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Discussion paper 3.2: Treatments for selected ecosystem services and related flows for the revised SEEA EEA

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Research area #3: Ecosystem services

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Background

This paper considers a range of issues concerning the description and measurement of ecosystem services that require discussion and clarification for ecosystem accounting purposes. Many of the topics have been discussed in other forums and contexts but clear outcomes that consider the accounting principles of the SEEA have not yet emerged. It is expected that on the basis of feedback on this paper, a clear set of labels and descriptions of ecosystem services will be able to be drafted for further discussion.

For a summary of the SEEA EEA revision process and background concerning the work to date on ecosystem services, please see the opening sections of Discussion paper 3.1 (DP3.1) which has been distributed concurrently. This paper, Discussion paper 3.2, complements DP 3.1.

1. List of ecosystem services

Background

For the purposes of compiling ecosystem services supply and use accounts it is necessary to record flows of ecosystem services between suppliers – the ecosystem assets, usually grouped by type of ecosystem (e.g. forests, wetlands) - and users. For final ecosystem services the users will be different economic units while for intermediate services the users will be ecosystem assets. Generally, the focus of ecosystem accounting is on recording flows for a number of types of ecosystem services. Therefore, establishing an agreed set of types of ecosystem services that are commonly described, defined and labelled is a relevant and important step to support comparison over time and across spatial areas (including countries).

Since the commencement of work on SEEA EEA, there has been a desire to establish an agreed classification of ecosystem services for ecosystem accounting purposes. The SEEA 2012 EEA included an interim version of the Common International Classification of Ecosystem Services (CICES) which has subsequently been updated to version 5.1[1]. CICES has been widely applied but there are also other approaches to the classification of ecosystem services including the National Ecosystem Service Classification Scheme (NESCS)[2] and more recently the typology of nature's contributions to people developed within the IPBES[3]. In the context of the SEEA EEA, most discussion has taken place between developers of CICES and NESCS, with the general conclusion that these classification schemes can be seen as complementary.

In practice, it is evident that ecosystem service measurers do not apply consistent definitions or labels. This may be satisfactory in a single study with a focus on measuring one or a few ecosystem services in a given location but for the purposes of accounting and cross-country comparison this is not advantageous. The practical realities of differences in definition and labelling of ecosystem services were very evident in the papers prepared for the January 2019 workshop on individual ecosystem

[1] https://cices.eu/resources/
[2] https://www.epa.gov/eco-research/national-ecosystem-services-classification-system-framework-design-and-policy
[3] https://ipbes.net/news/natures-contributions-people-ncp-article-ipbes-experts-science

services[4]. For the selected services, these papers contained quite a range of interpretations, descriptions and labels for different ecosystem services by different groups of experts.

Given the current state of development of ecosystem service classifications, it was proposed at the expert meetings in June 2019, that the focus in the SEEA EEA revision process should not be on establishing a full classification but rather the focus should be on determining a ***reference list of selected ecosystem services*** that provides commonly agreed labels and descriptions for an agreed set of key ecosystem services of relevance for ecosystem accounting. This reference list would provide support for discussion among ecosystem accounts compilers, the comparison of measurement and valuation techniques and the comparison of accounting results.

The reference list is not a full classification system. It is however anticipated that a complete and internationally agreed classification system for ecosystem services will be developed. To support this development, in preparing the list for the SEEA EEA revision, correspondences will be developed to CICES and NESCS to allow those using those classification systems to link to the reference list. Descriptions of the connections to other typologies of ecosystem services, e.g. IPBES and TEEB, will also be developed.

It is expected that the descriptions of each ecosystem service, as they are developed and amended, will reflect the overarching conceptual definition of ecosystem services for the SEEA EEA, i.e. as being contributions to benefits. Further, the label applied should reflect this contribution rather than the associated benefit. Since discussion is ongoing concerning the details of the definition and measurement scope of ecosystem services for SEEA EEA, an iterative process for the finalization of the reference list will be required. The proposals below are therefore not final.

Principles applied in the use of the reference list for ecosystem accounting

It is expected that it will be possible for each ecosystem service in the reference list to be measured in a mutually exclusive way such that there should not be double-counting of ecosystem contributions. Further, since it contains selected ecosystem services, the reference list is not exhaustive. It is perfectly appropriate for ecosystem services not included in the reference list to be included in a set of accounts. However, when this is done it would be also appropriate to ensure that the definition, labelling and measurement of those ecosystem services is done in a mutually exclusive way to facilitate comparison to those ecosystem services included in the reference list.

It is noted that the reference list is intended, conceptually, to reflect the extension of the SNA production boundary inherent in the ecosystem accounting approach. In this sense the reference list extends the current Central Product Classification (CPC) which lists the set of goods and services included within the SNA production boundary. Another way of viewing this is that the reference list will provide labels for the rows of the ecosystem services supply and use account in which transactions in ecosystem services are recorded between suppliers (ecosystem assets) and users. These same rows can then also be used to extend a standard supply and use account which has rows for goods and services using labels and definitions from the CPC.

It is also noted that within the reference list there is no need to identify the source of the ecosystem service (i.e. the type of supplying ecosystem asset) or the nature of the use of the ecosystem service (e.g. whether for use by households, for nutrition, for energy, etc). Much of this information will be evident from the place in the supply and use account where the transaction is recorded. Thus, for example, the supply and use account will use existing classifications of ecosystem types and economic

[4] https://seea.un.org/events/expert-meeting-advancing-measurement-ecosystem-services-ecosystem-accounting

units to organize information on each ecosystem service flow. By way of example, no distinction will be made in the reference list between water regulation of base flows services provided by forests or by wetlands – these are not considered different types of services.

As well, the reference list includes final and intermediate services. This approach aligns with the CPC which includes all products irrespective of use. The distinction between final and intermediate is not a reflection on the type of ecosystem service and instead is a reflection of who is deemed to be the user of the service (and hence where it is recorded in the supply and use account).

The reference list also includes some examples of abiotic flows, subject to ongoing discussions on the boundary between ecosystem services and abiotic flows which are summarized in this paper.

Initial reference list of selected ecosystem services

The primary criteria for inclusion in the reference list of selected ecosystem services is that the service is commonly agreed by the ecosystem accounting community and ecosystem service measurement experts to constitute a relevant and material ecosystem service in many countries and contexts. It is expected that the reference list will provide a good coverage of ecosystem services within each of the three high level groups of provisioning, regulating and cultural services. At this stage, a hierarchy of ecosystem services within each of these high level groups has not been developed.

The initial reference list proposed below has been formed primarily based on discussions among ecosystem services experts at the June 2018 Forum of Experts and at the January 2019 workshop on individual ecosystem services. It is intended to provide a starting point for discussion and ongoing feedback and comment is encouraged.

One challenge has been that in some cases there appear to be many sub-types – particularly concerning the provision of biomass. The intention in the initial list below is to highlight major types of services. Also included are what have been labelled as “likely additions” in the sense that these services have been proposed by various experts and appear from the literature to be commonly considered as ecosystem services using the concept applied for ecosystem accounting.

Aside from ongoing discussion and review, three specific steps are required as part of the further development of the reference list:

- Resolution of a range of boundary cases where the treatment of certain flows is not yet finalized. The following issues are a focus of this note and the initial reference list below notes these boundary cases separately.
    - The connections among climate regulation, carbon sequestration and carbon storage
    - The connections among water related ecosystem services including water regulation, water purification (nutrient removal and sediment retention) and water supply
    - The definition and description of cultural services including links to the conservation of biodiversity
    - The boundary between ecosystem services and abiotic flows, particularly with respect to water supply.
- The development of agreed descriptions and measurement boundaries for each ecosystem service on the reference list. There is a range of material available on which to base these descriptions that can be accessed.
- A thorough comparison of the coverage and labelling of ecosystem services to CICES and NESCS in particular, and other typologies as appropriate.

Table 1: Initial reference list of selected ecosystem services

ECOSYSTEM SERVICE	NOTES
Provisioning services	
Biomass provision	Many types of ecosystem services might be identified within this single ES primarily by type of biomass (e.g. crop, timber, etc). Distinctions based on type of use are not proposed (e.g. wrt nutrition, energy etc). Consideration may be given to identifying the management of the growth of the biomass (cultivated or natural). Decisions here will rely, in part, on decisions taken on the conceptual treatment and measurement boundaries of biomass provision (e.g. concerning the treatment of livestock and aquaculture)
Water supply	Included here noting this is the subject of ongoing discussion wrt the boundary between ecosystem services and abiotic flows.
Regulating services	
Global climate regulation, carbon sequestration & carbon storage	These potential ecosystem services and the connections among them are the subject of ongoing discussion
Air filtration	
Soil retention	Agreement is needed on the concept and the label. Alternatives/complements include soil erosion prevention, soil stabilisation, control/regulation of erosion rates. Potential distinction needed between keeping soil in a particular location and trapping soil as it travels down a slope (link here to water purification).
Water purification	Agreement needed on the constituent services since a range may be identified. These include sediment retention (link to soil retention), nutrient retention and absorption, removal of contaminants. To the extent that separate services are identified these would be added to the list
Water regulation of base flows	Encompassing water absorption and release
Flooding and tidal surge mitigation	
Other storm mitigation	
Noise attenuation	
Pollination	
Pest control	
Local (micro and meso) climate regulation	
Nursery population maintenance	Including associated habitats
Cultural services (tentative proposals pending further discussion of material in section 2.4 of this paper)	
Recreation related services	Label subject to ongoing discussion as part of broader discussion of cultural services and the appropriate words to describe the contribution of the ecosystem
Amenity services / aesthetic appreciation	
Education, scientific and research services	
Spiritual / religious services	
Conservation of valued species	
Contributions to non-use values	The agreed scope of ecosystem accounting will be an important factor in determining the inclusion and labelling of this service. Connections to option, existence and bequest values

Question:

Do you have comments on the coverage of the initial reference list of selected ecosystem services?

2. Selected issues in the description and treatment of ecosystem services

2.1 The treatment of biomass provisioning services

The discussion of the treatment of biomass provisioning services has been a longstanding one for accounting. The lack of resolution has been due, in part to the variety of ways in which people access and use biomass from the environment and, in part, due to the lack of common understanding of the treatment of stocks and flows of biomass in the standard national accounts. Since in ecosystem accounting the ambition is to both reflect the variety of ways of access and also align with the standard national accounts, a range of related discussion points generally emerge.

A significant issue in the discussion of this topic has been the use of language and terms which have often been interpreted differently by different experts. This reality appears to be due to the lack of ideal words, in English at least, to describe the intended concepts. The effort has been made here to get the language as internally clear and consistent as possible but it remains a challenge. Readers are encouraged to focus on the concepts in the first instance.

A critical distinction that must be retained through the discussion concerns the description of the ecosystem service and the measurement of that service. Often these two aspects are conflated with the measurement approach becoming a de facto description/definition. The ambition here is to maintain the distinction such that agreement can be reached on the appropriate description of the concept follow by a discussion of measurement options.

Concept of biomass provisioning services

There is clear recognition that people source and use biomass from ecosystems in a wide variety of ways and for different purposes, including for food, fibre and energy. Sometimes the biomass is accessed directly by an end user (e.g. household picking berries in a forest) but a vast majority of biomass is accessed by farmers, foresters and fishers (economic units both small and large) who harvest or otherwise secure the biomass and then supply it to end users.

At the point of being accessed, there is an instance of joint production in which the role of the ecosystem in supplying the biomass intersects with the activity (and associated human inputs) of people and economic units. The joint production results in a benefit being produced, including in the case of subsistence agriculture. These benefits are treated as products in standard national accounts and economic statistics.

Based on this framing, the logic that has been generally agreed for ecosystem accounting, and in other contexts, is that ***biomass provisioning services are the ecological contributions to the production of these benefits***.

The challenge for consistent description and measurement of this general concept has emerged because, in practice, the scope of joint production in the production of benefits is, in fact, much broader than the intersection of ecosystem and people at the point of access or harvest. That is, in many situations and for the majority of biomass benefits, the intersection between the ecosystem and

people occurs during the growth of the biomass as well as at the point of harvest. Cases involving both types of joint production (i.e. harvest and biomass growth) are referred to in this note as cultivated production as distinct from natural production (which involves only harvest).

Natural production processes

There seems general agreement on the appropriate description of ecosystem services in the case of natural production of biomass. In this case, the starting point is that there is no human intervention in the growing process and thus all of the biomass that is harvested can be considered the ecosystem contribution. In the SEEA Central Framework, the harvest of naturally produced biomass is recorded as natural inputs (including natural timber, wild fish, etc).

It may be that not all biomass harvested is subsequently sold or used by the harvester (an economic unit). This is relevant from the perspective of national accounting since the quantity of the product that should be recorded in the accounts is the quantity that is sold to other economic units or used by the same unit (i.e. on own-account, including in particular by households). This difference between the total naturally produced biomass that is harvested and the quantity subsequently sold or used is referred to in the SEEA Central Framework as natural resource residuals. Example of natural resource residuals include discarded catch in fishing and felling residues in timber.

Compilers are encouraged to record natural inputs in gross terms (including all of the flows from the environment into the economy) but to also recognize natural resource residuals when some of the natural inputs are not further used but are returned to the environment.

The key conceptual point is that the definition of the ecosystem service should be aligned with the gross quantity of biomass that is harvested, i.e. the gross natural input. This will be different from the total stock of biomass available for harvest and from the biomass that is subsequently removed from the ecosystem and sold or otherwise used.

This approach should apply in all cases of natural production of biomass, i.e. irrespective of (i) the length of time over which the biomass has been growing (e.g. old native timbers); and (ii) the derivative nature of the product, (e.g. honey from wild bees). Thus, focus is solely on the quantity of the biomass that is harvested or accessed.

Cultivated production processes

There is a very wide range of cultivated production contexts. Thus, the extent of human activity in the management of biomass growth can be very high (for example in the case of hydroponically grown strawberries) or very low (for example in lightly managed timber plantations). Further, depending on the type of biomass and the related product, the timing and context of the growth and harvest can vary significantly. To provide examples, consider the variation inherent in:

- The production of corn where the corn is harvested in the same year as it is planted.
- The production of timber in plantations where timber is harvested decades after the trees are planted
- The production of beef where the cattle are harvested (slaughtered)
- The production of milk where the cows are kept for at least five years and milk collected on a daily basis
- The production of apples where the trees are grown for a number of decades producing a new crop of apples each year

Of course, within each of these production contexts there are a wide variety of management practices. Further, for each production process there may be more than one benefit/product that is harvested. For example, the growing of corn may produce food or biomass for the production of energy. The slaughter of cattle will generate food as well as hides for leather and bones for fertilizer.

Notwithstanding this diversity of products, the key from an ecosystem accounting perspective is to isolate the ecological contribution. For this purpose, it is relevant to focus on the treatment in relation to the two different types of joint production identified above (i) harvest and (ii) growth.

In relation to **harvesting activity**, the starting premise in this note is that the nature of the joint production is the same in the natural production and cultivated production cases. Thus, it is considered that the activity of harvesting a tree, catching a fish, picking a crop, etc., is fundamentally of the same nature whether the biomass growth process is natural or cultivated. Hence the nature of the ecological contribution will be the same, notwithstanding the likelihood that different technologies and scales of operation will exist.

This also means that the nature of the ecological contribution to the harvest activity does not vary depending on the use made of the biomass once harvested – in effect the ecological contribution ends at the point of harvest. Of course, for analytical purposes it may be of interest to distinguish between, for example, corn used for food and corn used for biofuels but this difference in use will not affect the nature or description of the ecological contribution.

In relation to **growth activity**, the starting point is to recognise that there will be a range of relative ecological contributions in which the biomass growth is highly influenced by human activity or very little influenced, i.e. the extent of the ecosystem service will vary across production contexts. The concept of using the relative ecological contribution as the basis for defining biomass provisioning services has wide support. In practice, it implies estimating a share between 0 and 100 which is applied to total harvested biomass that reflects the quantity of the ecosystem service supplied. Indeed, this logic can be extended to also cover the natural production context where, by definition, the ecological contribution will be 100%.

An alternative framing is to recognize that the relative ecological contribution reflects aggregate of a range of ecosystem inputs that are combined in biomass growth. It is therefore possible to consider a focus on the individual inputs such as nutrients, water, soil retention, pollination etc. which will be used in different combinations in different contexts. This framing is often aligned with the idea that there is a boundary which these various inputs “cross” from the environment into cultivated production processes. Putting aside the measurement challenge of being able to identify all of the relevant inputs, in many respects it can be seen as a variation on the REC approach. That is, it would be expected that the quantity of ecosystem inputs that cross the boundary into the biomass growth process would be higher in cases where the relative ecological contribution was also high.

At the same time, it is noted that in the relative ecological contributions approach there is also an acceptance that the “task” of melding the inputs to create the biomass growth is itself part of the overall ecological contribution. This aspect would not be captured using an individual ecosystem inputs approach.

On the basis of this discussion, the proposed clarification to the description of biomass provisioning services noted above is that they are the ***ecological contribution to the gross biomass harvested by economic units including households***. This contribution will be 100% in the case of natural production processes and will be between 0 and 100 for cultivated production processes. The gross biomass

harvested will be greater than the quantity of biomass subsequently sold or used[5] due to (i) natural resource residuals (felling residues, discarded catch): (ii) harvest losses in the case of cultivated processes[6] or (iii) the general case that the biomass products produced will not utilize all of the gross harvest. As concluded earlier, the quantity of the ecological contribution is therefore not affected by the number or types of uses made of the gross biomass once it is harvested. (The monetary value of the ecological contribution will however be affected.)

Different outputs of biomass provisioning services

To clarify the application of this concept, this section considers the description above in the context of the variety of cultivated biomass outputs. Two distinctions are drawn (i) between single-use and derivative biomass outputs and (ii) between animal and plant based outputs. These distinctions are discussed using the list of examples of cultivated production processes above. These were:

- The production of corn where the corn is harvested in the same year as it is planted.
- The production of timber in plantations where timber is harvested decades after the trees are planted
- The production of beef where the cattle are harvested (slaughtered)
- The production of milk where the cows are kept for at least five years and milk collected on a daily basis
- The production of apples where the trees are grown for a number of decades producing a new crop of apples each year

It is noted that the following discussion pertains only to cultivated production contexts. In the case of natural production, the gross biomass harvested will reflected the biomass, plant or animal, that crosses into the economy – the wild strawberries, the bush meat, the wild honey, etc. All are implicitly considered single-use biomass outputs.

Single-use and derivative biomass outputs: The first three cases can be considered single-use – i.e. the biomass is cultivated such that it can be harvested or slaughtered, a process which in these examples can only occur once. In the last two cases, the production process is such that an animal or plant is cultivated to gain access to derivative products (in this case milk and apples). Derivative outputs may include animals retained for breeding, for transport or for entertainment (e.g. racehorses, zoos). Note that derivative outputs are different from secondary outputs such as leather obtained through the slaughter of cattle. Note too that the "source" animal or plant – i.e. the dairy cow or apple tree – will, in time, serve a single-use purpose.

Treatment of plants and livestock: In general, in the discussion of biomass provisioning services for cultivated plants, the focus has been on gross biomass harvested – e.g. quantities of corn and timber in the case of single use outputs and apples in the case of derivative outputs. This focus is considered appropriate and no alternatives are proposed here.

In contrast to cultivated plants, for services related to cultivated animals the focus has been on establishing a boundary between the economy and the ecosystem. Thus, for cattle – whether raised

[5] This is equal to the output recorded in the core national accounts

[6] Note that harvest losses are not defined in the SEEA Central Framework since the flows associated with the growth of cultivated biomass are considered to take place within the economy and increases in cultivated biomass are therefore not considered natural inputs. Harvest losses are discussed in the SEEA Agriculture, Forestry and Fisheries.

for slaughter or for milk – the ecosystem contribution has been commonly understood to be the role of ecosystem in providing feed – e.g. grass/pasture. The volume of feed consumed by cattle has thus been considered the gross biomass harvested in relation to animal outputs, recognizing that the relative ecological contribution to the feed will vary depending on the context (e.g. compare nomadic herders, to cattle on improved pasture, to feedlot cattle).

The consequence of this "feed input" approach is that all animal outputs – e.g. meat, milk, eggs, honey, dung, etc. – are regarded as not incorporating an additional ecological contribution. Put differently, in the transactional model of ecosystem accounting, there is a transaction in ecosystem services between the ecosystem (e.g. agricultural pasture) and a cattle farmer reflecting an ecosystem service input to the growing of the cattle, but there is no subsequent transaction in ecosystem services as an input to the production of the animal outputs themselves. This lack of ecological input will be more apparent for derivative products.

An alternative model, as applied in CICES v5.1 (as a change from v4.3), is that all animal outputs (single-use and derivative) should be considered to incorporate additional ecosystem services. Put differently, an "animal output" approach, means that each animal output would have its own relative ecological contribution. While conceptually plausible, a challenge emerges that the definition of the production chain is needed to be able to avoid double counting ecological contributions. That is, the ecological contribution to milk would need to be distinguished from the ecological contribution to the cow producing the milk and from the ecological contribution to the cow's feed (to use a simple example).

A third approach, would be to recognize that the growth of livestock embodies a collection of environmental inputs (more than only the feed input), and that the process of combining these inputs reflected in the growth of livestock should be considered an ecosystem service. For example, the inputs of water and shading/protection services from trees could be seen as combining with feed inputs to produce a cow (and different mixes of these inputs will be provided in different production contexts (e.g. through the use of livestock sheds). In this "livestock" approach, the gross harvested biomass is equal to the liveweight of the livestock. It would be possible to consider describing a relative ecological contribution directly for each animal (irrespective of the subsequent uses or derivative outputs) or to record each of the relevant inputs.

Conceptually, it seems that provided a clear understanding of the connections among various inputs and outputs in the biomass growth process can be articulated, all of these methods can be aligned. They will however give different results since the conceptual scope in terms of the range of ecological contributions that are recognized is different. It is narrower in the case of the plant only approach and broadest in the all animal output approach. A choice is needed on the appropriate way forward which should likely take into account measurement challenges.

Measurement considerations

Using the proposed definition of biomass provisioning services – ***the ecological contribution to the gross biomass harvested by economic units including households*** – there are two key challenges in measurement. The first concerns measuring the ecological contribution and the second concerns measuring the gross biomass harvested.

Measuring the ecological contribution

For natural production processes, the ecological contribution will be 100% and hence for measurement purposes it is likely to be appropriate to distinguish between natural and cultivated production processes even if conceptually this distinction is not necessary. It is fundamental to note

that making this distinction does not imply a need to distinguish between natural and cultivated ecosystems. This is a common misconception. The focus must be on the extent of management of the growth of the biomass not the characteristics of the ecosystem in which that growth takes place. At the same, it is likely in practice that for some biomass, e.g. timber, the determination of the extent of management will be based on land use characteristics.

To distinguish between different degrees of human input into the growth of biomass and hence assess the relative ecological contribution there are likely two main approaches:

- Use a general metric (for example energy input) that can be applied to compare both ecosystem and human inputs in different contexts
- Distinguish different management practices that, a priori, would have different levels of ecological contribution and assume appropriate ecological shares for the quantity of gross biomass harvested for each management practice. Examples of different practices include organic/regenerative farming, small scale farming, large scale commercial farming and indoor farming (e.g. greenhouses).

In either case, it is likely that considerable assumptions and/or detailed data will be required to advance measurement. This type of work is considered relevant, at least to establish benchmarks and to track changes in ecological contributions over time that can be linked to changes in farm management techniques and in turn associated with changes in ecosystem condition.

However, in the first instance it is likely to be necessary to proxy the ecological contribution by assuming that it is fixed and hence the quantity of biomass provisioning service is directly dependent on movements in the gross harvested biomass. As a measure of change over time, this will be appropriate assuming there is limited change in the relationship between ecological and human contributions over time. It is noted that this was the assumption applied in the SEEA 2012 EEA (para 3.30).

A likely concern about the use of this approach, notwithstanding its common application, is that it will give far more weight to cultivated biomass and thus, in terms of relative quantities, the ecological contribution of cultivated biomass will be overstated relative to natural biomass. While this result cannot be avoided unless assumptions (e.g. all cultivated biomass has a 50% ecological contribution) or other benchmark information can be incorporated, compilers need to be aware of the potential of a perception of bias towards agriculture and forestry being evident in the accounts. With that in mind, efforts to develop methods that better target the desired concept should be a focus of development.

It is noted that in theory at least, in monetary terms this imbalance will not arise since the relative cost shares of human and ecosystem inputs should emerge directly from the data on revenue and costs.

Measuring gross biomass harvested

The general starting point for measuring gross biomass harvested will be the measure of agricultural production – e.g. tonnes of wheat – provided in agricultural statistics. In concept this is not the correct target of measurement and instead the aim should be to provide a measure of the quantity of biomass that is harvested from which the agricultural output is subsequently derived. In many instances this is likely to be a relatively fixed ratio. However, it may change in trend terms over time for example due to changes in technology or to the extent that additional/secondary agricultural and other outputs are identified that allow for the sale of previously unused gross biomass. The use of crop and other residues for biofuels is a case in point.

Also, from season to season there will be variation, usually due to weather events, in the relationship between gross biomass and harvested output. For example, an entire, mature crop may be flattened in a storm. There are two alternative treatments in this case:

- The growth of the biomass is recorded progressively as an ecosystem service as, effectively, work in progress, and then written-off in the final period.
- No ecosystem service is recorded as there is no associated harvested output.

The former treatment appears well aligned with the treatment of agricultural production in the national accounts and would reflect the reality that the crop is growing over time and that the ecosystem is making a contribution over time. However, there is no final ecosystem service provided in the sense of the ecosystem providing an input to economic production and consumption and it is this reality that is aligned with the national accounts in practice in the sense that zero output would be recorded.

This same issue has arisen in the choice of terms to describe the ecosystem service concerning the distinction between harvested and harvestable. The term harvested is sometimes not liked because it may seem to align too much to the measure of agricultural output. The term harvestable is sometimes not liked because it may seem to align too much to the concept of a stock available for harvest (but not actually harvested). Here the proposed term harvested is intended to ensure that there is a clear transaction between ecosystem and farmer but it is accepted that this transaction might also be seen as taking place progressively as the crop grows.

The notion of recording the transaction progressively for cultivated production processes would align well with the proposed treatment of cultivated production in the SNA which recommends allocating the output of agricultural production over the growing period. This is a time of recording adjustment rather than one based on the location of the production boundary and it is simply noted here that time of recording adjustments can be applied in the ecosystem accounts to align with the recording of outputs in the SNA.

Views are welcome on the appropriate advice to be provided in terms of the treatment of harvest losses and the associated issue of the timing of recording of biomass provisioning services. It is noted that this issue only arises in the context of cultivated production processes. In the case of natural production processes only the amount of gross biomass harvested is included and this is recorded at the time of harvest.

Other measurement issues and considerations

The measurement of gross harvested biomass should encompass a range of situations both cultivated and natural in which there are ecological contributions to biomass growth and harvest that provide a final ecosystem service outside of the standard agricultural, forestry and fisheries contexts. These situations include the harvest of biomass in the following contexts:

- In subsistence agriculture, including the harvest of non-timber forest products, where the biomass is often produced and consumed on own-account within a household or community.
- In backyard production, for example of vegetables, eggs and honey where the biomass is often produced and consumed on own-account within a household.
- In recreational contexts such as fishing and hunting. In this case there will often be additional cultural services to measure in addition to the biomass.

- In cultural contexts where farming, fishery and forestry practices are undertaken to recognize and celebrate traditional practices or beliefs. In this case there will certainly be additional cultural services to measure in addition to the biomass.

In all of these contexts the same considerations as noted above should be taken into account.

Finally, in undertaking measurement of gross biomass harvested there should be no assumption that the quantity harvested is sustainable. There may be interest in comparing the actual level of harvest with estimates of harvest that may be considered sustainable, e.g. with respect to maintaining ecological condition of the agricultural land, but it is important for accounting purposes that the actual flows be recorded. A measure of sustainability will be able to be generated by recording measures of the degradation of ecosystem assets associated with the harvest of biomass.

Questions:

Do you agree with the proposed conceptual basis for the description of biomass provisioning services as the ecological contribution to the gross biomass harvested by economic units including households?

Do you agree with the framing for the treatment of ecosystem services related to livestock production and do you have a preference for the appropriate measurement scope?

Do you have comments on the discussion of measurement approaches, especially the indication that, initially at least, proxy measures of harvested biomass will be needed to estimate flows of biomass provisioning services in cultivated production contexts?

2.2 Carbon related services

Background

Given the high focus on climate change as a global policy issue, appropriately reflecting ecosystem services related to stocks and flows of carbon is a key requirement in the revised SEEA EEA. Through the revision process there has been focused discussion on carbon related services through the January 2019 workshop (see Edens et al[7]) and the June 2019 Forum of Experts and Technical Expert Meeting (session 5c[8]).

The key conclusions from those discussions were that:

- Carbon sequestration by the biosphere should be included as an ecosystem service
- Carbon storage by the biosphere should not be included as an ecosystem service
- The indicator of the quantity of carbon sequestration for any given ecosystem asset should be the net ecosystem carbon balance (NECB) following IPCC guidelines
- The compilation of a carbon stock and flow account is a good practice to support measurement of services and as a stand alone set of information.
- Valuation of carbon sequestration should adopt prices based on observed markets for carbon.

[7] https://seea.un.org/sites/seea.un.org/files/discussion_paper_6_-_valuing_carbon_final.pdf
[8] https://seea.un.org/events/2019-forum-experts-seea-experimental-ecosystem-accounting

In reaching these conclusions a wider range of issues were considered. This section summarizes these issues and presents some recent thinking to provide a basis for further engagement and establishment of treatments for ecosystem accounting.

The scope of carbon related services

From a SEEA EEA perspective, the predominant rationale for the inclusion of carbon sequestration comes from a supply perspective in the sense that land managers can make distinct choices to manage ecosystems to increase or decrease the amount of carbon sequestered and indeed in many cases can be paid for carbon sequestration. This provides prima facie evidence of a transaction from an accounting perspective.

At the same time, there has been a longstanding lack of clarity on whether carbon storage should also be considered an ecosystem service. Arguments for the exclusion of carbon storage consider the challenge of measurement, the fact that carbon storage would normally be measured using stock variables (e.g. tonnes of carbon stored) and the general challenge of framing the nature of the service, particularly how to establish a baseline against which the loss of the stock of carbon can be compared. Against this, one might consider that carbon storage would seem to be inherent to the role of ecosystems in reducing concentrations of carbon dioxide in the atmosphere, i.e. sequestration alone is not sufficient to provide a benefit and that payments are made in some cases to land managers for retaining carbon stocks (e.g. via REDD+).

The issue of the role of carbon storage can be considered from a number of perspectives:

- There is a discussion point about the length of time that sequestered carbon should be expected to be retained in the ecosystem in order for that carbon to be considered included in the carbon sequestration service. Following the IPCC guidelines implies that carbon need only to be stored for 1 year whereas some discussion suggests that expected storage for 100 years is required before treatment of the flow as an ecosystem service. There will be considerable differences in the total quantity of the service recorded under these different time frames.
- Taking this second option of 100 years would have the clear implication that a transaction in carbon sequestration involved both the capture and the storage of carbon.
- Not all stores of carbon are the same and, in particular, some stores will be more at risk of releasing carbon than others. This would suggest, in economic terms, that not all carbon stored is of equal value and that a higher price might be paid to keep stored those stocks of carbon considered at greatest risk of release.
- It would be relevant to record in carbon stock and flow accounts differences in the quality of different carbon stores (reservoirs).
- Changes in the quality of a carbon stock might be related to measures of ecosystem condition and, further, there are likely to be connections between changes in the carbon stock and measures of ecosystem degradation.

For accounting, a key question for treatment is whether a transaction between units can be recognized. If this is the case, then the question of what metric can be used to quantify the amount and price of the service can be developed. If a stock metric is used to measure the amount transacted this does not change the existence of a transaction. By way of example, a useful metric for understanding the quantity of house insurance services is the total value of the housing stock.

Beyond the discussion of carbon storage services, it is also note that in the classification systems of CICES and NESCS, carbon sequestration is considered an ecosystem process rather than a service. In CICES the relevant service is labelled climate regulation to which carbon sequestration is clearly associated In the NESCS framing a significant concern is that the extent of carbon sequestration in a single accounting period will not likely confer a benefit to users in the same accounting period.

More recent discussion on these issues has identified another framing for ecosystem accounting purposes. This framing starts from the observation that the total/aggregate stock of carbon on Earth is fixed but is present in varying quantities across different reservoirs - atmosphere, terrestrial, marine, geological and economy. The current challenge is that concentrations of carbon in the atmosphere are too high and this is having "bad" effects on human wellbeing. To meet this challenge what is required is improved/more climate regulation and in this context the primary driver of climate regulation services is changes in the stocks and flows of carbon.

In terms of providing climate regulation services:

- Terrestrial and marine ecosystems have the potential, through ecosystem processes, to reduce atmospheric concentrations and hence provide benefits to people/society. Those ecosystem processes involve the sequestration and storage of carbon which collectively provide an ecosystem service labelled ***climate regulation***
- The atmosphere can receive carbon but not store carbon over the long term without having an adverse effect on the global climate and hence cannot provide climate regulation services
- Geological reservoirs of carbon cannot sequester carbon on a sufficiently short time frame to provide benefits in reducing current atmospheric carbon concentrations and hence cannot provide climate regulation services
- The economy can sequester and store carbon through economic activities/technology including the use of timber but this is not an ecosystem service

The focus for ecosystem accounting is therefore the climate regulation services provided by terrestrial and marine ecosystems. To quantify these ecosystem service flows, the key from an accounting perspective is to estimate a total flow of services over an accounting period. The proposal here is that climate regulation services supplied by a single ecosystem asset (e.g. a forest) will be "embodied" in the total stock of carbon that it holds. Thus:

- Higher levels of carbon stock will embody/imply higher levels of climate regulation service
- Increases in stock (through sequestration) will imply an increase in services supplied
- Decreases in stock through the release of carbon will imply decreases in services supplied.

This approach is somewhat analogous to the services provided by a warehousing or storage company whose level of service will, in large part, depend on the quantity of goods being stored.

One challenge in this framing is that while the contributions of carbon sequestration and carbon release to the net change in stock can be estimated, it doesn't link directly to the framing of carbon sequestration and carbon storage being two separate services to be measured. That is, the climate regulation services as framed above does not easily translate to being the sum of sequestration and storage services. To the extent that these two services are seen as important to identify separately, for example because they have a different price associated with them, then other solutions will need to be considered.

Within this general framing, a few key points should be noted:

- The cause of the changes in stock is irrelevant – i.e. both human and naturally driven changes in carbon stock will affect the level of services being provided by the ecosystem. (By way of example – the recent bushfires in Australia releasing carbon imply a significant reduction in the climate regulation services supplied by the affected ecosystems. Their gradual recovery in the next 10-20 years will see gradual increases in the supply of services, ceteris paribus.
- It should be possible, and may be considered necessary, to partition the change in climate regulation services for any ecosystem asset (or group of assets) between those changes due to sequestration and those due to release; noting that the change in the climate regulation service will be the net change and in most instances not solely attributable to either sequestration or release.
- The level of the stock provides a quantity measure of the service and implies that a country with larger carbon stocks will supply more services. Further, since the stock level cannot be negative, there is no possibility of a negative level of service being recorded – even if there is an ongoing reduction in the level of service due to loss of ecosystem extent and condition. This result is an important one for applying accounting principles.
- Further consideration is needed of the treatment of harvested wood products (HWP). By looking solely at the change in stocks for an ecosystem – i.e. measuring the net ecosystem carbon balance (NECB) – it implies a reduction in ecosystem services when timber is harvested even though at least some of that carbon is not emitted because of its storage in wood products. An alternative would be to measure Net Ecosystem Productivity (NEP) but this would seem to overstate the climate regulation service since some of the harvest wood will lead to carbon emissions. Depending on the treatment the description of the framing above will need to consider whether to refer to releases or removals of carbon from the ecosystem.
- A common consideration in discussion of carbon storage has been around the issues of risk and likelihood of release of carbon. For example, it may be relevant to incorporate information concerning whether some terrestrial/marine stocks of carbon might be considered more important or more at risk than others. This might be effectively managed in considering different profiles of carbon stock change for different parts of the carbon stock (e.g. forests versus peatlands).
- Determination is needed on the allocation to users and beneficiaries. Allocation to general government is the most clear option and following the logic above would imply a larger benefit to larger countries in terms of physical size of the carbon stock. But options that consider exposure to climate change risk or population size may be considered and the discussion should also extend to considering the time frames over which the benefits are received (e.g. with respect to benefits accruing to future generations).

Valuation

A key challenge in considering ecosystem services of carbon storage or climate regulation concerns approaches to valuation. For SEEA EEA it has been generally accepted that carbon sequestration could be valued using observed market values accepting that these would not be perfect. However, for a framing that focuses on stocks of carbon as proposed above the valuation solutions are less clear. The following points are noted on this topic, recognizing the need for discussion with the working group on valuation.

- The value will **not** be equal to the volume of the stock multiplied by a unit price. As for mineral deposits this provide a value of the asset not the service flow.
- The question of how to estimate the unit price of the stock of carbon is relevant. Options include prices from carbon markets, from REDD+ schemes, using abatement costs and targets (UK approach) and using avoided damage based estimates. Further discussion is needed on what may be most appropriate for accounting purposes.
- Since the value of the service will not equal the stock multiplied by a price, one way forward may be to consider using standard capital accounting techniques to estimate a return to the total stock of carbon that recognizes the benefits of this stock remaining in situ. Such an approach might also incorporate thinking around future profiles for the stock (in a manner analogous to assuming depreciation profiles for produced capital). For example, estimates could be made based on assumptions that the stock "disappears" overnight, assume only above carbon stocks are released directly, assume a linear release over time, etc. Consideration will be needed here on the connection to existing carbon market prices.

- If this approach to valuation is considered inappropriate or too difficult to estimate another approach might be to focus instead on the change in the stock – which as noted above is equivalent to a measure of the change in the level of the service
    - Where the net change is positive then this presents no specific challenges for accounting – i.e. a transaction between the ecosystem and society can be recorded equal to the positive change. (Equivalent to the use of the NECB measure but noting still the need to consider the appropriate treatment of harvested wood products)
    - Where the net change is negative a proposal is to, **by convention**, record a negative output flow from the ecosystem to society. That is, negative supply is shown for the ecosystem and negative use is shown for society (government).
    - The potential to record negative output by convention reflects two unique aspects:
        - That the increases and decreases relate to the same ecosystem service of climate regulation which in turn is unique since one tonne of sequestered or released carbon anywhere in the world has the same effect on the climate regulation service.
        - That the value at the margin of the change in stock of carbon will be the same for increases and decreases in the stock. Consequently, the same price can be applied. (Although whether this is appropriate will require investigation, and indeed if the prices are different for increases and decreases this may not be an issue in any event)
    - This treatment/approach is deficient relative to the ideal approach above since the relative levels of the service are, largely, invariant to the stock levels, thus implying that no weight is given to ecosystems that retain important stores of carbon.

Other notes

The discussion highlights the key issues to be addressed in providing a basis for moving forward to finalise the appropriate treatment of carbon related services. For reference the following aspects are noted for future consideration:

- Considering the wider accounting implications, e.g. with respect to asset valuation, in using the stock based framing of climate regulation services
- Considering the appropriate accounting for the full GHG emissions story – i.e. beyond loss of carbon from ecosystems by human activity and capturing the effects of all greenhouse gases not only carbon dioxide. Options that might be discussed include – (i) recognition of a sink service by the atmosphere, (ii) record degradation of the atmosphere; (iii) work through a treatment related to payment of taxes in an SNA context; (iv) record unpaid ecological costs (following Vanoli) reflecting the build up of carbon in the atmosphere and (v) some externalities based framing and adjustment to polluters accounts (potentially following Muller (2011)).
- Alignment to the IPCC guidelines e.g. concerning the distinction in coverage between natural and managed processes, the coverage of areas within a country, the coverage of marine ecosystems including those outside national jurisdiction and the time of recording[9]
- The alignment to the recording of stocks and flows in a SEEA carbon account. In general terms it is accepted that alignment should exist but clarification on the various boundaries, including those just noted and, for example, the treatment of carbon in soils, carbon in peat stocks, etc would be appropriate.

Questions:

Based on the various framings described in this section, do you have comments or preferences for the recording of carbon related services in the revised SEEA EEA?

In particular, do you have views on whether it is important for the storage of carbon by ecosystems be recognized as an ecosystem service?

What are the key considerations in determining an appropriate treatment?

2.3 Connections between water related services

Background

Through the revision process there has been a discussion on the treatment of water related services through the January 2019 workshop (see Portela et al[10]) and at the June 2019 Technical Expert Meeting[11]. Based on the discussion papers and notes, more recent discussion in early 2020 revealed a range of additional considerations beyond the notes that had been drafted and identified two primary options for the appropriate accounting treatment. This section describes these two options and discusses a range of implications and issues.

Framing the issues for water related services

To tackle the question of recording linkages between different ecosystem services the starting assumption is that each of the services is well defined in the sense of being separable and mutually

[9] This point from Hein (2019)

[10] https://seea.un.org/sites/seea.un.org/files/discussion_paper_8_-_water_supply_service_final.pdf

[11] https://seea.un.org/sites/seea.un.org/files/water_related_chart.pdf

exclusively measured. In using water related services as the example, the following ecosystem services are primary (as identified in the figure from Portela et al which is shown below in the presentation of feedback on the discussion papers):

- Water supply
- Water regulation pertaining to maintenance of base flows
- Water purification pertaining to nutrient removal[12]
- Water purification pertaining to sediment retention[13]

As noted above, it is assumed for the purposes of this discussion that water supply is an ecosystem service. Once the relationships between the ecosystem services are mapped out using an input-output approach, it is straightforward to adopt an alternative treatment of water supply as an abiotic flow – the connections among the flows will remain the same.

Note that water regulation services related to mitigation of extreme events which was unfortunately integrated into the material in the discussion paper has been excluded here. It is agreed that these are important services but it is considered that these can be considered separately.

As in Portela et al, to aid discussion it is relevant to distinguish different use contexts. The proposed contexts for discussion here are irrigated agriculture, hydropower, water for domestic consumption, industrial use, commercial fishing, recreation, navigation and nutrient treatment (storage). This covers both consumptive and non-consumptive uses (note that in the SEEA use of water for hydropower is considered a consumptive use).

It is also necessary to clarify the ecosystem context. The starting point considered in Portela et al was situations involving the use (consumptive or non-consumptive) of freshwater bodies and aquifers within the context of the wider landscape. Feedback suggests that it would be useful to distinguish clearly between surface water and groundwater sources. The following discussion thus focuses more directly on surface water bodies recognizing the need to consider groundwater in the future. Also, in all instances, while the use context revolves around a water body, the relevant ecosystem processes will commonly involve other ecosystem assets within a catchment such as the role of forests in base flow regulation and sediment retention.

Given these components – i.e. services (or more generally flows since some may be considered abiotic flows), use contexts and ecosystem context – the following proposals are presented in Table 2 for documenting the relevant flows for various use contexts. It is expected that all of these use and activity contexts are relatively easily imagined and described, recognizing also that many variations and extensions could be described.

[12] It is noted that, in principle, the discussion could be extended to incorporate the filtration of other pollutants by surface water bodies, and more broadly, the retention of pollutants by surrounding ecosystems such as forests and agricultural land could be included in a more complete accounting. For articulation of the key recording principles these extension were not required.

[13] It is noted that this service will not be provided by rivers and water bodies but its supply by surrounding ecosystems such as forests and agricultural land does link to the supply of service and benefits related to the use of water (e.g. water supply, hydropower generation), hence it is considered here as a water-related service.

Table 2: Use contexts for water related flows for surface water bodies

Use / activity context	**Key ecosystem services and related flows & benefits**					
	Water regulation (base flows)	Water purification (nutrient removal)	Water purification (sediment retention)	Water supply	Biomass provision	Other benefits/ flows
Irrigation for agriculture	X		X	X	X	
Industrial use of water	X			X		
Domestic consumption of water	X	X		X		
Hydropower	X		X			Electricity
Release of nitrogen (N) (e.g. from agriculture)		X				
Commercial fishing	X	X	X		X	
Recreation / non-commercial fishing	X	X	X		X	Recreation
Recreation / swimming	X	X				Recreation
Navigation	X					Transport

Note that the focus in the discussion in this section is on the first four ecosystem services and flows shown in the table – i.e. from water regulation of base flows to water supply. Other flows concerning biomass provision, recreation, etc have been included to provide a more complete description of the use context. In practice, some of these flows may be recorded in ecosystem services supply and use tables, some may be recorded in other complementary accounts and some may appear in both. For example, flows relating to water supply and electricity generation will be recorded in the physical flow accounts of the SEEA Central Framework and fish catch will be recorded in the asset account for fish stock in the SEEA Central Framework. Separate advice will be provided on how these connections among the accounts can be made.

Recording in supply and use accounts

For any given context – i.e. a single row – a series of entries in a supply and use table can be recorded. For example, Table 3 shows entries for the context of the domestic consumption of water. Matching supply-use pairs reflecting transactions in ecosystem services are shown using letters A-D with associated units of measurement for each transaction. It should be clear that separate tables could be developed for each use context and then aggregated to provide totals for each ecosystem service.

Table 3: Supply-use pairs for domestic consumption of water

SUPPLY	Forest	River	Water supply company
Base flow regulation	A (rate of flow)		
Nutrient removal		B (tonnes N)	
Sediment retention	C (tonnes sediment)		
Water supply		D (m3 water)	
USE			
Base flow regulation		A (rate of flow)	
Nutrient removal		B (tonnes N)	
Sediment retention		C (tonnes sediment)	
Water supply			D (m3 water)

For the purposes of recording the transactions in the supply and use account it is not necessary to articulate the precise relationship between each flow. It is assumed for accounting purposes that estimates of each flow, for a given catchment/context, will be measured in an internally coherent manner. Thus the relationships between the flows are not the key focus of accounting. This is satisfactory since there is no ambition to predict future flows but rather to focus on what has happened. Certainly, in order to estimate the flows with a level of coherence an understanding of the relationships is needed but these are not required to be recorded in the supply and use tables themselves. Put differently, the starting point for accounting is to record observed flows of each service.

This point may be particularly relevant in understanding the entries for water supply. That is, in the framing provided here the other three services are commonly described as inputs to the final flow of water supply. However, for accounting purposes it is sufficient to record each flow rather than needing to determine underlying linkages. In turn this means that there is no expectation that the sum of the three services A, B and C will equal D.

To use a manufacturing analogy, a car manufacturer will purchase inputs of rubber, steel and glass to make cars but what is recorded in the supply and use account are the observed transactions in each product (some with suppliers and some with final purchasers). From this information it would be possible to determine a production function that shows the relationships between inputs and outputs but this function is not needed apriori to compile the supply and use account.

Discussion of supply and use account entries

Given this starting point for discussing the recording of water related ecosystem services the following points emerge:

1. On the supply side, it appears relatively straightforward to assign the contribution of relevant ecosystem assets to each service in each use context. In the following discussion it is assumed that this is a measurement rather than a conceptual issue.

2. On the use entries there are, in fact, some important choices that can be made concerning who is recorded as the user of the service. In Table 3 (above), the assumption is that the first three ecosystem services (A, B and C) are inputs to water supply following an ecological production function type of logic. The result of this assumption is that the user of these three services is shown as the river and the aggregate contribution of the ecosystem to the economy is embodied in one flow – in this case water supply supplied by the river. A similar result would apply in the case of recreation related services where the services of base flow regulation and nutrient removal can be seen as inputs to the relevant cultural ecosystem service. In these cases, a relevant accounting treatment would be to recognize a distinction between intermediate and final services, where services are recorded as intermediate when the user is an ecosystem asset.

3. A note is required concerning abiotic flows. If a decision is taken that water supply should be treated as an abiotic flow rather than a final ecosystem service (for a discussion see section 2.5 below), the general understanding is that the final ecosystem services that would be recorded for any relevant use case would be the services that are "next back" in the production chain. For domestic water consumption, this would mean that the three services of base flow regulation, nutrient removal and sediment retention would be treated as final ecosystem services and would be recorded as used directly by the water supply company rather than by the river. This is certainly possible in accounting terms (see Table 4, below) and note that it would still be possible to record the abiotic flow (although care would be needed in allocation of values to each of the input flows to the water supply company).

Table 4: Supply-use pairs for domestic consumption of water (water supply as abiotic flow)

SUPPLY	Forest	River	Water supply company
Base flow regulation	A (rate of flow)		
Nutrient removal		B (tonnes N)	
Sediment retention	C (tonnes sediment)		
Water supply (abiotic flow)		*D (m3 water)*	
USE			
Base flow regulation			A (rate of flow)
Nutrient removal			B (tonnes N)
Sediment retention			C (tonnes sediment)
Water supply (abiotic flow)			*D (m3 water)*

The same issue also arises in the use contexts of hydropower and navigation where the treatment of these flows as abiotic would imply that the related ecosystem services of base flow regulation and sediment retention are treated as final ecosystem services.

While this recording is plausible, it does have the effect of not showing linkages between ecosystem assets – i.e. in the domestic water consumption case, the connection between

forests and rivers with respect to base flow regulation is not shown explicitly. Depending on the analytical interest this may not be of concern, although issues may arise in terms of recording the timing of flows/contributions in some cases. It is noted that the relative contribution of each ecosystem asset is still reflected in the accounts. An alternative may be to develop conventions in which an abiotic flow can be considered as representing the final flow to people, in which case the entries would remain as in Table 3.

4. Although motivated by a focus on abiotic flows, it is worth considering whether all ecosystem services should be recorded as final – i.e. directly used by economic units as shown in Table 4. One logic of this treatment is that, at least implicitly, economic units are effectively purchasing a suite of ecosystem services even if they are all embodied in one final flow/interaction. In aggregate terms, this will not change the total contribution of ecosystems to benefits in any given use case, but it will affect the description of the connections (as just noted above).

   One reason for considering an "all as final" recording approach, is that from table 2 (showing different use contexts), it is clear that the same service is commonly an input to multiple use cases which will further commonly take place in a single water body. For example, it is relatively easy to imagine that one river in a single catchment will provide nutrient removal services in a range of use cases including, for example, domestic water consumption, fishing, and recreation.

   Using an "all as final" approach would imply considering the ecosystem contribution in each use case and then aggregating over the different use cases for each service – in effect, each use case generates a number of distinct transactions (purchases) between the relevant economic units and the ecosystem.

5. One potential concern about this approach is that there may be an impression of double counting. For example, all else being equal, when a rivers purifies water through nutrient removal (e.g. 10 tonnes of N), it may be considered appropriate that this single process should be recorded only once rather than being considered as an input to multiple benefits (e.g. through lower filtration costs to the water supply company and increased opportunities for recreation). However, following this argument would then require making a choice between use contexts such that only one supply-use pair (i.e. a single transaction) is recorded. It is unclear on what basis such a choice or accounting conventions might be established.

   To counter this concern, it is clear that the structure of the use table allows allocation of each service flow to multiple users and hence double counting can be avoided. At the same time, it is clear that co-ordination in measurement across services will be required such that there is no double-counting of use, perhaps implicitly, when recording flows of individual ecosystem services. An example here is the need for co-ordination of measurement of base flow regulation and water supply[14].

   Another way of responding to this concern is to consider there is a role of a river "natural capital" manager who looks after the process of removing nutrients and who can "sell" the benefits of that process to multiple parties. The fact that different parties use the same process in a different way is not the managers concern and indeed it may be quite reasonable for different prices to be charged to different users. Each sale then reflects a transaction in ecosystem services. In the ecosystem services literature this has been referred to as "benefit stacking".

[14] https://www.sciencedirect.com/science/article/pii/S0048969719311374#f0025

It is important to recognize that in establishing multiple transactions for a single service it does not imply that the actual volume of nutrients removed in biophysical terms should vary. Thus, if for example, 10 tonnes of N are removed and there are 4 users – it doesn't imply that each user is getting a volume equal to 10t or that the total of 10t needs to be allocated among the 4 users. Rather, the volume of the service received by user should reflect the extent to which nutrient removal contributes to the specific benefit that each user receives. A related case arises for the service of water regulation for extreme events leading to flood protection benefits. In this case, the assessment of the extent of regulation/mitigation is a jointly enjoyed benefit of people and businesses in the flood zone[15].

In more general terms, it is clear that a number of regulating services should be considered as non-rival services, i.e. where the benefits are received collectively. From a supply and use account perspective, as long as there is the potential for allocations across different users a suitable recording can be found. Nonetheless, further consideration of the appropriate accounting entries and options must be considered, including to consider approaches used in the national accounts for these types of services, e.g. policing services.

6. A very specific case of multiple use arises in the case of nutrient removal when a water body acts as a sink for excess nitrogen (released for example by farmers or water treatment plants). The nutrient removal process may be considered as having direct benefits to the polluters (at least in the case where regulation is involved)[16]. To demonstrate the potential entries in this case, the supply and use account shown in Table 4 (above) can be extended to include the use case of Release of nitrogen. As shown in Table 5 (below) the set of services/flows remains the same but an additional final user (polluting sectors) is included as a new column which also benefits from the nutrient removal service from the river. It is noted that this same extension can be applied to either Table 4 (as shown) or to Table 3.

Table 5: Supply-use pairs for domestic consumption of water and release of N (water supply as abiotic flow)

SUPPLY	Forest	River	Water supply company	Polluting sectors
Base flow regulation	A (rate of flow)			
Nutrient removal		B (tonnes N)		
Sediment retention	C (tonnes sediment)			
Water supply (abiotic flow)		*D (m3 water)*		
USE				
Base flow regulation			A (rate of flow)	
Nutrient removal			B^1 (tonnes N)	B^2 (tonnes N)
Sediment retention			C (tonnes sediment)	
Water supply (abiotic flow)			*D (m3 water)*	

[15] https://www.sciencedirect.com/science/article/pii/S2212041619302815

[16] https://oneecosystem.pensoft.net/article/20834/ and https://www.sciencedirect.com/science/article/pii/S0301479718307242.

Recording options

Based on these various considerations, the following options can be described for recording the use of ecosystem services

i. Following an ecological production function for each use context in which appropriate ecosystem services are shown as inputs into a final ecosystem service. This will facilitate recording connections/dependencies between ecosystem assets and also more readily ensure that there is no double counting in terms of the overall ecological contribution to benefits since flows along the production function will net out.

ii. Follow an approach of treating all ecosystem services for each use context as final – i.e. having a direct link to relevant economic units. This will limit the potential to directly record connections between ecosystem assets (although the relative contributions of individual ecosystem assets to the total will remain evident) but it will limit the potential for missing connections between the environment and the economy by recognizing all end users in all use contexts.

iii. Use option (i) or option (ii) depending on the use context.

Questions:

Do you agree with the general framing that there can be a sequencing or description of the relationships of water related flows using input-output/supply-use principles?

Do you have a preference for the recording options proposed, i.e. showing connections among ecosystem assets; showing all ecosystem services as final; or using a combination of these approaches depending on the use context?

Are there alternative choices or other issues that should be considered from an accounting perspective?

2.4 Cultural services

Background

There is no disagreement that there are important connections between people and ecosystems that are not provisioning or regulating in nature. The term cultural ecosystem services is used to encompass many of these connections. A key challenge however is that within the context of the definition of ecosystem services being “contributions” to benefits, a description of the ecosystem contribution for these services is difficult to describe.

Two aspects of the discussion seem clear. First, that there is a wide array of benefits. Second, that flows of cultural ecosystem services, representing the contribution of the ecosystem to those benefits, are based on the characteristics and qualities of ecosystems. Thus, recognizing the richness and functionality of space is fundamental.

However, there remains a requirement for a substantial increase in clarity on the description of cultural services in an ecosystem accounting context. This section aims to synthesise the issues which

emerged based on earlier consideration of recreation related services (see Barton et al, 2019[17]) and more recent discussion.

A key challenge in providing this synthesis is that while there seems much common thinking in broad terms, the description and treatment of cultural services is being approached and conceptualized from many entry points. In the synthesis here the material is organized following a number of key issues. It is intended that the feedback on these issues will provide a strong basis for developing more specific guidance in the next phase of the SEEA EEA revision process.

Describing cultural benefits

Focusing on the benefits, the proposed opening framing is that the benefits should encompass:

- Benefits from undertaking activity (including recreation) within ecosystems (i.e. in situ)
- Benefits from remote experience of ecosystems (including via various media – e.g. TV, music, photos, etc)
- Benefits from having a cultural, spiritual or similar relational connection to an ecosystem or the biodiversity it contains

The inclusion of the first set of benefits is uncontroversial.

For the second set of benefits there is some doubt as to whether any ecological contribution should be recorded with respect to these benefits; in part because it is unclear whether there is an actual interaction with the ecosystem in these cases. Further it may be that this contribution would in practice be very small although some exceptions may be found[18].

Separately, there may also be an existence value to certain images, etc if the species/ecosystem no longer existed. At an extreme for example, people would likely place a value on fossils and dinosaur skeletons.

If considered within scope, there may be the option of determining the ecosystem contribution using a parallel to the accounting treatment for intangible assets concerning entertainment and artistic originals. It this case one might consider that there is an interaction when 'ecosystem design' is incorporated e.g. in a documentary, but no interaction of the ecosystem when the documentary is copied/scaled. This is similar to other intellectual property rights. There is no interaction between the artist and the consumer of replicated art, but the artist retains an intellectual property right. If an ecosystem was given legal identity (as corporations have) then intellectual property rights and associated services might be ascribed to them.

For the third set of benefits, the description above seems to align well with the group of ecosystem services in CICES that covers "Spiritual, symbolic and other interactions with natural environment" with the addition of, for example relational and historic interactions. The general notion might be that the services relate to the "the things in nature that we think should be conserved". In this framing, it might be possible for this set of benefits to cover all of the remote benefits. At the same time, another interpretation of this set of benefits is that they have no obvious exchange value and hence may be out of scope of the accounts, at least in monetary terms.

[17] https://seea.un.org/sites/seea.un.org/files/discussion_paper_10_-_recreation_services_final_0.pdf

[18] The Ugandan Wildlife Authority, for example, extract some rent for the ecosystem contribution to nature films. See top of page 10. https://www.ugandawildlife.org/images/pdfs/UWA-Tariff-2018-2019.pdf

Further framing to clarify the scope of benefits and hence ecosystem services to be a focus of ecosystem accounting is required, particularly as it concerns the valuation boundary. In this regard, further engagement with the work of IPBES and the literature on shared values will be relevant[19].

Discussion reveals that different benefits can be motivated by a range of different values. Motivations can include:

- Conservation / protection of threatened species – existence values
- Maintaining ecosystems for use in the future – option values
- Maintaining ecosystems to reduce risk and uncertainty in the future – insurance values
- Preserving ecosystems for future generations/stewardship – bequest values
- Enjoying ecosystems with others – relational values

Aligning these various motivations with specific ecosystem services and benefits is a challenging task. In some cases, this might be straightforward for example relational values from a family picnic will be linked to in situ recreation benefits and bequest values might be linked to ensuring future quality of water. However, in some cases the connection to a service or benefit will be less clear. This is especially the case for option and insurance values for which the motivation is likely more systemic in nature and there is likely a close link to the value placed on the resilience of ecosystems. The question is whether, if a link to a specific future service cannot be made, a new and separate service can or should be articulated. The potential for such a service has been identified in the literature[20] and was discussed in King et al (2019) in their paper for the workshop on ecosystem services[21]. The topic will need further discussion in the context of ecosystem accounting.

Within this general framing, it is evident that more clarity is needed on the intended focus of the term benefits. Some earlier SEEA EEA discussion had indicated this term might be used to consider both outputs and outcomes that arise from contributions of ecosystem services. However, particularly with regard to cultural services and the common, relatively direct link to health benefits, there is a need to apply a clear and consistent focus.

With this in mind it is noted that, from a national accounting perspective, the general starting point is that health benefits (e.g. improved life expectancy) would be regarded as outcomes rather than outputs of a production process (e.g. visiting the doctor, purchasing medicine, etc).

Thus, while requiring confirmation, it is proposed that the revised SEEA EEA would also limit its scope to outputs arising from cultural ecosystem services. However, given the nature of the flows related to cultural services in which there is commonly a direct experience of nature, it can be challenging to distinguish outputs from outcomes.

[19] See for example Pascual et al 2017 and Kenter et al 2015

[20] See for example Baumgartner and Strunz (2014) and Dallimer et al (2020)

[21] https://seea.un.org/sites/seea.un.org/files/discussion_paper_11_-_biodiversity_habitat_final.pdf

Describing cultural services

The aim in describing the services is to connect the ecosystem characteristics on the one hand and the benefits and values on the other. From discussion, the wording that has emerged (building on the framing from Barton et al (2019) with respect to recreation) is that cultural ecosystem services are ***"the perceived or realized qualities of ecosystems that deliver cultural benefits"***.

This wording has the following features:

- It can be linked to the idea that cultural ecosystem services are evident in the opportunities that ecosystem provide for people (including future generations)
- It can be linked to the idea that the flows from ecosystems to people may be considered "informational" or "experiential".
- It allows for one ecosystem (and its characteristics/qualities) to contribute to a number of cultural benefits and to be driven by varying motivations/values
- It fits with the logic that cultural benefits result from a process of joint production involving ecosystem assets (natural capital), produced capital (e.g. access roads, on-site facilities, walking trails, residential location) and human capital (i.e. people's time, experience & knowledge, capabilities (physical and perceptional)).
    - Note that the concept of ecosystem asset applied here refers to the area/space encompassed by an ecosystem (or set of ecosystems) such that the presence of produced capital is seen as integral to the asset base in a joint production model.
    - The joint production approach should be aligned to the description/treatment of joint production in relation to provisioning services and with specific consideration of the treatment of subsistence production by households.

At this stage, the broad descriptions of cultural benefits and cultural services have not developed to the point of proposing a list or definition of specific cultural services. It is intended that on the basis of feedback on the framing provided here that a set of cultural services will be defined and included in the reference list of ecosystem services presented in section 1 of this paper.

Measurement of cultural ecosystem services

To support consideration of the issues presented above the following points have emerged concerning the measurement of cultural ecosystem services.

- Within the conceptual framing of cultural services described above, it is evident that, in practice, the common focus of measurement is on the extent of engagement with a given ecosystem. For in-situ benefits the common focus is on the number of visits (or potentially time visited), for remote benefits the number of views or similar might be used. More ideally, a measure of intensity of engagement, for example, in terms of time visited, would be used to get closer to the desired concept.
- However, travel cost/distance, number of visits and time visited are proxy measures of "the perceived or realized qualities of ecosystems that deliver cultural benefits", since the latter cannot be observed directly because they are jointly produced by the perception of the users.
- Further, there is a clear potential for simple indicators such as number of visits to misrepresent the more complex relationship that will exist between the benefits received and the characteristics of the ecosystem, including its associated facilities. Thus, ideally there would

also be direct assessment of the specific qualities of ecosystems (of forests, of lakes, etc) that generate cultural benefits.

- Social media and personal experience tracking applications will in future bring measurement closer to the target concept "perceived or realized qualities. GPS trackers in mobile phones and exercise applications are making it increasingly possible to measure time on site, and assess the spatial variation in use as a function of ecosystem site qualities. While closer to the target concept, these measurement approaches still face challenges of representation, but selection biases are being reduced by research.
- Much further consideration is needed of approaches to measuring benefits obtained remotely, although social media may play a role in this context as well, noting the potential to use this information to develop indicators of social preferences.
- In terms of valuation in monetary terms, it will be relevant to work backwards from valuation of the benefits to estimate the contribution of the ecosystem. This will, ideally, require removing the cost structures involved in supplying the benefits in a joint production context (i.e. following a production function / resource rent type of approach) although common measurement issues of low/zero rents may arise.
- Valuation of intensity/extent of engagement and time on site may be physically measurable, but need further work in terms of the exchange value per unit of information or time.
- Further work is needed to advise on valuation techniques related to donations and bequests, including identifying what set of services would be encompassed by a donation or bequest. That is, donations might be provided to support protection of the environment but with the aim of securing not only cultural services but also future provisioning and regulating services. In developing this line of work a link will also be necessary to the discussion of option and insurance values.
- Also, further work is needed to advise on valuation techniques for remotely derived cultural benefits. On possibility in this regard is to consider connection to maintenance costs for biodiversity since these expenditures, often by government, point towards the values that society generally would be willing to pay to secure the benefits.

Accounting for businesses involved in the joint production of benefits

In discussion of the joint production model described above in the context of in situ benefits, it becomes evident that there are two types of businesses involved:

- those involved in supplying access to the ecosystem and facilitating activities/experiences within the ecosystem (e.g. covering entry fees, guides, tour operators, equipment hire, etc.)
- and those involved in supporting visitation to an ecosystem (e.g. hotels, restaurants, fuel suppliers)

It seems likely that where payments are made to the first category of business a reasonable share of the payment could reflect an ecosystem service contribution. In the payments to the second, the ecosystem service contribution is likely to be much more marginal, i.e. it would exist in relation to other similar operations rather than in absolute terms.

In this framing the consumer surplus derived from travel costs (across visitors) would not be a measure of the value of the ecosystem services but payments to both types of business might provide an indicator of demand for the services.

Local recreation not involving travel outlays, where private residences are close to ecosystems (in cities or in buffer zones around protected areas), may identify cultural services through hedonic property pricing. Further work is needed on the opportunities to more directly value local recreation amenities through the private rental of residences (e.g. AirBnB), and possible issues of double counting with existing accounting practices of computing residential rental value. The use of domestic residence to 'produce' local recreation could be aligned with the joint production approach considered for incorporated businesses.

In terms of an overall measure of the ecosystem service flow it seems appropriate to consider adding these two separate contributions from different types of businesses also recognizing that there will likely be a further value to the visitor beyond payments to businesses.

For accounting purposes, it seems appropriate to record flows of ecosystem services as being used as inputs to businesses and to record separately a flow to households for the additional value. In effect the total ecosystem service will be routed through businesses to the extent necessary. In the case of local recreation the ecosystem service is 'routed through residences' (co-produced using a resident's time and residential capital) - where residences are rented for recreation purposes this is conceptually identical to the 'business routing'.

Habitat related services

One entry point to the discussion on cultural ecosystem services was the potential for the maintenance of habitat for the conservation of valued species to be considered an ecosystem service and early discussion placed this under the general heading of "habitat services".

Further discussion has reached the positions that the term habitat services should not be used. It is clear that habitat is important and underpins a range of ecosystem services but these services should not be viewed collectively. This includes, for example, nursery services (e.g. for fish breeding) and maintaining genetic material. The CICES framing identifies three specific services – pollination, maintaining nursery populations and seed dispersal.

Of particular relevance in considering the role of habitat is the topic discussed earlier concerning option and insurance values. One way of framing option values is in terms of knowledge in which there is a gap between ecological knowledge (i.e. the knowledge embedded and embodied in biodiversity, including allowing for functional redundancy) and human knowledge which cannot have complete understanding of ecological knowledge.

This gap in knowledge might then be recognized as being something that is of value to people, in the sense of valuing that the ecosystem is in good condition such that in the future ecological knowledge can be captured. Consequently, a cultural service could be connected to this value. Site knowledge increases "the perceived qualities of a site". Option value therefore also aligns with the information flow interpretation of cultural services.

Another framing of this, is to consider a general notion of human appreciation of biodiversity / living systems, wherein knowing that living systems will exist generates a cultural benefit. In this context, activities such as conservation, maintenance and protection are response to this desiring this benefit and it is the ecosystem service underpinning this benefit that needs to be the focus rather than the activity of conservation per se.

Next steps

There remain a range of issues to be addressed in this area beyond the initial framing presented here. One important part of taking this work forward will be comparison of terms and treatments across CICES, NESCS and IPBES. Other outstanding issues in the description of cultural services concerned detailing the link to the measurement of ecosystem condition (Working group #2) and clarifying the links to the recording of economic units in Working Group #5.

Questions:

> Do you have comments on the general framing of cultural benefits and cultural ecosystem services as presented in this section? Are there any perspectives missing? Do you have preferences for the appropriate measurement boundary for the revised SEEA EEA?

2.5 The boundary with respect to abiotic flows

In the discussion of ecosystem services, there is common recognition that the environment provides inputs to economic and human activity in many ways. Many, but not all, of these inputs reflect the contribution of ecosystems as a reflection of biotic processes. Some however, such as inputs of mineral resources and fossil fuels, do not reflect (current) biotic processes. Given this distinction a relatively simple framing can be provided which recognizes a broad set of environmental flows which may be sub-divided into (i) ecosystem services – reflecting biotic process related flows; and (ii) abiotic flows. The general focus of ecosystem accounting is on ecosystem services.

As with all systems, such simple framings are useful but do not cater for a range of environmental flows that sit on the border between biotic and abiotic. The following groupings of "borderline" environmental flows have been identified.

i. Water supply, relating to the abstraction of water
ii. Flows related to the generation of energy
iii. Flows related to the use of ecosystems for undertaking economic and other activities
iv. Flows related to abiotic components of ecosystems in the supply of regulating services
v. Flows related to residuals from economic activity
vi. Flows related to the use of the atmosphere

As a general observation, any final determination on conceptual grounds on the treatment of flows as either ecosystem services or abiotic flows, need not imply that accounting cannot incorporate all flows in some way. It is likely in many instances to be of significant policy relevance to understand the full range of environmental flows supplied from a given area or region and a focus only on ecosystem services is likely to be limiting for decision making in many contexts. The revised SEEA EEA will therefore provide suitable guidance to compilers as to how to best integrate information on relevant abiotic flows, for example in the context of the ecosystem service supply and use account. An important consideration in this regard will be clarifying the links to the SNA production boundary.

Water supply

The treatment of water supply as either an abiotic flow or as an ecosystem service has drawn strong opinions. The perspective taken in the SEEA 2012 EEA was "… that while water is an abiotic resource,

its availability in the environment is considered to be a result of ecosystem processes and hence the provision of water is considered an ecosystem service."(3.21)

In CICES v5.1 the provision of water is considered an abiotic flow. Strong feedback for and against this treatment has been evident in the SEEA EEA revision discussions. Key points raised are that (i) water itself is abiotic; (ii) the relevance, to varying degrees, of ecological factors and ecosystem processes in ensuring water supply, in particular the timing of flows and their quality; and (iii) the need for its inclusion in the accounts to ensure the relevance of ecosystem accounting in decision making contexts.

From an accounting perspective, if water supply was treated as an abiotic flow, this could still, by convention, be incorporated into an ecosystem services supply and use account. It has also been also observed that by treating water supply as an abiotic flow it cannot be a final ecosystem service and hence services such as water purification (nutrient removal and sediment retention) and water regulation of base flows can then be treated as final ecosystem services – i.e. they are the final ecosystem input to the abiotic flow – which might otherwise be excluded from the accounts. Certainly, it seems appropriate that water purification and water regulation of base flows are included as ecosystem services, but the desire for their inclusion does not mean that water supply must be considered abiotic since, as discussed in section 2.3, there are various ways of including both final and intermediate services in the accounts.

The scope of water supply as an ecosystem service should also consider the treatment of water sourced from groundwater, which may be considered to be "more" abiotic depending on the degree to which the source is closely connected to biotic systems.

The current, on balance, proposal is that water supply should be treated as an abiotic flow, albeit one that can be influenced by ecosystem processes. At the same time, it is also proposed that there is a high relevance in including water supply in the ecosystem accounts in some way.

Flows related to the generation of energy

For these flows it is useful to distinguish non-renewable and renewable sources of energy. For non-renewable sources, such as fossil fuels and uranium, it is considered that these are clearly abiotic flows and no further discussion is required. This treatment also applies to peat used as an energy source.

For renewable sources, three types can be distinguished:

- Biomass, including timber, maize used for ethanol, etc where the supply is clearly biotic and its provision should be considered an ecosystem service.
- Sources such as wind, solar, geothermal and tidal energy do not involve or rely on biotic processes and hence would be considered abiotic flows
- Energy from hydropower. This is separated as it links somewhat to the discussion of water supply above. In the SEEA CF, the use of water for generating energy, including run-of-river, is considered abstraction. However, for ecosystem accounting, it seems more clear cut that the source of the energy is related strongly to the landscape structure and geomorphology (for example the fall in the river). Thus while ecosystem services such as water regulation of base flows and water purification (in terms of sediment retention) are important ecosystem service inputs, the supply of hydropower itself is better considered as an abiotic flow rather than as an ecosystem service.

While all flows related to the generation of energy are considered abiotic except for biomass sources, it may be appropriate in certain context to record selected abiotic flows of energy in the ecosystem accounts, e.g. to capture a wider set of flows in the asset of trade-offs within an ecosystem asset.

Flows related to the use of ecosystems for undertaking economic and other activities

These flows relate primarily to the fact that, in biophysical terms, everything happens somewhere. The question here is to what extent the fact that something happens in an ecosystem implies that there is an ecological contribution which would in turn suggest recording an ecosystem service. As in the other groups, different types of uses of ecosystems can be identified.

- *Land supporting buildings, houses, roads, railways and other structures*. There seems no doubt that no biotic process is involved in this use of space and hence while clearly land is needed for supporting these structures, and some land is better suited to construction than other land, the benefits emerging do not contain ecological contributions.
- *Navigation on rivers, lakes and seas/oceans*. Here, the main concern lies in the role of ecosystem processes. In substantive areas of open water there seems little effect of ecosystem processes while in certain rivers the role of water regulation in ensuring base flows of water may be essential. In other cases, transportation via rivers (including for example the transportation of logs) may be most related to landscape form. It is proposed that, in general, navigation itself not be considered an ecosystem service but that where water regulation of base flows is an important ecosystem input, then this contribution should recognized as an ecosystem service but the navigation itself should be considered a benefit.
- *Activities of people in ecosystems*. These might be split into two types (i) in-situ recreational activities and (ii) activities relating to employment. The general discussion of ecosystem services has concluded that people's enjoyment of nature when recreating, at least in part, reflects a contribution of biotic processes (see section 2.4 for a longer discussion of this topic). Thus these uses seem best considered ecosystem services. The case of those working in the outdoors – such as farmers, tour guides, landscapers and others that might be considered to have more direct connection with the environment in their jobs – it seems possible that they might obtain some benefit from being outdoors that is similar to a recreation related service. While this might be investigated further, it is considered at present that any such benefits are considered indistinguishable from the provision of labour services and should not be recorded separately in the ecosystem accounts.

In determining an appropriate treatment for these flows one consideration is that the provision of space within an ecosystem for economic and other activities is captured in the SNA to the extent of land and associated rent payments. Clarity will be needed to align the flows already recorded in the SNA and the recording of ecosystem services and abiotic flows in this context. This will link to a wider discussion on ecosystem asset and land valuations within Working Group #5.

Flows related to abiotic components of ecosystems in the supply of regulating services

By definition, ecosystems are a mix of biotic and abiotic components and hence depending on the ecosystem and the type of service there will be a varying mix of contribution from these components. The following cases are considered:

- Mediation of air pollutants by abiotic components – here pollutants are absorbed, diluted, diffused or transported in some way but not actively mediated by biotic components
- Coastal protection services provided by unvegetated shingle or sand dunes – here it is largely the landscape form that drives the provision of the service and a question would be whether this landscape form is influence by biotic components (e.g. are sand dunes

influenced in their role in coastal protection by the associated vegetation) and whether the logic would extend to sea cliffs providing coastal protection.

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

In all of these cases it is considered appropriate to recognize these flows as ecosystem services, notwithstanding there may be a dominant role of abiotic components in some ecosystem types.

Flows related to residuals from economic activity

There are a range of residuals that are released through economic activity including emissions to air, soil and water and the generation of solid waste. In many cases the ecosystem acts as a sink or receiver of these residuals. Three cases are considered here:

- Where residuals are stored in specific areas, such as with landfill or mining overburden, this seems a clear case of using the ecosystem's location and no ecological contribution is involved.
- Where residuals are actively mediated or processed via biotic processes. Examples including air filtration, water purification, sewage sludge absorption, carbon sequestration. In these cases there seems a strong case to recognize an ecosystem service.
- Where residuals are passed through an ecosystem, for example where contaminants from effluent flow into freshwater ecosystems and are subsequently deposited within the sediment or passed on to the marine environment. The question is to what extent the ecosystem has played an active role in removing and/or storing pollutants.

A range of considerations emerge in the last cases. A key one concerns the extent to which residual flows are unmediated (not processed) and "remain a problem" (e.g. for human health). Over time, increasing concentrations of some residuals may be a significant factor affecting the condition of ecosystems – e.g. excess nitrogen leading to eutrophication. The question that arises is that, if residuals remain unmediated, then is the ecosystem providing a service simply by virtue of providing a location in which that residual "rests"?

There will also be close links to the second cases where mediation or processing of residuals does take place. Ideally, it would be appropriate to take into account the specific way in which different ecosystems mediate the residual since the chemical processes involved may generate other pollutants which will also need to be accounted for in some way. This will likely vary by time and place as well as from pollutant to pollutant and also recognizing that the provision of the service may be generated over time and not only in the period in which the residual enters the ecosystem.

A final consideration is that the third case in which ecosystems, especially river systems, receive residuals may be of significant implied benefit to the polluter who might otherwise be required to treat the residual flow generated (or reduce associated use). The role of the ecosystem may then be considered in terms of providing a sink service.

In line with the discussion in section 2.3 concerning water purification, provided a clear user of the sink service can be identified it is proposed that flows concerning the third case be treated as ecosystem services.

Flows related to the use of the atmosphere

The considerations here are largely an extension of the use of ecosystems discussed above. Two specific cases are identified. The first concerns the use of the atmosphere for transport which is generally considered to reflect an abiotic flow as for other transport services, subject to some degree of scarcity as for the treatment of navigation.

The second case concerns the use of the atmosphere as a sink for emissions of greenhouse gases. The challenges in this case are not only whether the storage of carbon in the atmosphere might be considered a service (consistent with the discussion above concerning mediated and unmediated flows) but also whether the atmosphere is considered an ecosystem at all. It seems likely that the atmosphere is not considered an ecosystem but it remains a consideration as to whether it might be consider to provide a benefit, via an abiotic flow, to emitters of GHG, to the extent that without the atmosphere some other means to capture the emissions would be required. It seems appropriate for no flow of ecosystem services to be recorded but, subject to further discussion on the topic of sink services, an abiotic flow may be considered.

General considerations

A key consideration in relation to the supply of ecosystem services described in many of these cases concerns the extent to which the characteristics of the ecosystem should be a determining factor. For example, should activities taking place in a coastal ecosystem consisting primarily of sand (which would itself be considered abiotic), or in an exposed rocky mountain range, be considered to have sufficient input of biotic processes to be treated as ecosystem services.

Given the range of ecosystem types and ecosystem services many combinations are possible in terms of the relative contribution of biotic and abiotic components. While it is possible to make decisions on a case by case basis it seems appropriate to establish some more general criteria that can be applied. Further, it may be relevant to consider whether the definition of ecosystem services needs refinement to, for example, focus more directly on only the biotic contributions of ecosystems.

On balance, the perspective of the reviewers was that provided the processes taking place were considered biotic, then the fact that these might take place in ecosystems heavily dominated by abiotic components was of less relevance. Further, while some criteria were proposed these were not broadly supported and if this route is to be taken then separate discussion will need to be conducted. Some proposals linking to systems ecology concepts were provided that might serve as a starting point and much discussion has taken place in the context of developing CICES v5.1.

Questions:

Do you have comments on the proposed treatments for:

- Water supply
- Energy flows
- Use of ecosystems for economic and other activities
- The role of abiotic components in the supply of regulating services
- Residual flows
- Use of the atmosphere

Do you have proposals for generic criteria or principles that could be applied to establish the boundary between ecosystem services and abiotic flows?