SEEA EEA Revision

Working group 5: Valuation and accounting treatments

Discussion paper 5.4: Recording degradation in ecosystem accounts

Lead authors: Carl Obst, Bram Edens

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1. Introduction

Accounting for ecosystem degradation, the cost of using up natural capital, has been a prime motivator of the SEEA since its origins in the 1980s and the topic has a much longer history in economics. Conceptually, the desire is to adjust measures of Net Domestic Product (i.e. GDP less the capital cost of produced assets) for the cost of natural capital and so demonstrate that a more complete measure of economic activity can be defined using national accounting principles.

Past proposals to adjust measures of economic growth for ecosystem degradation have been many and varied. This paper provides a summary of the various approaches from a national accounting perspective and discusses the potential for the SEEA ecosystem accounting framework to describe a range of complementary aggregates.[1] It also takes the opportunity to bring together various pieces of text on degradation and depletion in SEEA documents drafted in the past 8-10 years.

In addition to the discussion of ecosystem degradation, two related issues of accounting treatment are considered in this paper:

- *The treatment of ecosystem enhancement*– either as a result of human intervention or as a result of natural processes. This may be simply the opposite of the treatment of degradation but the fact that ecosystem assets can renew and regenerate themselves, unlike produced assets, means that additional thought is required in the application of the standard capital accounting theory.

[1] Future work will also encompass a review of other literature, for example Chapter 2 in Fleurbaey, M., Blanchet, D., 2013. Beyond GDP Measuring Welfare and Assessing Sustainability. Oxford University Press, New York.

- *Recording liabilities associated with ecosystem assets*. There has long been discussion of recognising liabilities associated with the declining condition of ecosystem assets. This section of the paper reviews the different parts of the discussion.

The paper starts from the strong assumption that measurement and valuation of ecosystem services and assets is possible, at appropriate scales, to allow for the integration of ecosystem information in monetary terms with the standard accounts of the SNA. This assumption allows for a focus on the conceptual aspects of alternative treatments but it is recognised that issues of feasibility and application will also need to be considered in due course. In that respect, this paper is aimed at identifying the theoretical target for measurement that can be the focus for measurement and the assessment of different approaches.

This is the fourth in a series of discussion papers on valuation and accounting treatments being prepared for Expert Review in the context of the SEEA Experimental Ecosystem Accounting (SEEA EEA) revision process. It builds on discussion papers that cover principles of valuation for ecosystem services (DP5.1), the valuation of ecosystem assets (DP5.2) and national accounting recording principles (DP5.3). It is anticipated that the key issues emerging from the discussion of those papers will inform how far the proposed accounting treatments in this paper can be applied at this stage. This paper also takes into account discussion of earlier versions of this material that were presented and discussed at the SEEA EEA Forum of Experts on ecosystem accounting held in Glen Cover, NY in June 2019.

2. Defining ecosystem degradation

Linking depletion and degradation

The definition of ecosystem degradation for SEEA EEA purposes must work within a national accounting context and hence must build on the long-established measurement of consumption of fixed capital (CFC) or depreciation of produced assets as described in the System of National Accounts (SNA). The focus therefore is on estimating the appropriate deduction from income that reflects the cost of using up capital in the production process.

A useful stepping stone for defining ecosystem degradation is to consider the definition of depletion in the SEEA Central Framework. The following text is drawn from SEEA Central Framework, Section 5.4.2 and provides a standard measure for depletion of natural resources (i.e. the cost of using up individual natural resources such as minerals, timber, fish).

SEEA Central Framework: Defining depletion in physical terms

5.75 In accounting for environmental assets, the measurement of depletion is often a particular focus. The depletion of environmental assets relates to the physical using up of environmental assets through extraction and harvest by economic units, including households, such that there is a reduced availability of the resource. Depletion does not fully account for all possible changes in the stock of an asset over an accounting period and hence should not be linked directly to measures of sustainability. Assessments of the sustainability of environmental assets should take into account a broader range of factors, such as the extent of catastrophic losses or discoveries and potential changes in the demand for inputs from environmental assets.

5.76 Depletion, in physical terms, is the decrease in the quantity of the stock of a natural resource over an accounting period that is due to the extraction of the natural resource by economic units occurring at a level greater than that of regeneration.

5.77 For non-renewable natural resources, such as mineral and energy resources, depletion is equal to the quantity of resource that is extracted because the stock of these resources cannot regenerate on human time scales. Increases in the stock of non-renewable natural resources (e.g. through discoveries) may permit the ongoing extraction of the resources. However, these increases in volume are not considered regeneration, and hence do not offset measures of depletion. The increases should be recorded elsewhere in the asset account.

5.78 For natural biological resources, such as timber resources and aquatic resources, the equality in physical terms between depletion and extraction does not hold. The ability for these resources to regenerate naturally means that under certain management and extraction situations, the quantity of resources extracted may be matched by a quantity of resources that are regenerated and, in this situation, there is no overall physical depletion of the environmental asset. More generally, only the amount of extraction that is above the level of regeneration is recorded as depletion. The following paragraphs outline in more detail the measurement of depletion in physical terms for natural biological resources.

5.79 Depletion is not recorded when there is a reduction in the quantity of an environmental asset due to unexpected events such as losses due to extreme weather or pandemic outbreaks of disease. These reductions are recorded as catastrophic losses. Rather, depletion must be seen as a consequence of the extraction of natural resources by economic units.

5.80 Depletion can also be measured in monetary terms by valuing the physical flows of depletion using the price of the natural resource in situ. This step is explained in detail in Annex A5.1. It is noted that the monetary value of depletion is equal to the change in the value of the natural resource that is due to physical depletion.

The fundamental aspects of this definition are that depletion is,

- Related to changes in the physical stock of environmental assets
- Arises due to the activity of economic units, including changes in activity arising from changes in relevant policy (including taxes) or technological developments

Consequently, changes in the value of environmental assets over an accounting period that (i) are due solely to changes in price (including the effect of broader economic and social changes on resource prices) or (ii) are due to factors not related to economic activity; are not considered within the definition of depletion.

While this is consistent with the definition of depreciation (consumption of fixed capital) provided in the SNA, in an environmental assets context there are some additional considerations. In particular, for produced assets it is generally assumed that depreciation arises due to the use of the asset in production by a single firm. In an environmental context, isolating changes in an asset that arise solely due to the use of the asset in production by a single firm may be very problematic.

Further, for produced assets the depreciation is readily attributed to the owner/user of the asset. For environmental assets, in cases where economic ownership can be readily established, this attribution is also possible but since the change in the stock may not be due to the activities of the owning firm, there may also be interest in understanding the effects of pollution, emissions and other activities of other firms that influence the change in the stock.

Although finalised before the completion of initial work on ecosystem accounting, the SEEA Central Framework provides a clear initial framing for ecosystem degradation in relation to measures of depletion. The text copied below (from Section 5.4.2) introduces some of the complexities in defining and measuring ecosystem degradation in a national accounting context.

SEEA Central Framework: The relationship between depletion and degradation

5.88 Although the measurement of degradation in physical and monetary terms is not pursued in the Central Framework, there are links to the definition and measurement of depletion that are explained here. The measurement of degradation is considered in the SEEA Experimental Ecosystem Accounts.

5.89 The focus in measuring depletion is on the availability of individual environmental assets in the future and changes in the availability due to extraction and harvest by economic units. There is particular focus on the specific benefits that arise from the extracted materials, including the capacity of the extraction of the resources to generate income for the extractor.

5.90 Degradation considers changes in the capacity of environmental assets to deliver a broad range of contributions – known as ecosystem services (e.g. air filtration services from forests) and the extent to which this capacity may be reduced through the action of economic units, including households. In this sense, since depletion relates to one type of ecosystem service, it can be considered as a specific form of degradation.

5.91 The measurement of degradation is complicated because the capacity of environmental assets to deliver ecosystem services is not solely attributable to individual assets, and because individual assets may deliver a number of different ecosystem services. Further, while individual environmental assets, such as water and soil resources, may have been degraded over time, separating the extent of degradation of the individual asset from the broader degradation of the related ecosystem may not be straightforward.

5.92 The measurement of degradation in physical terms is also complicated as it generally relies on a detailed assessment of the characteristics of environmental assets rather than the relatively simpler quantities of an environmental asset that are used in the estimation of asset accounts in physical terms and in the estimation of depletion. For example, to assess whether a body of water has been degraded, assessments might be made of the quantities of various pollutants in the water as part of a broader assessment of the overall change in condition. While individual accounting for each of these pollutants might be undertaken it will not be directly related to the volume of water in cubic metres that is used to account for water resources in an asset account.

Key points to note concerning degradation relative to depletion are first, that the change in the stock of the underlying asset encompasses both the extent and the condition/quality of the stock; and second, that each asset will supply a number of ecosystem services which will generally be of benefit to number of different users, i.e. there is not a necessary one-to-one match between an ecosystem asset and a single economic owner.

In line with the general premise of this paper, it is considered that the conceptual and practical issues of measuring (and valuing) multiple ecosystem services and measuring changes in the quality of ecosystem assets are dealt with in other discussion papers. For this paper, the focus is on describing the appropriate accounting entries on the assumption that these measurements can be completed.

Ecosystem degradation in the SEEA EEA

Building on the national accounting based framing for depreciation and depletion, the SEEA EEA developed the following definition of ecosystem degradation in Section 4.2.3.

4.31 In general terms, ecosystem degradation is the decline in an ecosystem asset over an accounting period. Generally, ecosystem degradation will be reflected in declines in ecosystem condition and/or declines in expected ecosystem service flows. Changes in ecosystem extent are relevant where they are linked to declines in ecosystem condition or expected ecosystem service flows. Since there may not always be a linear relationship between the condition of an ecosystem and the expected flows of ecosystem services, the measurement of degradation should involve the following two conditions:

a. That ecosystem degradation covers only declines due to economic and other human activity - thereby excluding declines due to natural influences and events (e.g. forest fires or hurricanes)[2]

b. That declines in expected ecosystem service flow where there is no associated reduction in ecosystem condition should not be considered ecosystem degradation (e.g. where, *ceteris paribus*, provisioning services from forests decline because of reduced logging due to decreases in expected output prices, or declines in cultural services due to a rise in national park entry fees).

As for the definition of depletion, the SEEA EEA retains the fundamental principles that ecosystem degradation:

- Must reflect a loss in condition; and
- That this loss in condition, must be due to human activity.

The first of these principles ensures that measures of ecosystem degradation are connected to physical changes in the quantity or quality of the ecosystem asset. The second principle aims to ensure that the measure of ecosystem degradation can be interpreted as a deduction from income earned from production, i.e. a cost of capital, as distinct from other causes of changes in wealth.

An initial definition of ecosystem degradation may therefore be proposed as:

> Ecosystem degradation is the decrease in the expected ecosystem services flows over an accounting period arising from a reduction in ecosystem condition that is due to human activity.

A significant challenge that arises in fully adopting this definition arises from the implicit intention to apply the definition to measurement in both physical and monetary terms. As discussed at length in the following paragraphs, integrating economic concepts of future service flows and ecological concepts of changing in condition is not as straightforward as might be hoped without specific assumptions. In part, this may be due to conflating the discussion across physical and monetary measurement.

With this particular issue in mind, we propose that the definition above apply specifically to measurement in monetary terms. Separately we propose that that physical underpinning of this measure be referred to as ecosystem deterioration. We therefore have two related definitions

> Ecosystem deterioration is the reduction ecosystem condition over an accounting period that is due to human activity.
>
> Ecosystem degradation is the decrease in the expected ecosystem services flows over an accounting period arising from ecosystem deterioration.

[2] Declines due to natural events are recorded in ecosystem asset accounts but are not considered a part of ecosystem degradation.

In the discussion that follows most of the focus is on the measurement of ecosystem degradation – i.e. in monetary terms and taking a more classicial economic and accounting perspective.

As should be evident, the description of ecosystem degradation in the SEEA EEA focuses heavily on the expected future flows of ecosystem services from a single ecosystem asset. This is due to the unique feature of ecosystem assets wherein there are multiple ecosystem services from a single ecosystem asset. The assumption in the proposed definition is that ecosystem deterioration (i.e. the loss of condition due to human activity) leads to a reduction in future ecosystem services. This is certainly analogous to the measurement of depreciation and depletion since, in these cases, there is only one service flow for each asset to be considered.

Even if this assumption is reasonable in a majority of situations, the presence of multiple ecosystem services requires this assumption to be unpacked such that a full range of potential combinations can be considered. Three key considerations emerge:

- First, since there are a number of ecosystem services, it seems conceivable that ecosystem deterioration could lead to either an increase or decrease in aggregate expected ecosystem service flows with losses in some services offset by gains in others. Unpacking the combinations of changes in condition and changes in expected ecosystem service flows is therefore relevant.
- Second, since there are multiple services there will likely be multiple users and beneficiaries thus implying that changes in ecosystem services flows will affect different units in different ways. The combinations of connnections between ecosystem assets and economic units, and the role of the concept of economic ownership needs to be incorporated in describing the accounting entries for degradation.
- Third, since the condition of ecosystem assets is likely to be influenced by many factors, rather than only the action of one economic owner, accounting for changes in condition that are not due to the activity of one economic unit need to be considered.

Terminology

Before discussing each of these considerations, a separate issue that has arisen concerns the use of the terms depletion and degradation. The distinctions between the use of these terms in the SEEA Central Framework and the SEEA EEA are reflected in the table below, where the series of entries between opening and closing stock are characterized for various types of assets. For ecosystem assets, depletion constitutes a subset of degradation, since depletion refers only to the capital cost associated with provisioning services from an ecosystem, in cases where the provisioning services are being generated unsustainably. Degradation encompasses capital costs associated with provisioning and other ecosystem services. An important requirement is that there is a consistency of treatment within the accounting framework with respect to consumption of fixed capital (depreciation of produced assets), depletion and degradation.

Table 1: Accounting entries for depletion and degradation (SEEA EEA Table 7.3)

	Accounting entry				
Type of assets	*Opening stock*	*Transactions*	*Other changes in volume*	*Revaluations*	*Closing stock*
Produced assets		Gross fixed capital formation (investment) **Consumption of fixed capital / Depreciation**	Primarily physical appearance and disappearance of assets - Discoveries - Catastrophic losses - Reappraisals of stock	Changes in value between opening and closing stocks due solely to changes in prices of assets	
Natural resources		**Depletion**			
Ecosystem assets		**Degradation**			

From this starting point, the following five options have emerged as potential alternatives for using the terms depletion and degradation in reference to the general concept of recording the cost of using up environmental assets (encompassing both natural resources and ecosystem assets).

i. Use depletion for all natural resources and degradation for ecosystem assets implying an overlap in scope. The current SEEA framing which effectively suggests that when accounting within the SEEA Central Framework context use depletion and when accounting within the SEEA EEA context use degradation)

ii. Use depletion for non-renewable natural resources only and degradation for renewable assets including ecosystems. This would eliminate the overlap in scope (pending clarity on the precise boundary e.g. with regard to peat and soil resources). It would reflect a change in the SEEA Central Framework interpretation in that the cost of using up biological resources such as timber and fish would be called degradation rather than depletion.

iii. Use depletion for all natural resources, including those within ecosystems (e.g. timber and fish), and use degradation for ecosystems but excluding reference to provisioning services. This is likely very problematic from conceptual and practical perspectives. While it retains the SEEA Central Framework approach, for ecosystem accounting it implies that ecosystem asset values can be partitioned by type of service and that the cost of capital with regard to each asset can be assigned to individual services (as distinct from attribution to individual users/economic units). From a presentational point of view, it would also seem odd if an ecosystem asset was shown as having both depletion and degradation.

iv. Use only one term in all contexts, i.e. either depletion or degradation whether recording the cost of using up natural resources or ecosystem assets. Merit in this option may arise in that the term depletion is evident in the SNA and also that the term degradation has a range of other interpretations outside of accounting (e.g. some interpret degradation as occurring when an ecosystem cannot be restored which may imply recording only after a considerable decline in condition has already taken place).

v. Introduce a new term, for example, consumption of environmental assets/natural capital, to be used in all cases. This may have some merit in the sense of being able to define a distinct concept for accounting purposes and, the phrasing given here is aligned with the SNA concept of consumption of fixed capital. While a neat resolution, it would continue to require explanation of the difference between the accounting concept and terms in general use – in effect mirroring the discussion previously held in SNA circles on switching from depreciation to CFC.

In the remainder of this paper the terms depletion and degradation are applied as per the current SEEA framing – i.e. option 1 – noting the amendment above that includes the additional term ecosystem deterioration to refer to the change in physical terms.

Aligning changes in condition and changes in expected ecosystem service flows

To help frame the discussion of the cases in which treatments need to be determined Table 2 presents the potential combinations. What emerges is that where the expected flows of ecosystem services move in the same direction as the change in condition, the treatment is relatively clear. However, it is less clear what to do in cases where they move in different directions, or when there is no change in condition. The initial proposal in Table 2, which is considered further in a worked example later on, is to record these changes as other changes in volume.

Table 2: Combinations of changes in ecosystem assets

		Rise in expected ES flows	**Fall in expected ES flows**
Decline in ecosystem condition	**Due to human activity (deterioration)**	Other change in volume	Degradation
	Due to natural influences	Other change in volume	Catastrophic loss, Disappearance
Rise in ecosystem condition	**Due to human activity**	Enhancement	Other change in volume
	Due to natural influences	Appearance	Other change in volume
No change in ecosystem condition		Other change in volume	Other change in volume

A starting point for working through these issues is to recognise that the bundle of ecosystem services from any single ecosystem asset will be a combination of competing and complementary services. Competing services are those where their increased supply is likely to reduce the supply of other services and complementary services are those where their increased supply will also see a rise in other services. In general terms, regulating services and many cultural services will be complementary and provisioning services and some cultural services will be competing. Further, all else being equal, the ongoing supply of competing services will likely be negatively correlated with ecosystem condition. The ongoing supply of complementary services will likely be positively correlated with ecosystem condition.

In aggregate then, where ecosystem condition is in decline, this is likely to reflect the effect of the increased supply of competing services and an associated fall in supply of complementary services. It is possible to imagine that the changes in supply of competing and complementary services may offset each other, and indeed, imagine scenarios in which the competing services rise to a greater extent than complementary services fall. However, it is considered here that these “net positive” changes in expected ecosystem service flows reflect short term, partial assessments that do not capture the full system-wide and intergenerational expectations. The converse applies in the context of rising ecosystem condition and falling expected ecosystem service flows.

In terms of accounting treatments, it is therefore proposed that, at least in theory, no entries are required to cater for the hypothetical situation of rising/declining condition and corresponding declining/rising expected ecosystem service flows. However, in sutuations where this does happen, we propose to record this as other changes in volume as shown in Table 2 and illustrated in the example later on.

The last case to consider concerns no change in condition but either rises or falls in expected ecosystem services flows. Where there is no change in condition, the starting assumption is that the ecological potential to supply the current bundle of ecosystem services is unchanged. In this context, rises or falls in the expected ecosystem service flows must arise via either changes in expected demand for services (e.g. through population growth/decline) or changes in the bundle of ecosystem services. Since there are no changes in condition it is not appropriate to record either degradation or enhancement but the changes in expected ecosystem service flows will reveal themselves in changes in the values of ecosystem assets recorded on the balance sheet. Consequently, an entry is required in the broader asset account to ensure coherence in the accounts.

As initial proposals, rises in future flows could be considered the appearance of an asset and declines in future flows could be treated along the lines of obsolescence for produced assets. In both cases the entries would be considered as an “other change in volume”. Changes that are purely related to expected changes in prices should be treated as revaluations.

An alternative framing in which accounting treatments could be developed is to depart from the core ecosystem accounting model which has a bundle of ecosystem services supplied by a single ecosystem asset and, instead, consider each future stream of ecosystems services as a distinct asset. In this framing there is no inherent aggregation or consideration of competing and complementary services. Degradation would be assessed at the level of a single ecosystem service in terms of changes in expected service flows and using a measure of condition that was solely related to the specific ecosystem service. The use of an ecosystem service specific condition measure would mean that there must be a positive correlation between changes in condition and changes in expected ecosystem service flows. In turn, this implies there will be no entries required to cater for the situation of rising/declining condition and corresponding declining/rising expected ecosystem service flows.

The significant cost in following this alternative framing is that the inherent link between each ecosystem service and the overall management of a given ecosystem can be lost unless this is forced analytically by spatially overlaying information on each service. Further, even if overlaying was undertaken, the interpretation will necessarily be incomplete since it is limited to the set ecosystem services that are included rather than being viewed from the alternative perspective of the underlying ecosystem asset.

Multiple users and beneficiaries

In concept and practice, the depreciation of produced assets and depletion of natural resources is readily attributed to a single economic owner since the future stream of income accrues to a single owner. Even in cases of joint ownership, or less distinguishable situations of mixed legal and economic ownership (which can arise in the context of mineral resources), attribution remains relatively straightforward since there is a single income stream that is involved and the estimated depreciation or depletion can be partitioned using appropriate conventions. The attribution to the economic owner reflects the fact that it is this economic unit that will suffer the income loss associated with the decline in the stock.

In the case of ecosystem assets, the existence of multiple ecosystem services, and hence multiple income streams, for a single asset which degrades as a single physical stock, the attribution of degradation is much less clear. The standard starting point from an SNA perspective is to attribute the degradation to the economic owner/manager of the ecosystem asset but it is also relevant to consider an alternative starting point in which degradation is attributed to the economic unit deemed to have caused the degradation – i.e. adopting a polluter pays principle. This alternative framing was embodied in the discussion of degradation in the 1993 SEEA using the notion of allocating “costs borne”. Given these two starting points, the following four treatment options can be considered.

A first option then is to consider that the total degradation is attributed to the economic unit that owns and manages the ecosystem asset (using general government as a default owner as required). This option assumes that as a consequence of being able to direct the management and hence condition of the ecosystem asset, this economic unit is the “ultimate” supplier of the bundle of ecosystem services and hence all degradation is attributable to them. This treatment reflects the default starting position from a national accounting approach in terms of its consistency with the treatment of capital costs associated with other assets. A drawback with this option is that some final users of the future ecosystem services do not have degradation costs deducted from those streams and the associated asset (balance sheet) values, assuming that it is appropriate that those users are treated as joint owners.

A second option is to partition the degradation by recognising multiple owners of a single ecosystem asset. In effect, each user of an ecosystem service is considered a part owner such that the total value of the ecosystem asset is partitioned and the degradation is also spread across each user. The drawback of this option is that it separates the ownership from the management of the ecosystem. Further, while the final user of an ecosystem service might be considered a joint owner, it is also possible to consider that there is a flow of the ecosystem service from the economic unit managing the asset to that final user, in which case the concept of ownership would not be appropriate. For example, suppose a forest manager receives income from selling timber and from carbon markets through sequestering carbon. In this case, while the final user of the carbon sequestration would generally be considered to be the government (on behalf of society), there is a clear benefit stream flowing to the forest manager for both ecosystem services. Attributing ownership, and degradation, to the government in this case would seem to ignore this benefit stream.

A third option is to consider a focus on the economic unit causing the degradation rather than on the economic owner (a polluter pays based approach). Of course, there will be many situations in which this is the same economic unit (e.g. deforestation of agricultural areas), in which case the attribution of degradation will reflect either option one or two. Indeed, it is interesting to observe that option 1 will capture the effects of the activities of the economic owner on other users and as such it might be considered a partial polluter pays approach.

A fourth option is to consider that the ecosystem asset is a stand alone economic unit and all degradation is initially attributed to that stand-alone unit. Subsequently, transfers could be included to attribute degradation to economic units following options 1, 2 or 3.

In deciding between these options for the attribution of degradation, it is fundamental that the question of ownership of ecosystem assets is more widely understood and discussed. This is a focus of discussion paper 5.3. No single proposal for the attribution of degradation is therefore made at this time here. It is also noted that, in due course, a complete set of accounting entries following the various allocation options will need to be developed.

Treatment of changes in the physical stock that are not due to economic activity

As noted above, from a national accounting perspective, ecosystem degradation reflects the capital cost that should be deducted from the gross income arising from the use of an ecosystem asset in production. Thus, degradation should not include changes in the value of the asset that occur for other reasons. Those reductions—which are treated as a distinct entry, namely, “Other changes in volume”—contribute to an understanding of the overall change in the value of assets over an accounting period.

In practice, national accounting has tended to take an exceptions based approach and records entries of “Other changes in volume” only in cases of clearly identifiable events. These include, for example, the discovery of mineral resources, and adjustments for the effects of large natural disasters where there is a significant loss of produced capital. It is proposed that a similar approach be applied for ecosystem accounting such that degradation is recorded following the general definition above, except in cases where the decline in ecosystem condition can be attributed to specific, discrete large events, especially natural disasters. In an ecosystems context, this approach reflects a grey line between declines in condition due to human activity and natural causes but it does not require a definitive position to be taken on the precise drivers for changes in ecosystem condition.

Other considerations

While the general intent of this definition remains valid, the treatment in a number of specific situations requires further consideration. Some of these were recognised in the SEEA EEA while others have emerged since. Three specific issues are noted here:

i. Treatment of complete changes (conversions) in ecosystem type, for example, from a forest area to an agricultural area (recognising that these might be considered as improvements in purely economic (SNA) terms);

ii. Treatment of situations in which economic activity, including household consumption, has indirect and potentially delayed impacts on ecosystem condition, for example, impacts arising from human-induced climate change;

iii. Treatment of declines in condition of ecosystem assets that are not direct suppliers of final ecosystem services, for example, remote forests.

Treatment of complete changes (conversions) in ecosystem type

In the discussion of ecosystem degradation during the drafting of the SEEA EEA, a particular concern was the ability to appropriately record degradation in cases where there was a complete shift in ecosystem type – an event referred to as an ecosystem conversion. Building on the definition of ecosystem degradation from SEEA EEA introduced above, the section (4.2.3) goes on to say:

> 4.32 This approach to conceptualising ecosystem degradation is particularly relevant in situations where the extent of an ecosystem asset does not change over an accounting period, or more specifically in the case of ecosystem assets defined by EAU [now EAA] (whose area will generally remain stable), when the composition of an EAU in terms of areas of different LCEU [now ET] does not change. However, where the extent or composition of an ecosystem asset changes significantly or irreversibly (e.g. due to deforestation to create agricultural land) the consequences for the definition of ecosystem degradation are less clear and will relate to the scale and complexity of analysis being considered. These types of changes are referred to as ecosystem conversions.
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> 4.33 From one perspective, the use of an area of land for an alternative purpose may result in a decrease or an increase in expected ecosystem services flows from that area. If it is the former then an argument may be made to call this decrease ecosystem degradation. However, since the general effect of ecosystem conversions is for there to be increases in some ecosystem services and declines in others, the comparison of expected ecosystem service flows will require assessment of two different baskets of ecosystem services. It is further complicated by the changes in inter-ecosystem flows that arise as the adjacent ecosystem assets may no longer receive or provide the same bundle of flows from/to the converted ecosystem asset. Adjacent ecosystem assets may thus also become degraded.
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> 4.34 Another approach in cases of ecosystem conversions is to focus only on changes in ecosystem condition in the area within the ecosystem asset that has been converted, e.g. the part of the forest that has been converted to agricultural land. Under this approach, it may be considered that ecosystem degradation occurs whenever an ecosystem conversion results in a lowering of ecosystem condition relative to a reference condition within the converted area. Then, irrespective of the impact of a conversion on expected ecosystem service flows from the ecosystem asset as a whole, it may be relevant to record ecosystem degradation so as to reflect an overall decline in condition due to human activity.

4.35 A third approach to ecosystem degradation focuses on the more general question of whether the change in the extent and condition of an ecosystem is so significant that it is not possible for the ecosystem to be returned to something akin to a previous condition – i.e. the change is irreversible. This approach is not followed in SEEA Experimental Ecosystem Accounting as it does not fit well within a model based on assessment of change over successive accounting periods. Thus, recording ecosystem degradation only at the time where it was known that the situation was irreversible would lack the transparent, ongoing recording of change in ecosystem assets that is one goal in ecosystem accounting.

Although the discussion of ecosystem conversion somewhat dropped out of the discussion on ecosystem degradation in the Technical Recommendations, the issues raised in the paragraphs above are no doubt real. Indeed, the topic of ecosystem conversions (without the use of that term) arose during recent discussion on the measurement of ecosystem condition, i.e. how to measure change in condition when a specific area changes from being, for example, a forest to cropland, and further, what is the relevant reference condition - should a natural state or desired/target state be used or perhaps both should be shown. Further, the issues of scale of analysis, described in 4.34 above, have re-emerged in the context of ecosystem asset valuation with regard to determining marginal and non-marginal changes, In this discussion, the valuation of marginal changes is considered more tractable but the spatial scale and resolution at which change is considered marginal is open to discussion.

It is certainly the case, as recognised in SEEA EEA, that the accounting concept of degradation (as with depletion and depreciation) works best when applied to a single type of asset progressively over time. Pending much further discussion on the appropriate accounting treatment, one way forward may be to recognise separate accounting entries for ecosystem conversions (both positive and negative) distinct from both ecosystem degradation and the entry of “reclassification” which would be the traditional default entry when an asset changes classes (and has been used in the design of the ecosystem extent account). Distinguishing ecosystem conversions from ecosystem degradation would better highlight issues such as deforestation and better recognise the outcomes from restoration activity.

At the same time, the reality that ecosystem conversions are likely to have mixed outcomes with respect to the volumes and values of ecosystem service flows means that there remain issues of treatment to work through. Also, there are potentially changes in economic ownership that need to be taken into account. Further, it will be relevant to work through a variety of scenarios since the reasons for changes in ecosystem type will vary and different reasons may motivate the use of different accounting treatments. This must include accounting for ecosystem conversions that arise through natural changes.

Treatment of situations in which economic activity, including household consumption, has indirect and potentially delayed impacts on ecosystem condition

The challenge here relates to estimating future flows of ecosystem services on the assumption that there are links between condition and service flows. In the context of the net present value framing, the fact that the impacts on ecosystem condition (and hence ecosystem service flows) may be well into the future is not a problem if the timing and magnitude of the impacts is known and can be incorporated into the estimation process. The challenge arises when the timing and magnitude are unknown and not incorporated in which case any ecosystem asset valuation and associated measures of degradation will not incorporate these effects.

A common scenario might be that evidence of impacts emerges such that the expectations of future service flows change. From an accounting perspective, identifying a change in expectations is relatively straightforward since each successive NPV (at the end of the accounting period) should be considered an independent assessment of the expectations at that point in time. However, it does raise a question as to the appropriate accounting entry to recognise the change in expectations during the accounting period. One option is to record the change simply as part of degradation. A better alternative in concept would be to record the change as a reappraisal.

In either case, it is not recommended to rework past valuations since if the evidence and associated expectations were not present, then it is not appropriate to suggest that the valuations would have been different. Certainly, there is a requirement to explain the change in value between points in time but this explanation should not be hidden in the accounts by recasting past estimates based on new assumptions.

Treatment of declines in condition of ecosystem assets that are not direct suppliers of final ecosystem services

The treatment of these declines in condition is a legitimate concern if the focus of measurement and valuation of ecosystem assets is only on final ecosystem services, i.e. where the user of the ecosystem service is an economic unit (business, government, household). This is because the ecosystem assets that are valued will be only those supplying final ecosystem services and this will ignore the role of other ecosystem assets in supporting the delivery of those services.

One accounting solution is to recognise the supply of ecosystem services between ecosystem assets, i.e. intermediate ecosystem services (as described in the SEEA EEA Technical Recommendations), and hence allow for the estimation of the NPV of each of the ecosystem assets that ultimately contributes to the final ecosystem service. There are some practical concerns about this approach since it may suggest that all flows of all services between all ecosystem assets must be recorded. In fact, as noted in the Technical Recommendations, the scope can be readily limited from an accounting perspective – for example, by limiting the inclusion of intermediate services to cases where there is a direct link to an observable final ecosystem service. In this way, not all potential connections between ecosystem assets need to be recorded and appropriate materiality considerations can be applied. While this approach can be reasonably readily applied in the context of supply and use tables, further discussion is needed on treatments in the context of the sequence of accounts where issues of sector allocation and ownership need to be considered.

If this approach is accepted, then measuring ecosystem degradation for remote ecosystem assets that supply only intermediate ecosystem services is conceptually identical to the approach used for those supplying final ecosystem services but utilising the NPV of the future stream of intermediate services as the basis for the calculation. It is noted that with respect to a single final ecosystem service, the effect of recording an extended supply chain of services from multiple ecosystem assets, is to partition the NPV across ecosystem assets that would have previously been attributed solely to the ecosystem asset supplying the final ecosystem service.

Notwithstanding the conceptual framing suggested here, there may be significant measurement challenges in implementing such an approach, particularly in terms of assigning values to intermediate ecosystem services. Also, there are some questions of economic theory to work through including understanding the potential effects of policy changes and the assessment of general equilibrium effects.

3. Linking ecosystem degradation and ecosystem capacity

The Technical Recommendations, building on earlier work in Hein et al 2016, described the possibility of linking the theory and measurement of ecosystem degradation with the measurement of ecosystem capacity ,where capacity was considered to provide a bridge between the condition of the ecosystem and the future flows of services. Discussion of this proposal in Glen Cove in June 2019, indicated that there was merit in further developing the concept of ecosystem capacity to underpin discussion of the sustainabile use of ecosystem assets. However, linking capacity to the measurement of ecosystem degradation was considered to be advancing too far in accounting terms. This section describes the proposal to link ecosystem capacity and degradation to support understanding of the idea and to seek wider feedback on the approach.

Defining capacity

Capacity for an ecosystem asset - EA, *of ecosystem type i,* to provide a set of services *j* can be defined as the following function:

$$(1)\quad Capacity(EA_i) = \sum_{j=1}^{n} ES_j^{sust} = f(condition(t)|regime(t);\ extent(t))$$

That is each ecosystem asset has a capacity to supply a certain set of ecosystem services indefinitely, depending on its condition (at *t*) and conditional on the current management regime or existing institutional mechanism (at *t*) and its extent at time (t). Indefinitely is meant here in a physical sense e.g. sustainable yield when talking about fisheries.

The concept of capacity captures the sustainable supply of a given set of ES for a given ecosystem asset while maintaining a given condition. This is important as ecosystems are living things with the power to rebound / rejuvenate / regenerate, which warrants a different approach compared to non-renewable assets.

Where the ecosystem asset generates a set of complementary (non-competing) ES, there exists a unique capacity set, defined by the capacities with respect to each individual ES. However, where the asset provides a set of competing ES, there may be multiple capacities. To be concrete, the capacity of Ecosystem A could be defined as: supply ES_1 at 100 units, ES_2 at 50 physical units, ES_3 at 80 units. The assessment of capacity is herewith primarily an ecological / scientific question, although it is possible that there currently is over-use / over-extraction of the ecosystem, depending on the current management regime.

The capacity of an ecosystem will depend on its condition. The link with condition is essential to ensure that we are developing an integrated ecosystem accounting system.

The management regime is important. The regime defines the interventions affecting condition as well as thresholds for use. If we are talking about a protected area, even though there may be interest in logging, if this is not allowed, it is not a feasible service flow. There may be policy interest in assessing the potential of an ecosystem in supplying timber (e.g. when doing a cost benefit analysis) but in that situation we would be discussing a distinct concept, referred to here as the capability of an ecosystem i.e. we reserve the concept of capability to discuss alternate management regimes. The management regime is used as a checklist to assess which ES are currently allowed/provided (and hence can be expected).

The actual demand level for the services does not enter the capacity function as we are assessing sustainable levels in a physical sense. The only thing that is relevant is whether a specific ES flow is taking place (0 or 1). If logging is allowed, but does not take place (and is not expected to take place), then it would not be part of the set of ecosystem services, and hence not part of the capacity set.

A concrete example including a spatial dimension[3]

As ecosystem accounting is spatially explicit, it is important to also take changes in extent into account i.e. ecosystem conversions. Table 3 contains a worked example that shows how one can derive an exact decomposition of opening and closing stocks in terms of degradation/enhancement and

[3] The example assumes that no interaction takes place between the variousETs.

ecosystem conversions. The approach described provides a potential pathway forward in implementating accounting conventions in the context of ecosystems.

The starting point is an ecosystem accounting area (EAA) consisting of 4 different Ecosystem Types (ET), (forests, agricultural land, wetlands and water/lakes) with areas measured at t1 and t2. The forest ET has 3 different ES that are being supplied (timber, carbon sequestration and nature based recreation), and agricultural land, wetlands and water/lakes all supply one ecosystem service. All ET's (and in fact all ES) are characterized by a condition variable (for instance "age" for forest, soil depth for crops provisioning), which increase / decrease from t1 to t2 (indicated in colors: up, down, equal). We assume we have been able to estimate all ES in physical terms and we are able to estimate the level of sustainable flows / capacity (in terms of annual rates) at t1 and t2. We further assume that the price of all services is 1. To give an example, the actual ES flow of timber harvest is 10, whereas the sustainable flow is 8, therefore we see a deterioration in condition, causing the sustainable flow for t2 to be reduced from 8 to 7.

We assume that forests and wetlands are being converted into agricultural land. We further assume a discount rate of 10 %, a life time of 10 years for the service flows (e.g. as we are overusing the ESs). This leads to a net present value for all ETs in the EAA of 1450 in t1 – the beginning of the accounting period, which declines to a net present value of 1253 at the end of the accounting period -t2.

Table 3: Mock-up example of estimating degradation and enhancement

forest		wetland										
crops		water										
t1								physical	monetary	monetary		
ET	ES	actual	unit	condition		area	price	capacity	actual	tot_act	NPV act	act_acre price
Forest	timber	10	tons	age		4	1	8	10	40	$246	$61
	carbon sequestratio	12	tC	biomass		4	1	12	12	48	$295	$74
	nature based recreat	20	visitors	shannon		4	1	16	20	80	$492	$123
Agricultur	crops	8	tons	soil depth		4	1	6	8	32	$197	$49
Wetland	fishing	5	tons	BOD		4	1	5	5	20	$123	$31
Water	provisioning of wate	4	m3	PB		4	1	4	4	16	$98	$25
											$1,450	
forest		wetland										
crops		water										
		actual	unit	condition			price	capacity	actual	tot_act	NPV act	act_acre price
Forest	timber	9	tons	age	down	3	1	7	9	27	$166	$55
	carbon sequestratio	12	tC	biomass	equal	3	1	12	12	36	$221	$74
	nature based recreat	20	visitors	shannon	down	3	1	14	20	60	$369	$123
Agricultur	crops	9	tons	soil depth	equal	6	1	7	9	54	$332	$55
Wetland	fishing	5	tons	BOD	up	3	1	6	5	15	$92	$31
Water	provisioning of wate	3	m3	PB	up	4	1	4	3	12	$74	$18
											$1,253	

In order to get an exact decomposition (in which opening stocks + sum of all changes equal closing stocks without any residual terms) we estimate; i) the V_{act}(ETi)) ii) V_{act} per acre in t1 and t2) iii) the average acres (between t1 and t2) . As shown in Table 4 – we can decompose the value changes into 2 elements: (i) the changes in net present value per unit of an ecosystem type (e.g. average forest area during the accounting period multiplied with change in Vact per acre of forest between t1 and t2); and (ii) the changes in net present value of each ecosystem type due to land conversions (i.e. (average value in the accounting period multipled by change in area per ET from t1 to t2).[4] This is relatively

[4] This approach is essentially the same as followed in SEEA CF where the asset price in situ is derived based on V(asset)/Stock – here we derive a net present value per acre of ecosystem type.

standard price and volume decomposition and builds on the approach described in the SEEA Central Framework Annex 5.2 for estimating the value of depletion for a renewable asset.

Table 4: Decomposition of changes in value between t1 and t2

Opening stock		**1450**	Condition	ES flows
	delta forest (average)	-22	down	fall
	delta water (average)	-25	up	fall
	delta agriculture (avera	31	equal	rise
	delate wetland (averag	0	up	equal
	conversion forest	-255	loss in forest area	
	conversion water	0	area remains equal	
	conversion wetland	-31	loss in wetland area	
	conversion cropland	104	gain in cropland area	
Closing stock		**1253**		

In a next step, we need to interpret these changes and label them as degradation, enhancement or other elements of the asset accounts described in this paper. For the first group of changes, the treatments from Table 2 can be used. Thus:

- For forests, the change is clearly degradation since there are declines in both condition (at least for 2 out of 3 ES – we will discuss this point further below) and expected ES flows.
- For water, we see that the condition improves (better water quality), but the expected ES flows decline (e.g. due to lower demand). This element can be characterized as an other change in volume.
- For agriculture, we see that condition remains equal, but expected service flows go up, so this is an example of enhancement.

Regarding the conversion changes, what we see is an increase in cropland areas at the expense of forest and wetlands. This change (according to UNCCD guidelines[5]) should be interpreted as land degradation (in a physical sense – deterioration in the terms used here). As the expected ES flows related to this change are also decreasing, we should classify the net effect of these changes as degradation. NB: if the changes in service flows would have been positive, we would classify this as other changes in volume.

With that we are able to compile the asset account for the combined area as in Table 5 – the total degradation costs would amount to 203, enhancement 31 and other changes in volume -25.

[5] This is the approach at least of the definition of SDG indicator 15.3.1 – land degradation. This indicator combined 3 sub-indicators on 1) land cover change 2) land productivity and 3) carbon stocks. The land cover change sub-indicator captures essentially ecosystem conversions, with a default interpretation of green (improvements) and red (degradation). Land productivity is assessed based on NPP (combining state, trend and performance); carbon stocks are assessed based on SOC. The One Out All Out principle is applied at a per pixel basis. The final indicator is reported as a percentage of degraded over all (terrestrial) land.

Table 5: Decomposition of changes in value between t1 and t2

Opening balance			**1450**
	degradation		-203
	enhancement		31
	obsolescence		0
	(dis)appearance		0
	other changes in volume		-25
Closing balance			**1253**

The example can be expanded to take price changes (e.g. leading to revaluation) or changes in management regime (e.g. leading to obsolescence) into account. The decomposition will become more compex, but the principle stays the same: i.e. decomposing the change in net present value into price and quantity components, which are then classified in a second step based on the agreed definition of what constitutes degradation, enhancement, etc. The example serves to illustrate that the current notions of extent, condition, capacity, degradation/enhancement/conversion can be captured comprehensively.

Additional considerations

The implementation of management regimes will likely involve costs (e.g. maintaining fire safety zones; maintaining hiking paths). These will be recorded in the SNA production accounts and may also be captured in complementary environmental protection or resource management expenditure accounts. A possibility would be to reclassify these costs as inputs into generation of ES, e.g. for governments from government final consumption towards intermediate consumption by ecosystems. In this case, when accounting for ES flows, it would be relevant to record both the output of ES and the costs of generation thus estimating a value-added for the ecosystem asset that is less than the value of the outputs.

Illegal activities that are actually taking place, say poaching from protected areas, or provisioning of bushmeat, are included as ES even when not part of the formal management regime. This is consistent with the production boundary of the national accounts, which includes production of these goods (and as a consequence the associated consumption) whether production is illegal, hidden, subsistence, etc. The ES reflect the inputs to the production of these goods.

Linkages to the condition account

The working assumption has been that the condition account would describe for each ecosystem type (and a fortiori for each individual asset) a set of condition indicators, that would be sufficient to allow estimating the capacity of the asset (and hence the sustainable flows of the set of individual ES which make-up the capacity set) in question. This does not imply that we need to specify ecological production functions, it may be sufficient to have at least one condition variable that is indicative to assess the sustainability for each individual ES. For the decomposition approach in the example above (i.e. with a forest generating 3 ecosystem services), we determined whether the condition of a specific ecosystem asset (in this case the forest) was declining or improving – that is we need to be able to aggregate the condition variables for the individual services to establish an overall aggregate indicator.[6]

[6] It may be technically possible to avoid this, by spliiting up the forest into 3 – for each ES and decompose at a more detailed level but this seems less intuitive and also inconsistent with the general concept of ecological integrity.

This places a demand on the content and compilation of the condition account and hence further discussion on the connections between the measurement of condition and capacity is important.

4. Alternative approaches to the measurement of ecosystem degradation

Notwithstanding the challenges of definition and treatment of ecosystem degradation in specific scenarios as discussed in the previous section, it is clear that the ecosystem accounting framework described in the SEEA EEA has opened a new pathway for national accounts to discuss issues around the recording of ecosystem degradation. Indeed, the conceptual alignment of ecosystem accounting with standard capital accounting means that, at least in theoretical terms, the measurement of ecosystem degradation can be described in analogous fashion to the measurement of depreciation and depletion.

At the same time, there have been a range of other approaches to the measurement of degradation that have been developed in a SEEA context. The on-line supplement to this discussion paper provides a summary of materials from the SEEA 1993 and SEEA 2003 which describe these other approaches to degradation. In general terms the focus is on different framings of costs associated with environmental degradation, either the costs caused or the costs borne. Both perspectives are of relevance to decision making and their connection to the approach described in ecosystem accounting needs to be clearly articulated.

The SEEA Central Framework and SEEA EEA build on the developments in the earlier SEEAs, although in the area of ecosystem accounting this bridge is far less clear. While a number of relevant concepts were discussed in the 1993 SEEA and SEEA 2003, the integrated capital-based accounting described in the SEEA EEA represents a different framing of the issues. Of particular note is the focus in the earlier SEEAs on economic aspects as distinct from the incorporation of ecological aspects (such as concerning the measurement of condition).

5. Recording measures of ecosystem enhancement

In economic terms, it seems clear enough that the treatment of ecosystem enhancement would in some way mirror the treatment of ecosystem degradation. Indeed, the proposed definition and description of ecosystem enhancement in the SEEA EEA (just below) points in this direction. However, as described following the SEEA EEA text, a number of other accounting issues need to be considered.

SEEA EEA text: Ecosystem enhancement and other changes in ecosystem assets

4.36 Ecosystem enhancement is the increase and/or improvement in an ecosystem asset that is due to economic and other human activity. Ecosystem enhancement reflects the results of activities to restore or remediate an ecosystem asset beyond activities that may simply maintain an ecosystem asset. As for ecosystem degradation, different measurement perspectives may be considered for ecosystem enhancement that focus on changes in expected ecosystem service flows in combination with changes in ecosystem condition and extent. Again, ecosystem enhancement associated with the conversion of ecosystems to alternative uses, requires specific consideration.

4.37 Increases and declines in ecosystem assets that are not due to economic or other human activity should be recorded as other changes in ecosystem assets. Changes due to natural regeneration and normal natural loss should incorporate inter-ecosystem flows (both into and out of the ecosystem) and implicitly should reflect the ongoing intra-ecosystem flows since it is these flows which underpin the regeneration process. For some purposes it may be useful to explicitly account for certain inter-ecosystem flows to highlight dependencies between ecosystem assets (e.g. flows of water between ecosystems). It may be the case that reductions in inter-ecosystem flows reduce the capacity to generate some ecosystem services.

4.38 In practice, consistent with the measurement of the depletion of biological resources as defined in the SEEA Central Framework, it is necessary to account for both reductions in expected ecosystem service flows due to human activity (most commonly through the extraction and harvest of biological resources) and the increases in expected ecosystem service flows (not necessarily of the same services) due to natural regeneration of the ecosystem. To the extent that the reductions are greater than the increases then ecosystem degradation should be recorded.

4.39 For a single ecosystem asset, if, over an accounting period, the increases due to natural regeneration are greater than the reductions due to human activity, then ecosystem degradation should be zero and the extra regeneration should be shown as an addition to ecosystem assets.

Treatment options for ecosystem enhancment

To frame the discussion in accounting terms, it is important to recognise that the issue at hand does not concern recording the total change between the opening and closing balance sheet positions. As for all assets, this change may be positive or negative. The question for accounting is how to record the components of that change, for example whether they are due to human activity or use of the asset in production, due to price changes or due to natural events. Depending on the source of the change, different accounting treatments and recording conventions will be relevant, recognising the broad requirement that the total change in the value is fully apportioned across relevant accounting entries.

Further, it may be useful to distinguish different degrees of enhancement. Within the UNCCDs Land Degradation Neutrality conceptual framework a distinction is made between:

- Restoration: where the aim is to re-establish pre-existing structure and function, including biotic integrity
- Rehabilitation: where the aim is to reinstate ecosysem functionality with focus on supplying a range of ecosystem services
- Reclamation: where the aim is to return degraded land to a useful state, e.g. for agriculture.

It is likely that the same accounting treatments and entries should be applied in each of these cases, building on the following discussion, but for analytical and policy purposes separating these types of enhancement may be relevant.

Four cases are therefore considered concerning increases in asset value (referring here to changes in nominal values between balance sheet dates):

i. The increase is due to changes in asset prices
ii. The increase is due to natural events/processes leading to an improvement in condition
iii. The increase is due to human activity leading to an improvement in condition
iv. The increase reflects increases in the expected ecosystem service flows without change in condition

In practice, some combination of the four is likely and indeed there will likely be offsetting decreases that also need to be recorded. Nonetheless, considering each of these specific cases in turn will be appropriate in decomposing the change and describing the accounting issues. As a general observation, the earlier discussion on the challenges of accounting for ecosystem conversions in the context of defining degradation will be equally relevant here.

For case (i) the treatment is straightforward and these changes are recorded as revaluations. Not considered in this paper, but worthy of further discussion, is the treatment of changes in the asset value that are due to changes in the assumptions used to estimate the NPV of an asset between opening and closing positions, for example applying a changed discount rate. This issue is a general issue rather than an ecosystem accounting specific one, but clarification on the appropriate treatment for national accounting related purposes is required.

For case (ii) it seems unlikely that significant increases in condition due to natural events and processes will take place over a single accounting period (unlike the potential for significant losses of ecosystem condition through natural disasters such as cyclones and bushfires). Nonetheless, two situations can be distinguished. The first concerns ecosystems where there is active human extraction of natural resources (e.g. from forests or fisheries) and over the accounting period there will be the potential to estimate both the volume of extracted resource and the volume of regeneration of the resource. In forestry this would be referred to as a net increment. It is proposed that these increases in volume be regarded as affecting (reducing) the rate of overall depletion/degradation of the asset and hence they would not be recorded as distinct measures of ecosystem enhancement. Of course, there may be periods during which the net extraction is negative (i.e. the overall growth of the resource is greater than the harvest). It is proposed that such net amounts be recorded as the appearance of an asset.

The second situation is where there is no extractive activity and the ecosystem asset "simply" improves in condition through natural regeneration. In this case as well, it is proposed that the changes be recorded as the appearance of an asset. However, this proposal should be considered in the light of any discussion about case (iii) below.

For case (iii) where there is activity undertaken by economic units to improve ecosystem condition, i.e. restoration activity, the treatment in accounting terms is less clear. The challenge involves reconciling (1) the reality in the SNA that the activity of restoration can be considered to be a process of production that results in a produced asset; and (2) the extension of the SNA production boundary to encompass ecosystem services within the SEEA EEA. Two main alternatives appear possible but accepting that much further discussion is needed to work these options through:

a) To treat the expenditure on restoration activity in line with the treatment of land improvements in the SNA whereby the costs of the activity are capitalised as a produced asset and incorporated into the overall value of the associated/underlying asset. This would result in an entry as gross fixed capital formation with the consequent impacts on GDP to be worked through. Note that as for the valuation of land – there may well be changes in the value of the ecosystem asset from opening to closing that are greater or less than the value of the costs of the restoration/improvement. It would seem appropriate in this situation to treat these as appearances of an asset.

b) To recognise the costs of the economic activity as an input to the activity of the ecosystem asset in regenerating itself but where the value of the regeneration is reflected in the change in the expected flows of ecosystem services. In effect this could be seen as creating an operating surplus (ES outputs less intermediate and capital costs) that is attributable to the ecosystem asset as a producing unit through a process of own-account capital formation. In taking this alternative, the implication is that the ecosystem asset becomes akin to a produced asset. While this may sound a more unusual alternative, it is perhaps the appropriate "mirror" treatment with respect to ecosystem degradation and is a potential pathway through the unfortunate SNA convention wherein the value of a produced asset (land improvements) needs to be somehow partitioned from the value of a non-produced asset (land) on the balance sheet.

There are likely a range of other considerations to be discussed here and these paragraphs should be considered a catalyst for discussion. It is simply noted that the broadening of the production boundary to include ecosystem services opens up the possibility of re-framing the distinction between produced and non-produced assets. It is further noted that this issue does not arise, or need to be considered, when, there is a persistent decline in the condition of ecosystem assets due to human activity.

For case (iv), it is considered that if the condition of the ecosystem does not change then ecosystem enhancement should not be recorded, notwithstanding the potential for the expected service flows to increase due to other factors, e.g. population growth. These increases should be recorded as appearance of an asset as required.

Overall, there are some interesting issues requiring consideration in the area of ecosystem enhancement. They deserve attention given the increasing awareness of the need for restorative action, especially with regard to conserving and increasing biodiversity. In addition there may be some important connections to the discussion of the treatment of other unpriced stocks and flows, such as relating to the use of data and information. These topics are under discussion in the national accounts community in the context of measuring the digital economy and some of the underlying accounting and economic aspects may be applicable in an ecosystem context.

6. Recording liabilities related to ecosystem assets

Examples of approaches to recording liabilities related to ecosystem assets

The recording of accounting entries concerning changes in ecosystem assets, primarily degradation, has also been associated with a notion of recording ecological liabilities (and the associated concept of ecological debt). The general idea is to use the accounting concepts of assets and liabilities to make explicit that current economic activity is degrading the environment and leaving future generations with a cost that must be paid, thus establishing a current liability.

While this general idea appears compatible with standard accounting treatments, the various proposals cover a range of different interpretations of the concept of liabilities as understood in national and corporate accounting. In short while there may appear a close connection between recording degradation and recording liabilities, in fact the connection must be seen as more nuanced.

This section describes the alternative approaches to establishing ecological liabilities that have emerged in the literature and discusses the extent to which they are aligned with standard accounting treatments.

Unpaid ecological costs and similar approaches)

The concept of unpaid ecological costs refers to uncompensated ecosystem and ecosystem services loss and was described by Vanoli (2015), presented by Kervinio (Bonn ecosystem valuation workshop, 2018) and summarised in Schweppe-Kraft (2019). This approach starts from the premise that the actual expenditures undertaken to restore ecosystem function can be compared to the estimated expenditures to restore ecosystem function to a socially desired state and, to the extent that the actual expenditures are too low, the difference represents unpaid ecological costs. The real challenge here is determining the socially desirable state where the costs of achieving this reflect a social willingness to pay. Considerations in making this determination would be based on an understanding of the benefits obtained from the ecosystem (e.g. ecosystem services, intrinsic values); an understanding of relevant ecological thresholds and boundaries; identification of the socially desired state and connections to relevant environmental regulations, standards and policy which can be used as an indicator of social preferences. It seems likely that the use of this approach implies an assumption, or starting point, of strong sustainability, which may not be compatible with the valuations of other assets and liabilities elsewhere in the national accounting system.

Liabilities in corporate natural capital accounting

Corporate natural capital accounting (CNCA) is an approach developed under the auspices of the UK Natural Capital Committee (eftec et al, 2015). It has a range of features that are very similar to ecosystem accounting including the recognition of ecosystems as assets and recording the flow of ecosystem services. Aside from being intended for application at the business level, it is also clear that the CNCA places a stronger emphasis on valuation and aggregates in monetary terms. With this in mind it has incorporated an estimate of liabilities that reflect future maintenance costs associated with ensuring that the ecosystem asset meets required condition standards that have been set in law/regulation or set in other business policies (e.g. meeting Forest Stewardship Council certification requirements). This estimate of future costs is deducted from the gross ecosystem asset value to provide an estimate of net natural capital value.

Recognising liabilities under Australian Accounting Standards

Ogilvy et al (2018) apply a related line of thought to that expressed in CNCA but focus more specifically on integration with the full suite of financial and economic accounts. In this approach, a direct link is made to the relative condition of the relevant ecosystem asset and the estimable costs of restoring condition. Unlike the other approaches described, the context for estimating the liability is set in terms of a lease arrangement where the owner of the ecosystem (grazing land) leases the land to a manager with the stated requirement that the land is returned at the end of the lease in the same condition as when the lease commenced. It is demonstrated in this approach that standard accounting valuation techniques can be applied such that the liability is recognised progressively through the course if it emerges that the condition of the grazing land cannot be returned to the condition at the start of the lease. The valuation of the liability, payable by the lessee to the lessor, encompasses both the estimated actual expenditures required to restore the land and any lost income associated with the reduction in condition such that the lessor is unable to receive the same stream of rent that would otherwise have been payable. Usefully, from a SEEA perspective, it is shown that the relevant accounting entries can be recorded following both corporate accounting standards and the SNA (although a slight variation in the treatment of resource leases is required to ensure equivalent balancing items under the two accounting systems).

Liabilities in capital accounting

A final perspective on liabilities comes from consideration of the economic literature on the valuation of assets. In this view, assets are valued based on the present value of expected real income flows where real income reflects the net benefits arising from the asset. Fenichel et al (2018), in the context of valuing natural assets in an ecosystem setting, describe the situation in which when there are multiple components within an ecosystem each contributing to an overall asset value there may be situations in which a single component has a negative influence on the overall asset value in which case this component would itself have a negative price and hence could be regarded as a liability. Put differently, there is an opportunity cost associated with failing to dispose of the asset.

Discussion of approaches

Aside from the final perspective, which is somewhat of an outlier in accounting terms, two core issues emerge:

i. The estimation of liabilities at a minimum requires an understanding of estimated expenditures and costs in relation to an agreed or expected condition.

ii. The determination of the circumstances under which a liability should be recognised in accounting terms.

On the first, it is clear from national and corporate accounting standards that liabilities only arise when there are clear and accepted future obligations and costs (see Ogilvy et al 2018 for a summary). Recognition of liabilities should therefore be seen as distinct from the valuation of assets. By way of example, the value of a house should not be considered to be the market value of the house less any associated home loan. This net position represents the net wealth/worth of the owning household, but it does not reflect the value of the asset itself.

This paper assumes that the estimation of future expenditures and costs is possible, at least in theory, for any agreed condition. Although it is noted that the scope of relevant expenditures and costs will need further discussion, particularly since corporate accounting standards (as discussed in Ogilvy et al) allow for expected income losses to be included in addition to restoration costs. In particular, it needs to be clarified as to whether this opens the door to the recognition of future losses of non-market benefits. A starting position on this is that it does not – i.e., for accounting the intent in measuring liabilities is limited to cash related expenditures and costs. This is directly associated with the concept that liabilities in the national accounts are more strictly financial liabilities which each have a corresponding financial asset within the SNA's quadruple entry recording system. There may be more leeway here in the double entry recording system of corporate accounting which could be an interesting area of discussion.

On the second issue, which feels to be the larger challenge, its resolution also requires determination of an agreed/target condition potentially legally, scientifically or socially established. As a first observation, if there is no expectation that the restoration will occur, then, at least for accounting purposes, no liability should be recognized. In this regard, as evident in the work of Ogilvy et al, it may not be sufficient that there be a legal requirement for restoration but also that the relevant laws and regulation are actually expected to be enforced.

With this rule of thumb in mind, it then becomes an open question as to whether the unpaid ecological costs approach which is based around the use of legal and policy context to provide evidence of social preferences, gives a sufficiently strong sense of the likelihood of restorative action (and hence the incurrence of a liability). In many respects, one might think that the situation in terms of expectations of restorative action is changing but understanding the requirements from an accounting perspective and being able to talk to the assumptions underpinning the estimates will be fundamental.

Beyond these two issues, but linked to the first, there will be a need to be clear about the recording of liabilities in the accounts relative to the recording of assets. In general terms, while accounting defines a balancing item of net wealth reflecting the value of assets less liabilities, there is no explicit "matching" of individual assets and liabilities to provide estimates of net wealth within an entity (linking to the housing example above). Indeed, when the ecosystem asset and the future restoration costs are conflated, it can give rise to an interpretation that sees the recognition of the liability as reflecting the degradation of an asset, implying that there is a fall in asset value and an increase in a liability for the same event. In turn this suggests a double-counting on the balance sheet in terms of the impact on net wealth.

On further consideration however, this interpretation may not be appropriate. In fact, it is plausible to record the value of an asset at its depreciated value as well as recording the existence of a liability associated with future costs – the housing example applies here very well. The confusion arises from not placing a sufficiently broad context on the entities and entries involved. Specifically, while the ecosystem asset has value in and of itself, the liability will have an offsetting financial asset (in effect a type of "accounts receivable" for those undertaking the restorative work). The overall net wealth effect then, ignoring value added associated with the restoration work, will be only the decline in ecosystem asset value.

The discussion to this point has focused directly on liabilities related to the changing condition of ecosystem assets. A broader framing might also consider the idea of environmentally related liabilities in the sense of capturing additional costs, for example in relation to the loss of produced assets, that can be associated with changes in environmental assets (e.g. deforestation leading to increases in air pollution and effects on buildings), with the extraction of natural resources and similar economic activity (e.g. oil spills), or as a result of climatic events and trends (e.g. from hurricanes, rising sea levels).

Overall, clarifying the relevant entries in the sequence of accounts with respect to recording ecosystem assets and any associated liabilities will be important, particularly in terms of attribution to economic units and sectors. Also necessary, will be demonstrating the appropriate interpretation of any liabilities that are recorded in the system.

7. Conclusion and research questions

The paper covers a very large range of issues relevant to the accounting for ecosystem assets and the changes in these assets over time, particularly ecosystem degradation. Importantly, there is a significant quantity of existing material and a history of thinking about these matters that can be drawn on to establish appropriate accounting treatments. This paper provides a particularly national accounting perspective to the framing and discussion of the issues and, in due course, this will need to be complemented with material from an economic perspective. As highlighted in the companion discussion papers on the valuation of ecosystem assets and on national accounts recording principles, there is much commonality among accounting and economic approaches but there are important issues to consider in the definition of measurement boundaries that need greater exposition and understanding.

Following initial discussion and review of the various materials, the following key issues emerge as being of particular importance in identifying appropriate accounting treatments for the revision of the SEEA EEA.

- Establishing an agreed use of the terms, including: depletion, degradation, deterioration, enhancement and restoration
- Clarifying the scope of degradation with regard to human activity and unforeseen events
- Mapping out the links in monetary and physical terms between degradation and
    - changes in condition
    - changes in ecosystem capacity
    - changes in expected ecosystem service flows, including those due to changes in demand
- Considering the treatment of ecosystem conversions (i.e. changes in ecosystem types) recognising that these changes are likely to be non-marginal in economic terms and also of different types and hence potentially requiring alternative accounting treatments.
- Clarifying the approach to the valuation of ecosystem assets that supply intermediate ecosystem services
- Clarifying the approach to recording ecosystem enhancement, considering also links to work on other unpriced stocks and flows such as those related to data and information.
- Ensuring clear and coherent connections to the ownership of ecosystem assets in the context of the SNA definition of economic and legal ownership, and the relationship to the flows of multiple ecosystem services to multiple beneficiaries.

- Determining appropriate approaches to the allocation of degradation, considering both the attribution of the cost to the owner of the ecosystem asset and the attribution of the cost to the economic units that are considered to cause the degradation. Elaborating the various accounting entries in the full sequence of accounts using a numerical example would be an important component of this work.
- Assessing the merits of the various approaches to recording ecosystem related liabilities, especially in the context of the overall balance sheet.

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