon and carbon storage

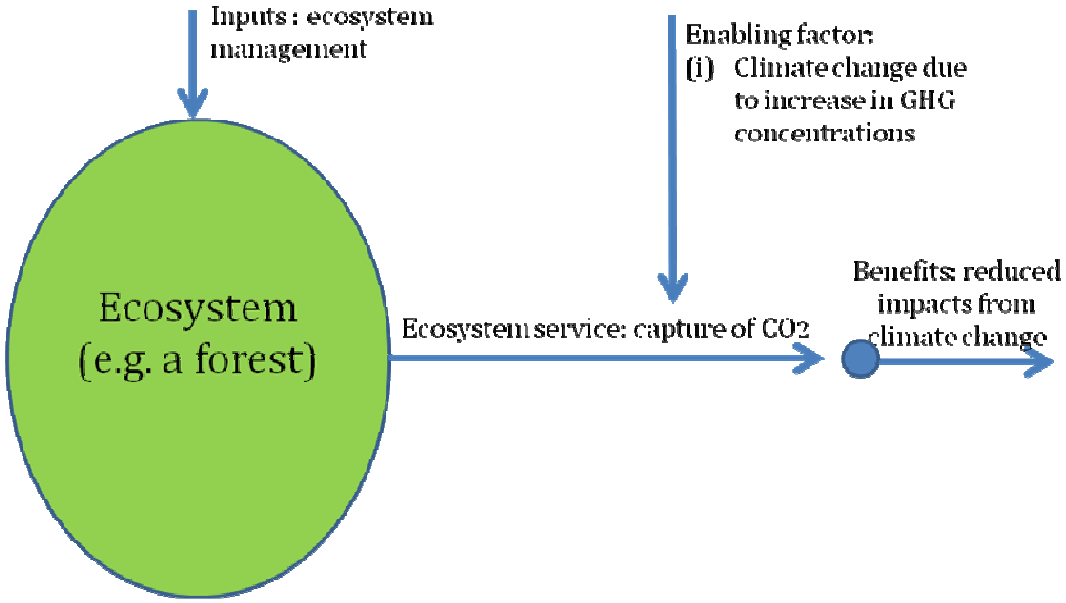
3.55 Often, the services of sequestering of carbon and carbon storage are labelled by the single term "carbon sequestration". However, they are quite different ecosystem services, albeit linked within the broader carbon cycle. Both services are important for ecosystem management and therefore for ecosystem accounting. The release of carbon stored in above ground biomass or in below ground stocks, such as peatlands, is an important source of greenhouse gas emissions worldwide. It is also the subject of much debate in the international arena, in particular with regards to the REDD (Reduced Emissions from Deforestation and Degradation) payment mechanism. At the same time, the sequestering of carbon, i.e. the ongoing accumulation of carbon due to ecosystem processes in particular Net Ecosystem Production, is relevant since this removes carbon dioxide from the atmosphere.

3.56 In order to capture both the stock and the flow aspect of carbon, the following conceptualisation of this ecosystem service is used for the purpose of ecosystem accounting. Analogous to other ecosystem services, the sequestering of carbon and carbon storage are service flows that can only have positive values. In both cases the flows is expressed as tons of carbon(equivalent)/year, and should be specified for spatially defined areas that can be aggregated for the purpose of national level ecosystem accounting. The service of the sequestering of carbon is equal to the net accumulation of carbon in an ecosystem due to growth of the vegetation and due to accumulation in below ground carbon reservoirs. The ecosystem service of carbon storage is the avoided flow of carbon resulting from maintaining the stock of above ground and below ground carbon sequestered in the ecosystem.

3.57 To calculate the second part, i.e. the flow that can be attributed to maintaining carbon in storage, the avoided emissions are calculated. These avoided emissions only relate to the part of the stored carbon that is of clear risk of being released in the short term due to land use changes, natural processes (e.g. fire) or other factors. No service is delivered if all stocks at risk of being released are released but positive service flows are recorded where stocks at risk remain in storage.

3.58 The conceptual model of the ecosystem service as a function of ecosystem state and enabling factors is presented in Figure 3.7. Figure 3.7 shows that ecosystem management will generally affect the net sequestration and/or the storage of peat in the ecosystem. The enabling factor for this service is the occurrence of climate change, which causes carbon sequestration and storage to provide an economic benefit resulting from avoided damages, at present and in the future.

Figure 3.7 Sequestering of carbon



Air filtration

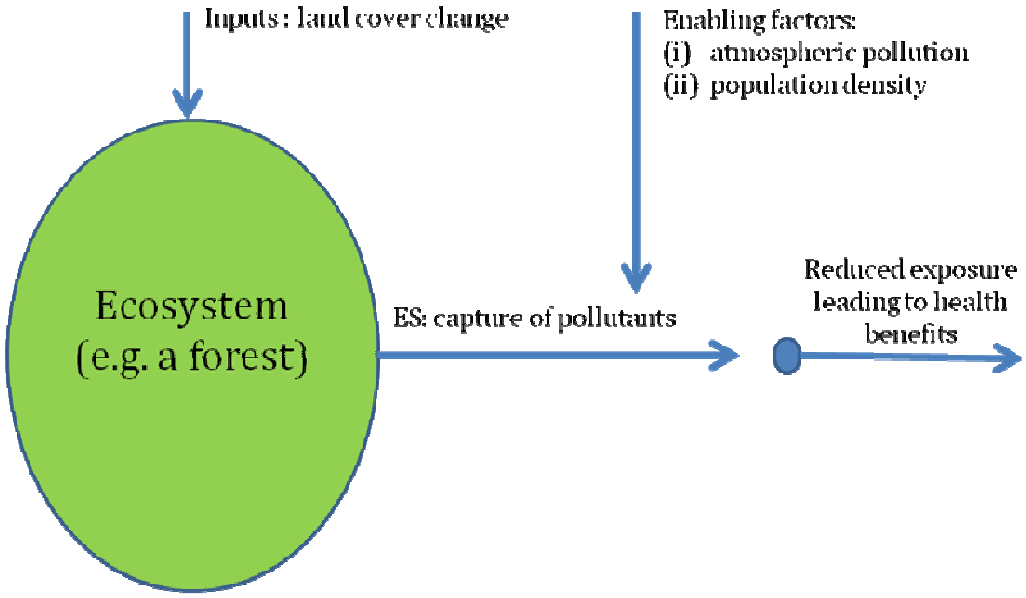
3.59 Air pollution arising from particulate matter (in particular the smallest fraction of PM: PM2.5 with a diameter <2.5 μm) is a major health problem in many countries. Statistically significant relationships between PM concentration and cardiovascular and respiratory diseases, as well as lost working days due to air pollution-related illnesses have been shown in a range of studies. Air pollution removal takes place through the interception of PM by leaves (dry deposition). The amount of interception depends on the state and management of the ecosystem (for instance, on an annual basis evergreen trees capture more PM than deciduous trees). Two enabling factors are needed to turn the ecosystem process of deposition into an ecosystem service. First there needs to be a certain pollution load (that can be measured in terms of PM concentration) and second there need to be an exposure of people to air pollution in the zone affected by PM deposition by the ecosystem.

3.60 The total amount of particulate matter deposited in an ecosystem can be estimated as a function of the area, deposition velocity, time period and average ambient PM2.5 concentration, according to the formula $PM\downarrow = A*Vd*t*C$, in which $PM\downarrow$ = deposition of PM2.5 (kg), A= area (m^2), Vd = deposition velocity as a function of the Leaf Area Index of the vegetation (LAI) (mm s^{-1}), t= time (s), and C = ambient PM2.5 concentration (kg/m3). The deposition velocity depends on the vegetation type, and there is an increasing number of

measurements of deposition velocities as a function of vegetation type, in particular in European countries.

3.61 A cause of uncertainty pertains to the distance at which vegetation influences air quality. The UK NEA assumed that health benefits from air filtration by forests only occur at short distances (<1 km) from the forest. Other studies states that damage assessments of particulate matter pollution need to consider that air pollution (PM) can spread over distances of several hundreds of kilometres from an emission source, which means that the effect of large forests on air quality may be noticeable at larger distances from the forest edge.

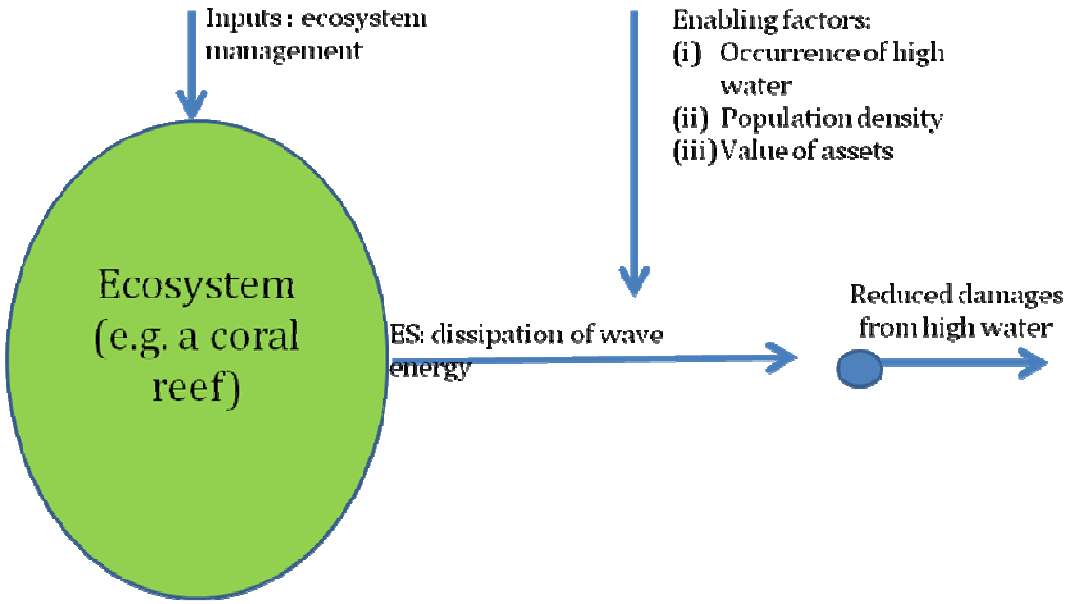
Figure 3.8 Air filtration



Flood protection

3.62 It is clear from a range of studies that specific ecosystems can reduce the extent and intensity of floods, thus reducing the risk of damage to built environments and other ecosystems. Ecosystems such as mangroves, dunes or coral reefs, or riparian forests, are particularly relevant in this regard. This service is only relevant where there is (i) risk of high water and wave energy as a function of wind patterns and local bathymetrics; and (ii) the presence of people, economic activity and assets susceptible to loss in the exposed flood risk zone. Storm occurrence and therefore flood risk may be modelled in a probabilistic manner, on the basis of the occurrence and magnitude of storms in recent decades and on the basis of climate models accounting for climate change. In coastal areas, the ecosystem service involves the dissipation of wave energy and the prevention of inundation. In inland areas, the ecosystem service involves the channelling and dispersion of water.

Figure 3.9 Flood protection



3.4.3 Cultural Services

3.63 Cultural services are more difficult to scope than provisioning and regulating services since they reflect the nature of human relationships with ecosystems rather than more direct extraction or use of ecosystem processes. At the same time there are some cultural services that are quite obvious, particularly tourism and recreation services, and the benefits that arise from these services are often an important part of economic activity.

3.64 For those cultural services that are not within scope of the SNA production boundary, the aim is to define the amenity or utility that people derive from the landscape. For many people, particularly indigenous peoples, this may be strongly spiritual and cultural. In general terms, the extent of these services will be a function of human access to the ecosystem (perhaps based on the number of people interacting with the ecosystem) and the quality of the ecosystem and surrounding landscape.

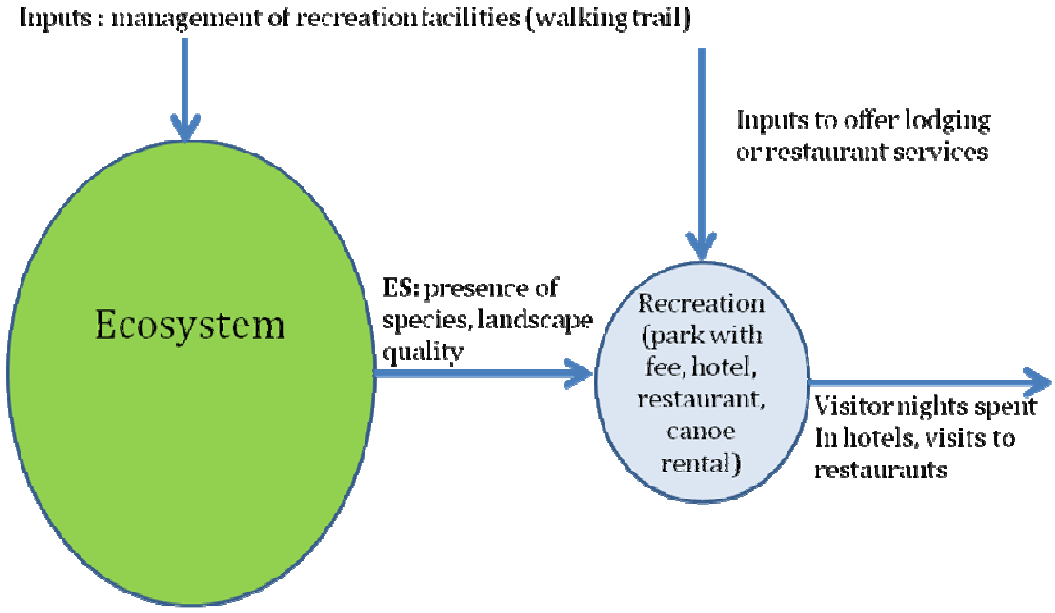
Tourism and recreation

3.65 Ecosystems provide an opportunity for tourism and recreation. Tourism is generally interpreted as involving overnight stays, potentially from visitors abroad, and recreation is more usually associated with day trips. The service requires some degree of investment in the ecosystem, for instance to lay out walking trails, cycling paths, and camping sites. In physical terms, this ecosystem service can be measured in terms of the number of people visiting the ecosystem. The benefits accrue to visitors themselves, and to nearby suppliers of tourism and

recreational facilities to the extent that they can attribute their operation to the ecosystem. For instance, some tourism facilities can only exist because of the presence of the ecosystem, as in the case of an enterprise renting out skis or canoes. For other enterprises, the picture is mixed, and only part of their activity may be attributable to the ecosystem, as in the case of hotels or restaurants located in or nearby natural parks.

3.66 Physical measurement of the ecosystem involves recording the number of visitors, in terms of visitor-days, or overnight stays, to ecosystems. Ecosystems such as national parks that are publically accessible are most relevant for this service. As in the case of provisioning services, the use of ecosystem services in tourism involves a specific activity being undertaken, i.e. the recreation activities by people in an ecosystem.

Figure 3.10 Tourism and recreation services



3.4.4 Ecosystem services and biodiversity

3.67 The relationship between ecosystem services and biodiversity is complex and difficult to conceptualise and measure. On the one hand, biodiversity is a core characteristic of ecosystems much akin to supporting services. However, many people also value species diversity and/or the protection of rare species independent of the role of these species in supplying other ecosystem services. Even though the service is difficult to measure and record, it is complementary to other ecosystem services and is therefore included in the framework.

3.68 Biodiversity is generally assumed to include the three levels of genetic, species and ecosystem diversity. Hence biodiversity is not equivalent to nature nor does it necessarily fully represent the natural value of an ecosystem. For instance the preservation of a conservation flagship species, for instance the orang-utan, may be perceived to be more important than the

preservation of a rare beetle, even though the extinction of both species would reduce biodiversity by one species.

3.69 A measurement consideration is that the preservation of some species may be important for the overall functioning of the ecosystem, in particular where it concerns species that occupy a specific role or trophic niche in the ecosystem. Ecological theories indicate that maintaining species diversity within functional groups is important for ecosystem functioning and resilience.

3.70 The measurement of biodiversity is generally in the form of indexes that focus on species or protected areas. A measurement framework for biodiversity and the key indicators that can be used in ecosystem accounting is discussed in Chapter 4.

3.5 Setting priorities for selecting ecosystem services in ecosystem accounts

3.71 In piloting ecosystem accounting at the national scale, it may be most feasible to initially select a limited rather than a comprehensive set of ecosystem services for inclusion in ecosystem accounts. The potential feasibility to measure ecosystem services at the national scale, both in physical and in monetary terms, differs strongly between different ecosystem services. These differences occur due to differences in data availability, different methodological constructions, and different complexities related to scaling up and aggregating physical and monetary units associated with ecosystem services. In addition, there may be different policy priorities for analysing ecosystem services.

3.72 To facilitate the selection process of ecosystem services in ecosystem accounts, a list of criteria for ranking ecosystem services with regards to their potential suitability for inclusion in ecosystem accounting is presented in Table 3.6 below. The applicability of the criteria will differ between countries and the list should be seen as indicative only.

Table 3.6 Criteria for prioritization of ecosystem services for accounting purposes.

	Criterion	Brief explanation
1	Availability of broadly accepted methods for analyzing ecosystem services supply in physical terms at a high aggregation level	Initial consideration may initially be given to services for which broadly accepted modelling / quantification techniques are available.
2	Availability of broadly accepted methods for analyzing ecosystem services supply at a high aggregation level in monetary terms	Initial consideration may initially be given to services for which broadly accepted valuation approaches are available.
3	Availability of data for measuring ecosystem services in physical terms	Producing national level accounts will often require scaling up parcel level estimates of ecosystem services to a national level based on underlying spatial data. Both point-based data and spatially explicit data (e.g. land cover, soils, water tables, ecosystem productivity, etc.) are required to analyse a service at the national level.
4	Availability of data for measuring ecosystem services in monetary terms	
5	Plan to generate new data on ecosystem services supply	A firm intent or high likelihood that new environmental monitoring will provide essential data.
6	Economic importance of the ecosystem service.	Initial consideration may be given to those services that generate the highest economic benefits.
7	Possibility to influence environmental and/or economic policy and decision making (decision making context)	Initial consideration may be given to services that can relatively easily be influenced by decision making in order to have maximum relevance for policy making.
8	Sensitivity of the service to changes in the environment, including from anthropogenic stressors.	Initial consideration may be given to services that are sensitive to environmental change / well reflect changes in natural capital stocks.
9	Likelihood of irreversible loss of ecosystem services including by the supplying ecosystem being pushed past a significant threshold and out of its "safe operating range".	Initial consideration may be given to services that are generated from ecosystems that are generally understood to be close to significant environmental thresholds.

3.73 Data availability and policy priorities will differ per country, hence the selection of ecosystem services for ecosystem accounting will differ per country. In general, from a methodological and data perspective, most feasible for ecosystem accounting are the provisioning services including water supply and carbon sequestration, as described below.

3.74 *Provisioning services.* Since many provisioning services are already included in SNA, there is generally high potential to link these service to ecosystems.

3.75 Data on water resources is partly available, in particular regarding the production volumes of drinking water and to some extent irrigation water. However, the link between ecosystem management and water provisioning is less clear, with regards to such aspects as water purification in aquatic ecosystems or in the soil, water storage in ecosystems in upper watersheds, etc. Given the economic importance of water supply and the declining water resources in many parts of the world, including this service in ecosystem accounts may be a priority in many countries. A challenge is to better understand, in particular at high aggregation levels, the infiltration, purification and storage processes involved.

3.76 *Sequestering carbon and carbon storage.* Recent years have seen a strong increase in interest in the carbon related ecosystem services and there is a large amount of research on-going aimed at quantifying these services at different scales, from local processes to national stocks

and flows. The development of REDD (Reduced Emissions from Deforestation and Degradation) market mechanisms means that there is also, increasingly, information available on markets related to carbon. Given the broad interest and the increasing availability of methods and data relevant for this service, this service has a high potential for inclusion in ecosystem accounts.

3.77 A challenge with regards to this service is to account for both the storage and the sequestering of carbon. Storage and sequestering are not aligned. A high carbon stock may mean that sequestration is limited because the vegetation is close to its maximum biomass under the ecological conditions pertaining in the particular area. A low carbon stock may mean that there is scope for additional sequestration (e.g. in a recently cut forest with intact soil fertility), but this doesn't have to be the case (e.g. in a desert).

3.78 It should be noted however, that although scientific methods and data are relatively well developed for this service, this does not equally apply to all ecosystems, with relatively much data available for forests, and relatively few data for lakes and coastal systems. There may also be data and/or methodological constraints related to analysing carbon sequestration in degraded forests and in forest/landscape mosaics.