Ecosystem condition – discussion questions and background for the London Group

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Introduction

Understanding the purpose of ecosystem condition accounts, defining it more clearly and achieving a more common approach to measurement is needed if System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA-EEA) is to move from an experimental to standard framework of accounting.

This is clear from the SEEA-EEA Research Agenda which has two items specifically on ecosystem condition:

- Item 2. Indicators of ecosystem condition (including the role of composite condition indicators)
- Item 8. Articulation of the links between ecosystem assets (and their condition) and the supply of ecosystem services

Other items in the research agenda are also related to condition, including Item 13 Defining and measuring degradation.

To advance the discussion of ecosystem condition we have proposed four questions to prompt the discussion and see what the experience of implementing the SEEA-EEA has taught us so far:

- What is the purpose of the condition account?
- How do ecosystem condition indicators relate to the ecological production function approach?
- Are the characteristics of condition set out in the SEEA EEA the key ones and are they workable?
- How to aggregate the characteristics of condition across an ecosystem and across different ecosystem types in a meaningful way?

Before moving to a short discussion of the questions it is worth recalling some of the key definitions and guidance from the SEEA-EEA on the concept and measurement of ecosystem condition. These are found in Chapter 2 of the SEEA-EEA:

> "2.31 *Ecosystem assets are spatial areas comprising a combination of biotic and abiotic components and other characteristics that function together*. Ecosystem assets are measured from two perspectives–that of *ecosystem condition* and *ecosystem extent*; and that of *ecosystem services*. A particular combination or "basket" of ecosystem services

will be generated at a particular point in time from a specific ecosystem asset. The aggregation of all future ecosystem services for a given basket provides an estimated stock of expected ecosystem service flows, at a point in time.

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2.35 *Ecosystem condition reflects the overall quality of an ecosystem asset in terms of its characteristics*. The assessment of ecosystem condition involves two distinct stages of measurement with reference to both the quantity and the quality aspects of the characteristics of the ecosystem asset. In the first stage, it is necessary to select appropriate characteristics and associated indicators of changes in those characteristics. The selection of characteristics and associated indicators should be carried out on a scientific basis so that there is an assessment of the ongoing functioning, resilience and integrity of the ecosystem asset. Thus, movements of the indicators should be responsive to changes in the functioning and integrity of the ecosystem as a whole.

Additional detail is found in Chapter 4 of the SEEA-EEA.

What is the purpose of the condition account?

Developing a common and more detailed of understanding the purpose of the condition account should help to inform the technical choice of which ecosystem characteristics to measure and the indicators to be used for measurement.

It seems there are two general strands to the purpose of condition accounts. The first is related to sustainability and hence addresses the question – what is the state of the ecosystems and can the ecosystems continue to provide services to people? The second general purpose addresses a different question – what is the state of the ecosystem in terms of its ability to continue to function without reference to human use. These two general streams could be called 'anthropocentric' and 'non-anthropocentric' and are aligned with different world views broadly represented by economists (anthropocentric) and ecologists or physical scientists (non-anthropocentric) (categorisation after Saner and Bordt 2016).

Traditionally ecologists and the conservation movement have been focused on the non-anthropocentric view and the intrinsic value of nature. That is: nature is valuable for its own sake. This view of condition relates mostly to "natural" ecosystems and hence urban areas and farmland are not usually considered ecosystems and are out of scope for condition assessments. The focus is generally on biodiversity or the living components of ecosystems, and the question is, for example, about the condition of forests to support wildlife. In this example, the condition of the forest should be maintained or enhanced for the benefit of the wildlife, irrespective of whether the wildlife is used or appreciated by people. From this perspective, the management questions that might, for example, be answered by an ecosystem extent and condition account are:

- Is the extent and condition of the ecosystem sufficient to support a viable number of a particular species?
- Where could the extent and condition of the ecosystem be improved most for a particular species?

- What is driving the changes in extent and condition?

The anthropocentric view is focused on the management of ecosystems to maintain the basket of services to people, so the questions are anthropocentric. For example:

- Is the extent and condition of the ecosystem sufficient to continue to provide the current range and level of ecosystem services (to people)
- What are the characteristics of the ecosystem assets (that are key to the supply of services) that are most vulnerable to change?
- What is driving the changes in extent and condition?

In both cases what is driving change is important and hence the need to distinguish these is vital as per the rows of SEEA-EEA Table 4.4 (below). It seems that the condition accounts produced have so far been based on SEEA-EEA Table 2.2 (=4.3) and Table 4.4 Changes in ecosystem condition.

Table 4.4 of the SEEA-EEA:

Changes in ecosystem condition for an LCEU

	Characteristics of ecosystem condition				
	Vegetation	Biodiversity	Soil	Water	Carbon
	Examples of indicators				
	Leaf area index, biomass, mean annual increment	Species richness, relative abundance	Soil organic matter content, soil carbon, groundwater table	River flow, water quality, fish species	Net carbon balance, primary productivity
Opening condition					
Improvements in condition					
Improvements due to natural regeneration (net of normal natural losses)					
Improvements due to human activity					
Reductions in condition					
Reductions due to extraction and harvest of resources					
Reductions due to ongoing human activity					
Catastrophic losses due to human activity					
Catastrophic losses due to natural events					
Closing condition					

How do ecosystem condition indicators relate to the ecological production function approach?

The ecological production function approach to valuation estimates the contribution of ecosystem services to the value of the products traded in the market (see SEEA-EEA paragraph 5.98). In order to do this, the inputs from the ecosystems need to be quantified and incorporated into the production function. As ecosystems in different condition produce a different range of inputs, the ecological production functions reveal how the characteristics of ecosystems (e.g., different kinds of wetlands, or wetlands in different landscape settings) produce [market] goods and services (Bruins et al, EPA, 2012).

These characteristics may be reported in the condition account, but in practice the variables needed for the specification of the ecological production function may range much more widely. For example, management practices and protected area status are often key to the delivery of certain ecosystem services but have not generally featured in discussions on the structure of the condition account.

Clearly, the research involved in defining and specifying ecological production functions can be directly used in identifying the and measuring the causes of change, as set out in Table 4.4 of the SEEA-EEA.

Are the characteristics of condition set out in the SEEA EEA the key ones and are they workable?

Chapter 2 of the SEEA-EEA presents a stylized table for measures of condition (Table 2.2, repeated as Table 4.3) showing a range of characteristics and some potential measures of the characteristics. The SEEA–EEA provides a general outline of the measures, for example in paragraph 2.36:

> 2.36 Measures of ecosystem condition may be compiled in relation to key ecosystem characteristics (e.g., water, soil, carbon, vegetation, biodiversity) and the choice of characteristics will generally vary depending on the type of ecosystem asset. Further, the selection of characteristics should take into account current and expected future uses of the ecosystem (e.g., whether for agriculture, forestry, carbon sequestration, recreation), since these uses are likely to impact most directly on certain characteristics and hence on the overall condition and capacity of the ecosystem asset to generate alternative baskets of ecosystem services. Usually, there will not be a single indicator for assessing the quality of a single characteristic. Both the selection and measurement of characteristics and associated indicators are likely to present measurement challenges

The characteristics and indicators noted in the SEEA-EEA condition account are evident in a range of studies. Vegetation, carbon and water are common characteristics, with indicators being leaf area index, primary productivity, gross or net carbon change in carbon stocks, carbon concentrations, and water sediment and nutrient loads. Some indicators are used for more than one characteristic. For example, the indicator gross or net carbon change in carbon stocks is used for both vegetation and carbon.

A general group of indicators not currently recognized in the SEEA-EEA is related to vegetation and the position in the landscape. These variables are related to the size (extent), shape and location (proximity to similar ecosystems) of patches of vegetation as well as the age of the vegetation since disturbance (e.g. by fire or harvesting). These are usually derived from large-scale remotely sensed information. Extent *as a measure of condition* is evident a few studies.

Table 2.2 of the SEEA-EEA

Measures of ecosystem condition and extent for an EAU at end of accounting period

Type of LCEU	Ecosystem extent	Characteristics of ecosystem condition				
		Vegetation	Biodiversity	Soil	Water	Carbon
		Examples of indicators				
	Area	Leaf area index, biomass, mean annual increment	Species richness, relative abundance	Soil organic matter content, soil carbon, groundwater table	River flow, water quality, fish species	Net carbon balance, primary productivity
Forest tree cover						
Agricultural land[a]						
Urban and associated developed areas						
Open wetlands						

a Medium to large fields of rain-fed herbaceous cropland.

A second group of characteristics not identified in the SEEA-EEA is specified at the site level – for example, bare ground, presence of fallen logs, leaf litter and vegetation structure (e.g. presence of understory, trees with hollows). The vegetation structure is related to biodiversity and in particular the habitat for animals, almost exclusively vertebrates.

The biodiversity characteristic has not generally been considered in studies. Species level accounts are prepared but these have not been integrated into a condition account. Understanding how the thematic accounts, like biodiversity, carbon and water, fit into the condition account is an area that has not been addressed systematically.

The SEEA-EEA highlighted the expected difficulties in the choice of characteristics and indicators. This text from paragraph 2.36 and elsewhere also points to the flows of ecosystem services being a factor in choice of characteristics to measure. As such it is a move away from the text in paragraph 2.35 which says:

> "The selection of characteristics and associated indicators should be carried out on a scientific basis so that there is an *assessment of the ongoing functioning, resilience and integrity* of the ecosystem asset."

The different focus of the paragraphs 2.35 and 2.36 is an example of the two different views of condition, one in which people are at the centre of ecosystem condition (ecosystem services and hence anthropocentric) and the other where they are not (on-going function, resilience and integrity of the ecosystem asset or non-anthropocentric). The discussion about condition inevitably leads to: "condition for what?"

It is possible to interpret the ongoing functioning, resilience and integrity of ecosystems as a description of condition irrespective of human use and management. This is often what ecologists will call "natural", and hence any ecosystem dominated by human structures or management (e.g. urban areas or farmland) is always in worse condition than areas less modified by humans.

It is interesting to note that many, if not most, studies do not explicitly make the distinction between the characteristics and the indicators. It is also interesting that some indicators relate to more than one characteristic and are sometimes chosen precisely for that reason (e.g. age since disturbance), although the nature of the relationships between different characteristics is not always apparent.

In summary, the broad characteristics of condition identified in the SEEA-EEA have all been tested in practice and seem workable. However, the indicators used to measure condition have varied considerably. Additional landscape (extent, shape and location) and site-level (understory and tree hollows) indicators related to vegetation have been identified. A case could be made for including a new category of *landscape* characteristics. Additionally *site-level habitat* characteristics related to non-living vegetation (e.g. leaf litter and fallen logs) could be added to those mentioned in the SEEA-EEA.

In addition, a few practical and theoretical aspects need to be explored further. These include:

- Whether using extent as a measure of condition is an aspect of condition accounting
- Understanding how to present indicators which are used for more than one aspect of condition
- Determining whether, and if so how, thematic accounts of biodiversity, carbon and water should be integrated into the condition account.

Finally it's worth noting that in various types of environmental statistics, and in particular State of the Environment Reporting, indicators are usually presented by theme (e.g. land, water, biodiversity). The themes in such reporting are broadly equivalent to the characteristics identified in the SEEA-EEA condition account and can provide a starting point for a set of indicators for those wishing to produce bio-physical accounts of condition.

How to aggregate the characteristics of condition across an ecosystem and across different ecosystem types in a meaningful way?

The SEEA-EEA Table 4.3 presents the characteristics of condition for different ecosystems and naturally leads to questions about producing aggregate measures of condition for each ecosystem (i.e. sum by columns) or aggregate measures of the characteristics (sum of rows). Both require a sum across various indicators sets, some of which may be missing for a particular ecosystem or characteristic, or defined in different ways.

Aggregated indicators of condition have been produced for a number of accounts and are also used in other reports on environmental condition (e.g. State of the Environment Reporting). Indicators such Ecological Footprint, "Green GDP" or the Genuine Progress Indicator are in wide use. This is largely because such indicators are wanted by potential account users involved in the communication of results to the general public and high-level decision makers. In the face of this overwhelming demand for summary indicators, how meaningful any aggregated indicator derived from the accounts might be is almost a moot point. The real challenge is to provide the best summary information possible and to make sure that those advising senior decision makers can properly interpret the indicator through a more detailed examination of the accounts.

The summing of indicators requires an index to a reference period or condition. To date, summary indicators have been indexed to either a recent (i.e. last 10-20 years or even the last year) or distant past or a reference state. If the distant past is used it is usually to pre-industrial times and is an approximation of a natural or at least pre-industrial state. In some cases the reference is to a counterfactual – a world without people. These views of reference condition are related to the non-anthropocentric perspective, and as noted above, can only really be applied to habitats which have not been heavily modified by anthropogenic use. It follows that it will not be possible to aggregate these indicators across all ecosystem types.

The alternate, anthropocentric, view of condition is related to the sustainability of use of the ecosystems. That is: the condition of the asset is maintained if the flow of ecosystem services from the asset can be maintained in perpetuity. A reference condition in this case could be aligned to the notion(s) of (maximum) sustainable yield in natural resource management, where the amount used is equal to the amount generated. As noted in the SEEA-EEA (paragraph 2.32), this works well for provisioning services and in particular the provisioning of one service from one ecosystem, but would be more complex with multiple services. However, it would seem that the notion(s) of (maximum) sustainable yield are capable of being adapted to the regulating and cultural services, and hence a reference condition for these could be derived.

The anthropocentric view of condition is also behind the notions of ecosystem capacity, ecosystem capability and ecosystem potential that are being explored by a number of people (e.g. Lars Hein, Ken Bagstad, Michael Bordt, Carl Obst).