Theoretical and practical issues with measurement of capacity, condition, and conversion in the SEEA-Ecosystem Accounting

Paper prepared for the 27th Meeting of the London Group

27-30 September and 4 October 2021

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A tree in agricultural ecosystem in good condition or Box-gum Grassy Woodland in poor condition?

Summary

The definitions of ecosystem capacity, condition and conversion in the SEEA EA are inter-related and central to the structure of ecosystem accounting. They have important ramifications for the measurement of the concepts and the population of accounts. Using real and abstract examples we highlight issues with the theory and practical application of these the terms for ecosystem accounting.

Theoretical issues

- The definition of condition is limited and represents only two of four views of ecosystem condition.
- The definition of ecosystem conversion refers to one view of ecosystem condition and ecosystem services, which is not mentioned in the definitions of ecosystem extent or condition.
- The definition of ecosystem capacity requires consideration of condition, management of ecosystems assets, and a determination of the sustainability of a single ecosystem service flow from ecosystem assets.
- There is a discrepancy between the way capacity is described in physical and monetary terms. In monetary terms it is described as a stock whereas in physical terms it is described as a flow.
- There is no concept analogous to ecosystem capacity in the System of National Accounts (for produced or non-produced assets in reference to flows of goods and services)
- The definition of physical capacity requires account producers to determine what rate is sustainable, something which is not done in any other part of the SEEA or SNA.
- The place of capacity in the SEEA-EA framework of accounts is unclear

Practical issues

- Identifying measurable indicators of condition and whether they should or should not be related to the intent of land management and ecosystem capacity. One of the four views of ecosystem condition – intrinsic and anthropogenic – is potentially a measure of condition.
- The measurement of ecosystem conversion from one ecosystem type to another and how to interpret what is “a distinct and persistent change” so that changes in ecosystem extent can be distinguished from changes in ecosystem condition. Some changes to ecosystems are temporary and may be related to managed or natural impacts.
- The practical issue of the difficulty of measuring conversion highlights the theoretical problems in the definitions of condition and capacity.
- The process for defining ecosystem capacity in the SEEA-EA and its relationship to the definitions of ecosystem condition and ecosystem conversion was not transparent and provided little, if any, room for discussion

Conclusions

- The definition of ecosystem condition should recognize that multiple views of condition are possible and useful (as is said in the supporting text, e.g. Paragraph 5.2)
- The definition and description of ecosystem capacity is reassessed via an open and transparent process
- For the definition and description of ecosystem capacity it is either:
    - As a characteristic of ecosystems assets rather than a function of ecosystem services, management and use and the sustainability of one ecosystem flow.
    - Or included (subsumed) and include as one view of ecosystem condition (i.e. as a characteristic of ecosystem assets).
- That the relationship between ecosystem assets, ecosystem condition, ecosystem services and ecosystem capacity is clearly identified in the conceptual framework (e.g in paragraph 2.39 and Figure 2.2 of SEEA-EA)
- In practice, the definition and description of ecosystem conversion is dependent on land management and land use, the interpretation of persistent (time scale) and the units of observation and their aggregation to ecosystem types within ecosystem accounting areas (spatial scale)

Introduction

The aim of this paper is to clarify the concepts of ecosystem capacity, ecosystem condition and ecosystem conversion and how they are interrelated in the System of Environmental-Economic Accounting- Ecosystem Accounting (SEEA-EA). The definition of concepts has important ramifications for the measurement of the concepts and the development of accounts and these are illustrated with a hypothetical and a real example.

The paper examines each definition in turn, discussing key theoretical and practical aspects, and how they are related in the overall accounting structure. The paper also comments on the process for the developing the definition of ecosystem capacity. It finishes with conclusions and suggests some next steps.

Ecosystem condition

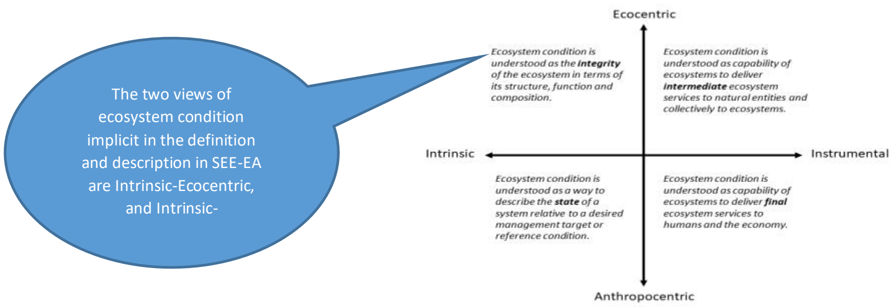
Paragraph 5.2 of the SEEA-EA defines ecosystem condition, viz:

> **"***Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic and biotic characteristics."*

The paragraph 5.2 goes on to describe ecosystem condition in terms of: composition, structure and function; ecological integrity of the ecosystem; capacity to supply ecosystem services on an ongoing basis; measures of ecosystem condition may reflect multiple values, and be undertaken across a range of temporal and spatial scales.

The description of ecosystem condition mentions "multiple values" but is centered on two of four possible views for condition identified by Keith et al. 2020 (Figure 1). The four views are Intrinsic-Ecocentric, Intrinsic-Anthropocentric, Instrumental-Ecocentric and Instrumental-Anthropocentric. We will return to these four views in the discussion of ecosystem capacity.

Figure 1. Fours view of ecosystem condition



Source: Keith et al. (2020) A conceptual framework and practical structure for implementing ecosystem condition accounts. https://doi.org/10.3897/oneeco.5.e58216

Ecosystem conversion

Ecosystem conversion is defined in paragraph 4.23 of SEEA-EA, viz:

> "Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a *distinct* and *persistent* change in the ecological *structure, composition and function* which, in turn, is reflected in the supply of a different set of *ecosystem services*." (emphasis added in *italics*)

Practical issues are noted, and guidance provided in the supporting text. Consideration is given to the scale at which the conversion of ecosystem assets is assessed and to the expected state of the ecosystem in the future. A theoretical example of this is a forest ecosystem, part of which is cut for timber. While the part of forest cut will have a distinct and persistent change in its composition, structure and function and type and level of ecosystem services changes, it is said to remain a forest, because of the spatial and temporal scales at which conversion is assessed and the consideration of management. In this case, provided that part of the forest is expected to grow back, and it is part of larger forest, it would be recorded as a change in forest condition, not a conversion. The change is temporary on a longer time scale, not persistent.

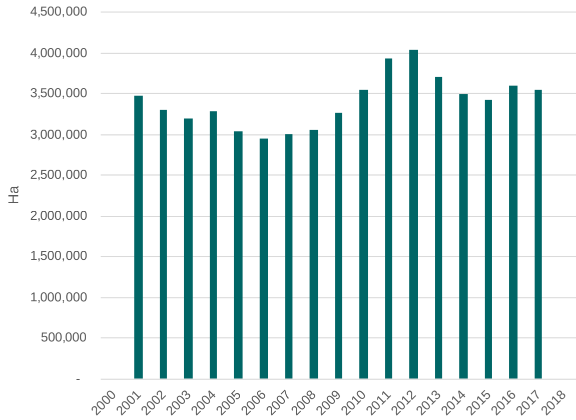
The definition and description of ecosystem condition does not refer to ecosystem management, even though this would be a key determining if this change was persistent (and hence recorded as either a change in ecosystem extent or condition), nor the ecosystem services changes which are a factor in determining conversion. While the definition of conversion says that the change in ecosystem type would be *reflected* in a change in service provision, a non-persistent change will also have an impact on services and it may be that non-persistent changes in the ecosystem type are recorded as well as persistent changes. With fine-level spatial mapping and modelling of current and future expected ecosystem services, it would be possible to measure the changes and to record the change in the forest ecosystem in composition, structure and function as a conversion (e.g. from forest to bare-earth or grassland) within the ecosystem asset, rather than a change in condition.

A real example of the practical and theoretical problem with measuring changes in extent or condition was encountered the development of ecosystem asset accounts for the Box-gum Grassy Woodlands, a Critically Endangered ecosystem in Australia. In 2010, the extent of BGGW was estimated to be less than 10% of its pre-European settlement distribution. The Box-gum Grassy Woodlands occurred mostly within the Murray-Darling Basin and its loss is mainly due to agricultural activities. Fertile soils in this region, in addition to its reasonable rainfall and relative flatness, made it desirable for agriculture. The ecosystem was estimated to have occurred across a large part of south-eastern Australia (nearly 50 million ha) and now it mostly occurs on private land. A National Recovery Plan was produced for Box-gum Grassy Woodlands, but it is unknown whether this community's status has improved or declined since 2010.

To assess the current extent and condition of Box-gum Grassy Woodlands, ecosystem accounts were designed. They were populated by combining new remotely-sensed data on land cover with existing data ecosystem extent, land management and a model previously developed to predict the likely occurrence of the Box-gum Grassy Woodlands.

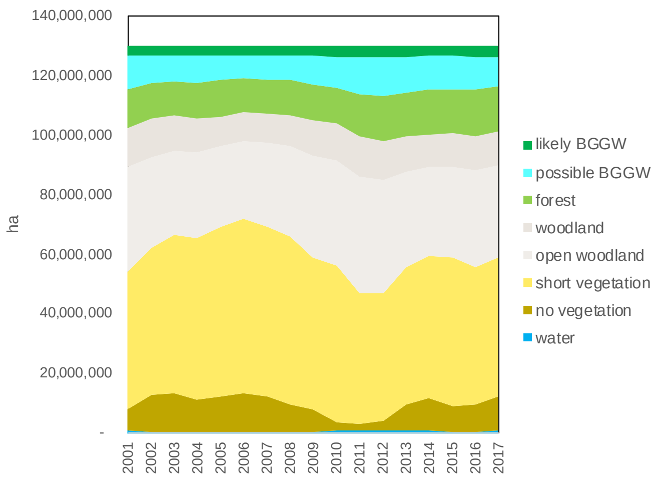
The prediction of the likely extent of Box-gum Grassy Woodlands is shown in Figure 2, with the extent shown in the context of other ecosystems in Figure 3. Variation is apparent in both the extent of Box-gum Grassy Woodlands and other ecosystem types. The variation is due to natural variation in leaf area due to wetter conditions, with leaf area being a factor that determines crown cover in trees, a key variable used in the model to predict the occurrence of Box-gum Grassy Woodlands as well as the limits of remote sensing and the need for on-ground measurement to calibrate model predictions.

Figure 2. Likely extent of Box-gum Grassy Woodland in south-eastern Australia (ha), 2001 to 2017



Source: Vardon et al. (submitted). Accounting for the Critically Endangered Box-gum Grassy Woodlands

Figure 3. Extent of different ecosystems assessed for presence of Box-gum Grassy Woodland (BGGW) in south-eastern Australia (Ha), 2001 to 2017



Source: Vardon et al. (submitted). Accounting for the Critically Endangered Box-gum Grassy Woodlands

Some of the changes observed in Box-gum Grassy Woodland may be changes in the condition rather than conversions to or from Box-gum Grassy Woodland. Some conversions are clear (distinct and persistent), while others are not, through being slow and gradual. The difficulty of determining thresholds of change is recognised in the SEEA-EA but no guidance on how to deal with the problem is provided. The difficultly is apparent in the ecosystem extent change matrices prepared for the years 2001 to 2017. These matrices were prepared for the entire area, plus land management regions and an example for one region, the Central Tablelands, is shown (Table 1).

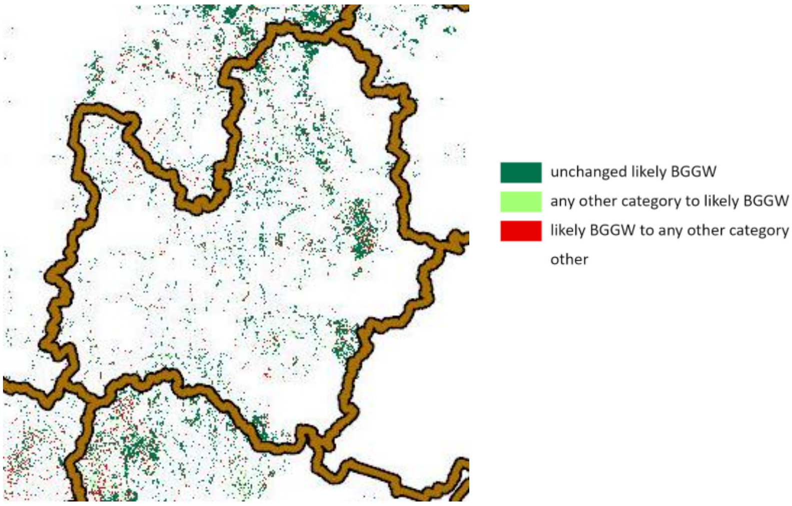
Table 1. Ecosystem extent change matrix for the Central Tablelands, 2001 to 2017, ha.

	water	no vegetation	short vegetation	open woodland	woodland	forest	likely BGGW (BGGW
2001	***5,911***	***3,244***	***878,555***	***928,643***	***594,657***	***501,574***	***224,199***
water		85	81	574	- 22	- 18	24
no vegetation	- 85		- 1,364	- 1,307	- 652	- 603	- 106
short vegetation	- 81	1,364		- 208,694	- 784	- 2,592	- 12,725
open woodland	- 574	1,307	208,694		- 13,051	- 5,800	-
woodland	16	652	784	13,051		21,726	-
forest	13	603	2,592	5,800	- 21,726		- 2,998
likely BGGW (BGGW and open BGGW)	- 24	106	12,725	-	-	2,998	
2017	***5,188***	***7,362***	***1,102,066***	***738,066***	***558,423***	***517,286***	***208,394***

Source: Vardon et al. (submitted). Accounting for the Critically Endangered Box-gum Grassy Woodlands

Three changes are highlighted in Table 1. The change of 106 ha from Box-gum Grassy Woodlands to no vegetation was verified via aerial photography with part of the area a conversion to a housing development. This is clear, distinct and persistent change. The change of 12,725 ha to short vegetation could be due to number of reasons: the clearing of trees for agriculture or the collapse of trees in agriculture land. Clearing for agriculture is sudden and distinct, while the collapse of trees is gradual. The change of 2,998 ha to forest is gradual, with more trees growing, increasing crown cover to the threshold where is becomes a forest rather than a woodland. The reverse changes also occur, although not shown in the change matrix, as it shows net changes (and is apparent from spatial data) (Fig. 4).

Figure 4. The change in extent of Box-gum Grassy Woodland in the Central Tablelands



Ecosystem capacity

Ecosystem capacity is important for linking the concepts of ecosystem extent and condition to ecosystem services. The definition of ecosystem capacity is in paragraph 6.141 of the SEEA-EA that was adopted in March 2021. The definition is:

> "*ecosystem capacity is the ability of an ecosystem to generate an ecosystem service under current ecosystem condition, management and uses, at the highest yield or use level that does not negatively affect the future supply of the same or other ecosystem services from that ecosystem.*"

The text in paragraph 6.145 says that the current *approach* is not systematic or ideal. It is not just the approach that is not ideal, it is the definition of the concept that is not ideal. This is for several reasons, some of which are recognised in the text.

The focus on a single ecosystem service flow, rather than a suite of flows from assets, is a recognised limitation of the current definition of ecosystem condition. Ecosystem assets provide a suite of flows. Implicit in the definition of ecosystem capacity (and backed up by the text) is that accountants must decide on what is sustainable to measure and record ecosystem capacity in the accounts. If something is unsustainable, then this would emerge in the assets accounts as a reduction in the extent of ecosystem assets or a degradation in the condition of assets, or both.

The definition of ecosystem capacity has no apparent anchor or starting point the SNA. There is no analogous concept of capacity in the SNA. Neither produced or non-produced assets are related to the production and use of goods and services. Furthermore, there is no apparent precedent in the SNA for the definition of sustainability.

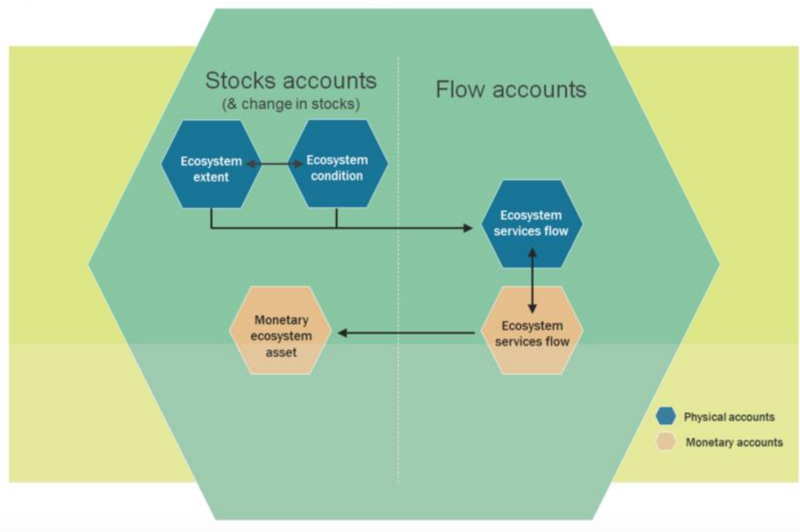
Conceptually, there is an anomaly in the description of ecosystem capacity in physical and monetary terms. The definition and text in paragraph 6.143 put ecosystem services flows at the centre of the definition. This is reinforced in dot point one of paragraph 6.149 which states explicitly that ecosystem capacity is measured as a rate per year. However, the text in 6.147, implies that capacity in physical terms can be measured using an approach akin to net present value of future expected income to value assets. This is reinforced explicitly in the discussion on monetisation of ecosystem capacity in the last dot point of paragraph 6.149. In this, ecosystem capacity is framed as a characteristic of physical flow whereas in monetary terms it is a characteristic of a monetary asset. Something cannot be a physical flow and a monetary asset. The definition and text grapples with both conceptual and measures issues and neither is resolved.

A key problem is that it is unclear where capacity sits in the system of accounts. Paragraph 2.39 of SEEA-EA says:

> *"The logic underpinning the connections between the various ecosystem accounts is articulated in Figure 2.2."*

However, neither Figure 2.2 of SEEA-EA (included below as Figure 5), nor the supporting text, explain how ecosystem capacity relates to the other parts of the accounts – ecosystem extent, condition or services.

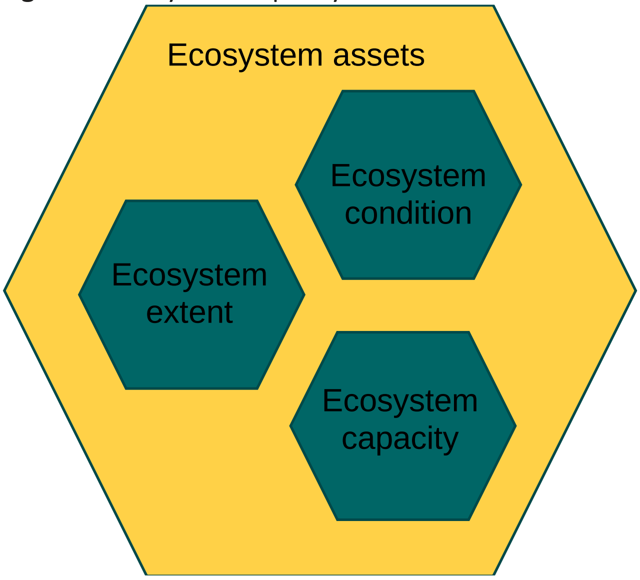
Figure 5. Connections between ecosystem accounts ()



Source: SEEA-EA, Figure 2.2, p. 32

Our notion of ecosystem capacity is that is a characteristic of an ecosystem asset that is aligned with the instrumental-anthropocentric view of ecosystem condition. Ecosystem capacity could be added as an extra view of ecosystem condition or it could be added as an additional characteristic of an ecosystem asset (Fig 6.) and included in the stock accounts, shown in Figure 2.2 of SEEA (and as Figure 5 in this paper). With ecosystem condition being considered as a characteristic of ecosystem assets, measuring the degradation of ecosystems would be more tractable, as the description of the monetary valuation of ecosystem capacity hints at in paragraph 6.149 of SEEA-EA.

Figure 6. Ecosystem capacity and characteristic of ecosystem assets



A note on process for defining ecosystem capacity

Ecosystem capacity was known to be of high interest but there has been very little, if any, public discussion of the definition of this concept. Concern about the absence of a definition of ecosystem capacity was expressed in consultations on individual chapters and a definition and description of capacity was not included in SEEA-EA drafts until the 2020 October draft. ABS (2020), Vardon and Keith (2020) and others commented on the definition of capacity, as noted in the Summary of feedback and responses to Global Consultation. However, there was no change in definition in the version prepared for consideration at the UNSC 2021, although there were some changes to supporting text. It was acknowledged that the concept of ecosystem capacity was problematic and was placed at the top of the research agenda.

Conclusions

The definition and description of ecosystem condition needs clarification. For example, to recognize that multiple views of condition are possible and are useful (as is indicated in the supporting text, e.g. Paragraph 5.2). At present, the definition included in the SEEA-EA recognizes just two of at least four possible views of ecosystem condition. This is particularly important as the definition of ecosystem capacity aligns with one of the four views of condition (Instrumental-Anthropocentric).

The definition and description of ecosystem capacity should be reassessed via an open and transparent process. Two options for the definition and description of ecosystem capacity are that it is: a characteristic of ecosystem assets rather than a function of ecosystem services, management and use and the sustainability of one ecosystem flow; or included (subsumed) as one view of ecosystem condition (again as a characteristic of ecosystem assets).

The relationship between ecosystem assets, ecosystem condition, ecosystem services and ecosystem capacity needs to be clarified in the conceptual framework (e.g. in paragraph 2.39 and Figure 2.2 of SEEA-EA).

The definition and description of ecosystem conversion is dependent on land management and land use, the interpretation of 'persistent' (e.g. by reference to time scale), and the units of observation and their aggregation to ecosystem types within ecosystem accounting areas (spatial scale). In some circumstances, it is very difficult to determine if a change in the composition and structure of ecosystems is a change in extent or a change in condition. The management of ecosystem assets is a key part of determining conversion, and there are limitations to the measurement of conversion using remote-sensing alone.

Questions to London Group

Q1. Do you agree with the conclusions?

Q2. Have others encountered these theoretical and practical issues?

Q3. If so, how have they or how could they be addressed?