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Session 3d: Valuation and accounting treatments

Discussion paper 5.4: Issues and options in accounting for ecosystem degradation and enhancement

Working draft

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SEEA EEA Revision

Working group 5: Valuation and accounting treatments

Discussion paper 5.4: Issues and options in accounting for ecosystem degradation and enhancement

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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 1980 and has a much longer history in economics. Conceptually, the intent is to be able to adjust measures of Net Domestic Product (i.e. GDP less the capital cost of produced assets) for this natural capital cost and so demonstrate that a more comprehensive measure of economic performance 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 provide additional alternatives.[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.

Beyond the discussion of ecosystem degradation, three other issues of accounting treatment are considered in this paper:

- *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 treatment of ecosystem enhancement and restoration* – both 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.

- *The extended SNA sequence of accounts.* The intent to provide adjusted measures of national income and wealth is ultimately reflected in national accunting terms within a complete sequence of accounts that highlights the linkages between production, income, saving, capital accumulation and balance sheets. Extended sequences of accounts are proposed in SEEA EEA Chapter 6 but there is a choice provided between a so-called Model A in which the ecosystem asset is attributed to the balance sheet of an existing economic unit (e.g. agricultural land attributed to a farmer); and a Model B in which ecosystem assets are treated as a new quasi-institutional unit. There are pros and cons of both approaches and discussion of the options (and possible alternatives) is undertaken.

Before discussion of each of these topics, the paper provides an overview of the framework for accounting for assets and income in the national accounts that, in turn, provides the basis for developing accounting treatments within ecosystem accounting.

All of the discussion in this 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. However, since this is a strong assumption and measurement practice in this area is still developing, the paper also considers a range of alternative approaches that may assist in at least broadening the discussion in national accounting terms if not providing a final, fully integrated solution.

This the third in a series papers on valuation and accounting treatments being prepared as part of the revision of the SEEA Experimental Ecosystem Accounting (SEEA EEA) for discussion at the Forum of Experts on Ecosystem Accounting to be held in New York in June 2019. The two other papers cover issues on the valuation of ecosystem services for accounting purposes and the valuation of ecosystem assets. 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.

2. Framework for accounting for assets and income in the national accounts

Before discussing how to account for the degradation of ecosystems, it is important to outline some of the key accounts, concepts, definitions and accounting rules that underpin ecosystem accounting which emerge from the System of National Accounts (SNA). The SNA is a set of accounts or economic statistical statements, each one providing an aggregated portrait of economic activity during a given period. Each account differentiates itself from the others by providing a different perspective of the economy, whether it measures production, the generation and distribution of income, the use of income, capital formation, financing activity, wealth positions or our engagements with the rest of the world.

Because these accounts all use a common set of definitions, concepts and classifications, and are explicitly related to each other, they form an integrated system. As a result, the economic information occurring from the "system" are coherent. At a high level the "system" records the change in wealth from one period to another by recording the transactions and other economic flows that occur during an accounting period. The system is often described as starting with the production account but in fact the starting point is the opening balance sheet. This is particularly important in the context of ecosystem accounting since one of the main areas of analysis involves recording the degradation in ecosystems resulting from economic activities. The complete list of accounts is shown in table 1.

Table 1 Elements of the sequence of accounts and their balancing items.

Account	Key Activity	Balancing item
Current accounts		
Production account	Production	Gross value added

Generation of income account	Income accruing to the factors of production	Gross operating surplus and mixed income
Allocation of primary income account	Income accruing to the owners of the factors of production	Balance of primary income
Entrepreneurial income account		Entrepreneurial income account
Allocation of other primary income account		Balance of primary income
Secondary distribution of income account	Re-distribution of income	Disposable income
Use of disposable income account	Use of income via consumption or saving	Saving
Redistribution of income in kind account		Adjusted disposable income
Use of adjusted disposable income account		Saving
Accumulation accounts		
Capital account	Capital transfers and investments in non-financial assets	Net borrowing or lending
Financial account	Investments in financial assets and borrowing	Net borrowing or lending
Other changes in the volume of assets account	Other economic flows	
Revaluation account	Other economic flows	
Balance Sheet Account	Stocks	Net worth

Each account within the SNA has the same structure. One "side" of the account is used to record increases (+) in value and the other "side" of the account is used to record reductions (-) in value. The difference between the increases and reductions is referred to as the balancing item.

Production, wealth (as reflected in the value of the stock of assets) and income play a prominent role in the sequence of accounts. Production is an activity carried out by an institutional unit using capital, labour and intermediate inputs. Wealth aggregated across all sectors is represented by assets that are owned and used repeatedly in the production process for more than one year or that otherwise generate a series of benefits for an economic owner (e.g. interest and dividend flows). Income represents the payments to the factors of production that were used in the production process or primary incomes that accrue to owners of financial assets.

The sequence of accounts starts with the opening balance sheet account. The balance sheet account records the stock of non-financial assets, financial assets and liabilities and the resulting net worth both for the economy as a whole and for each resident institutional sector (households, non-profit institutions serving households, financial corporations, non-financial corporations, general governments).

Non-financial assets are further broken out into produced non-financial assets and non-produced non-financial assets. Produced non-financial assets (such as machinery and buildings) enter the system via the ***production account***. Changes in non-produced assets, such as land are recorded via the ***other change in the volume of asset account***. Like land, ecosystems themselves are considered non-produced assets in the SNA.

Beyond the produced/non-produced distinction, the second important SNA concept pertinent to ecosystem accounting concerns ownership. The SNA distinguishes between two types of owners of assets. The legal owner which is the institutional unit that is entitled under law to claim the benefits of the asset and the economic owner which is the institutional unit that is entitled to claim the benefits associated with the use of asset by virtue of accepting the associated risks. In many cases the legal owner and the economic owner are the same institutional unit but this is not always the case, for example when an airline company (the lessee) leases planes from a financial corporation (the lessor). The issue of ownership is complicated with ecosystem assets since it may not be clear who is the legal owner of the asset. Further, the economic owner may not be apparent since there may not be institutional units that have assumed the associated risk with using the ecosystem.

The 'second' account in the SNA sequence of accounts is referred to as the generation of income account. The generation of income account shows, for sectors and industries, how the income generated through production is distributed to the factors of production. In general terms it records the payments to capital and labour. The payment to labour is referred to as compensation of employees and the payment to capital (the assets used in the production of the goods and services) is referred to as gross operating surplus (or gross mixed income when the payment to labour and capital cannot be distinguished – one from the other).

Gross operating surplus is further divided into two components. One component is referred to as consumption of fixed capital. When assets are used to produce goods and services part of the life of the asset is consumed or used up during the accounting period. From one perspective, consumption of fixed capital can be seen as the decline in the value of the stock of fixed assets owned and used by a producer as a result of physical deterioration, normal obsolescence or normal accidental damage. Consumption of fixed capital can also be viewed from an income perspective. It can be seen as representing the income that needs to be set aside to replenish that part of the asset that was 'used up' in the production process. Consumption of fixed capital is valued at replacement cost – or the cost to the institutional unit to replace the capital it consumed at today's prices. The remainder (the difference between gross operating surplus and consumption of fixed capital) is referred to as net operating surplus. This represents the return to owners of capital (of all types) after accounting for the income required to replenish the fixed capital stock.

At this point it is good to pause and discuss the implications of these entries when accounting for ecosystems. As noted, ecosystems are not produced and consequently, their degradation is not covered in the measurement of consumption of fixed capital. "***Consumption of fixed capital does not, therefore cover the depletion or degradation of natural assets such as land, [ecosystems], mineral or other deposits, coal, oil or natural gas or contracts, leases and licences***" (2008 SNA, paragraph 6.241). The complication with ecosystems, and indeed other non-produced assets, is that institutional units can and often do 'use' the capital (ecosystems) 'free' of charge. Because they are able to use the ecosystem free of charge there is no "payment" recorded in the SNA with respect to ecosystems that reflects the capital cost.

A 'third' set of accounts in the SNA that records income flows is referred to as the ***allocation of primary income account***. This account is used to record the 'transfer' or allocation of income from the institutional unit using (financial) capital to the institutional unit owning (financial) capital. The complication associated with ecosystem accounting is that even if we are able to attribute some of the gross operating surplus to ecosystems it is not clear where (which institutional sector) the income should be transferred. This is why the issue of the ownership of ecosystem assets is critically important. Also relevant with respect to income flows are the use of income and redistribution of income accounts. These accounts allow for transfers between institutional units to be recorded including taxes and government transfers. The balancing item for these accounts is net saving.

The **capital account** subsequently records the resources or funds available to purchase capital and the uses of the funds for the net purchase of non-financial assets. When the sources of funds are greater than the use of funds the sector is a net lender and when the sources of funds is less than the use of funds the sector is a net borrower. The resources come from three main sources, current period net saving, the consumption of fixed capital (noted earlier) and net capital transfers received. The consumption of fixed capital can be viewed as the funds or income the firm (sector) needed to set aside to maintain its capital stock.

The recording in these accounts is well established provided we are not including the role that ecosystems play in the production of goods and services. If we consider that ecosystems are an asset and that during the production process the ecosystems are 'used up' (i.e. there was degradation) then some income should be set aside to allow for the replenishment of the ecosystem. The key challenge, which is the topic of this paper, is what value do we place on the degradation of the ecosystem and to which sector should it be allocated.

In addition to transactions in non-financial assets (recorded in the capital account) and transactions in financial assets (recorded in the **financial accounts**), changes in assets are also recorded in the **revaluation account** and the ***other change in the volume of asset account***. The latter account is used to record changes in wealth that are not due to transactions or revaluations, but are the result of other economic flows. For example, if a building is destroyed in a fire, there is a loss in value but it is not due to a transaction (including depreciation) or revaluation. The other change in the volume of asset account is used to record the appearance of an asset, the disappearance of an asset or the change in the value of an asset this is not due to a transaction or a revaluation. Again, this is particularly important for ecosystems which are often impacted (positively or negatively) by such events. If an ecosystem is destroyed by a fire or impacted by a flood then the loss in wealth would be recorded in this account.

Finally, as noted earlier the stock of assets is recorded in the ***balance sheet account***. Assets are classified as either produced assets or non-produced assets and are recorded at market prices. Non-financial assets are recorded against the sector of the economic owner rather than the sector of the legal owner. Both the market price valuation principle and the ownership principle pose problems for ecosystem accounting. First, ecosystems are not sold on the market and therefore determining an appropriate valuation requires consideration of non-market values. Second, many benefits from ecosystem asset can be considered public goods and hence the link between benefits and economic owners is likely to be unclear. Having said that, the SNA can provide a framework for the recording of ecosystem assets as well as the degradation of ecosystem assets that occurs as a result of the production of goods and services and other economic activities. Using the national accounts framework would make the information coherent with the other parts of the System of National Accounts.

3. Defining ecosystem degradation

Linking degradation and depletion

The definition of ecosystem degradation within a national accounting context 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 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 two fundamental aspects of this definition are that depletion is,

i. Related to changes in the physical stock of environmental assets

ii. Arises due to the activity of economic units.

Consequently, changes in the value of environmental assets over an accounting period that are due solely to changes in price or due to factors not related to economic activity are not considered within the definition of depletion.

While this is consistent with the definition of deprecation (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 the 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, provided ownership can be established this attribution is also possible but since the declining condition may not be due to the activities of the owning firm, there may also be interest in understanding the effect of pollution and emissions of other firms. More discussion is required on how this question of scope and attribution of degradation should be dealt with for the SEEA EEA, recognising the framing inherent in the SNA for produced assets. Such discussion must encompass the treatment of expectations with respect to future changes in the asset (including with respect to extreme events) and the role of obsolescence in the definition of depreciation.

Although finalised before the completion of initial work on ecosystem accounting, the SEEA Central Framework provided a clear initial framing for ecosystem degradation in relation to measures of depletion. Later in Section 5.4.2 it notes

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.

This text from the SEEA Central Framework introduces some of the complexities in defining and measuring ecosystem degradation in a national accounting context. In general terms, and in line with the general premise of this paper, it is considered that the issues of measuring multiple ecosystem services and changes in the quality of ecosystem assets are dealt with in other discussion papers.

Ecosystem degradation in the SEEA EEA

Based on this general framing, 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).

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

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

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

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

iii. 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;

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

What is not covered in this paper but remains for discussion is the treatment of declines in the expected service flow when there is no change in condition (noting that a change in condition may be reflected in a changing composition of the stock of an asset). Such a change will reveal itself in changes in the values of ecosystem assets recorded on the balance sheet but an entry is required in the broader asset account to ensure coherence in the accounts. As initial suggestions, it is noted that such changes should likely be treated as revaluations if they are purely price related. Falls in future flows might be treated along the lines of obsolescence of produced assets (which raises a question of expected and unexpected obsolescence). Rises in future flows with no change in condition might be considered appearance of an asset as an "other change in volume". Overall, this is considered to be a relatively marginal issue in practice but determining the appropriate treatment may provide insights for the choice of accounting treatments in other situations.

More broadly, to help frame the discussion of the cases in which treatments need to be determined, consider the following table. What emerges from the table is that where the expected flows of ecosystem services moves in the same direction as the change in condition the treatment is relatively clear. It is far less clear what to do in cases where they move in different directions, or when there is no change in condition. Some of these issues are a focus of discussion in this paper but it is clear that further discussion is required. It is noted here that an important consideration will be the definition and treatment of ecosystem capacity which itself may embody both condition and ecosystem service flows.

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**	Degradation?	Degradation
	Due to natural influences	Appearance?	Catastrophic loss, Disappearance
Rise in ecosystem condition	**Due to human activity**	Enhancement	Enhancement?
	Due to natural influences	Appearance	Disappearance?
No change in ecosystem condition		Appearance?	Obsolence?

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. In particular, reductions in asset value due to unforeseen events that are not related to the use of the asset in production (e.g., natural disasters) are not considered part of degradation for accounting purposes. 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. A point for further discussion however is exactly what constitutes "unforeseen". In an ecosystems context there are many future outcomes that are "knowable" from a scientific perspective even if there may be a lack of knowledge on the part of an individual economic unit. Unpacking the meaning and application of the term "unforeseen" and in particular how it might be considered with respect to individual economic units will be important. Further, changes in the value of an asset may be due solely to changes in prices, in which case they are considered revaluations for accounting purposes and separately recorded.

The distinctions between accounting entries are reflected in the table below, where the series of entries between opening and closing stock are characterized for various types of assets. It is to be noted that 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 3: Accounting entries for depletion and degradation (SEEA EEA Table 7.3)

<table>
<tr><td></td><td colspan="5">Accounting entry</td></tr>
<tr><td>Type of assets</td><td>Opening stock</td><td>Transactions</td><td>Other changes in volume</td><td>Revaluations</td><td>Closing stock</td></tr>
<tr><td>Produced assets</td><td></td><td>Gross fixed capital formation (investment)
Consumption of fixed capital / Depreciation</td><td rowspan="3">Primarily physical appearance and disappearance of assets
- Discoveries
- Catastrophic losses
- Reappraisals of stock</td><td rowspan="3">Changes in value between opening and closing stocks due solely to changes in prices of assets</td><td></td></tr>
<tr><td>Natural resources</td><td></td><td>Depletion</td><td></td></tr>
<tr><td>Ecosystem assets</td><td></td><td>Degradation</td><td></td></tr>
</table>

An interesting question arises in the cases of changes in the net present value of ecosystem assets over an accounting period that are not the result of changes in the capacity of the ecosystem to produce a given ecosystem service but rather due to unexpected declines or increases in the demand for specific ecosystem services. Since there is no reduction in capacity (assuming increases in demand are within appropriate thresholds), an entry of ecosystem degradation would appear to be inappropriate or at least misleading. At the same time, this change in value seems to reflect neither a change in volume or a revaluation. An initial proposal is that in such instances the change be treated as a reappraisal of the ecosystem asset. There are perhaps parallels here to the treatment of obsolescence[3] in the measurement of produced assets and also considering treatments used in the national accounts with respect to decommissioning costs.

A separate issue that arises from the table above is the use of the terms depletion and degradation. The table and description above convey the logic currently contained in the SEEA Central Framework and SEEA EEA in which there is an overlap between the measurement scopes of these two concepts since many natural resources are also components of ecosystems – e.g. timber and fish resources. Of course some natural resources, primarily mineral and energy resources are not components of

[3] See SNA2008 para 29.xxx: "The value of assets may decline not merely because they deteriorate physically but because of a decrease in the demand for their services as a result of technical progress and the appearance of new substitutes for them. In practice many structures, including roads and railway tracks, are scrapped or demolished because they have become obsolete"

ecosystems so there is no perfect nesting possible and conventions need to be established in terms of the use of the terms.

The following five options may be considered in using the terms depletion and degradation in reference to the general concept of recording the cost of using up environmental assets (natural capital).

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 in that an ecosystem asset could have 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. Further feedback on these options would be appreciated.

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 goes on to say:

> 4.31 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.

4.32 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.

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.

4.34 Another perspective 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 to reflect an overall decline in condition due to human activity.

4.35 A third perspective on 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 shifts from being, for example, a forest to cropland and 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 emerged in the context of ecosystem asset valuation with regard to determining marginal and non-marginal changes where 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. Further, it will be relevant to work through a variety of conversation scenarios since the reasons for changes in ecosystem type will vary and different reasons may motivate the use of different accounting treatments.

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 is 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 taking a change in expectations into account 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. It does raise a question as to the appropriate accounting entry to recognise the change in expectations during the accounting period. One option would be to record the change simply as part of degradation. A better alternative in concept would be to record the change as a reappraisal. 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 over 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 are those supplying final ecosystem services thus ignoring 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 legitimate concerns about this approach requiring all flows between ecosystem assets to be recorded. In fact, as noted in the Technical Recommendations, the accounting scope can be readily limited from an accounting perspective – for example, 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 should come into play. 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.

Linking ecosystem degradation and ecosystem capacity

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:

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

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*). 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 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 CBA) 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.

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.

We can now estimate two different asset values for the ecosystem asset in question; based on capacity (2) or based on expected flows of ecosystem services (3).

$$(2)\ \ V_{cap}(EA_i) = NPV(\sum_{j=1}^{n} p_j * ES_j^{sust})\ \ \text{[t = 1 .. infinity]}$$

$$(3)\ \ V_{act}(EA_i) = NPV(\sum_{j=1}^{n} p_{j,t} * ES_{j,t}^{act})\ \ \text{[t = 1 .. infinity]}$$

In the formula's NPV stands for net present value, $p_{j,t}$ the price of ES_j at time *t*. In lien with accounting practices, time is assumed to be discrete (e.g. denoting accounting years) – not continuous. The formula's show that V_{cap} is a lot easier to evaluate than V_{act}, as we would not need to estimate paths of how future ES develop, nor would we need to estimate the development of future prices for the individual ES_j.- hence t does not enter these subscripts in equation 2. In both equations we would need to assume a discount rate – an interesting question is whether that would have to be the same discount rate, or whether for Vcap social discount rate could be more appropriate.

These asset values will differ for a range of reasons, and the capacity value of the asset may be higher or lower than the actual value (depending on the profile of ES in combination with the chosen discount rate(s).

$$(4)\ \text{Degradation}\ (EA_i) = d\ V_{cap}\ EA_i\ /\ d\ \text{condition}\ (EA_i)$$

Ecosystem degradation - in monetary terms - can be subsequently defined as the change in capacity of an ecosystem asset to supply a set of ecosystem services (based on the management regime in place at the beginning of the accounting period), due to changes in condition (during the accounting period) only.[4] For example, it may well be that in the current situation, there is overuse of the ecosystem. This will likely imply that the condition of the ecosystem will deteriorate so by the end of the accounting period, the capacity of the ecosystem to supply the same set of services will have declined e.g. (and building on the example figures above) ES_1 at 95 physical units, ES_2 at 50 physical units, ES_3 at 78 units – which will also result in in monetary units The differences provide an estimate of degradation (or enhancement).

This implies the following:

- Changes in demand (reductions or increases) are not part of degradation (but other accounting entries e.g. obsolescence, appearance may be relevant)
- Changes in value due to changes in the regime (e.g. opening up for logging / prohibiting logging/regulating the type of logging) are not considered degradation. They may enter as obsolescence, reappraisals or potentially ecosystem conversions.

A concrete example including a spatial dimension[5]

As ecosystem accounting is spatially explicit, it is important to also take changes in extent into account i.e. ecosystem conversions. Table 4 contains a worked-through example that shows how one can derive an exact decomposition of opening and closing stocks (capacity and actual) in terms of degradation/enhancement and ecosystem conversions.

The starting point is an 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, 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, which increases / decreases from t1 to t2. We assume we have valued all ES in physical and monetary terms, and we are able to estimate the sustainable flows / capacity at t1 and t2. 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), infinite lifetime of course in case of capacity based valuations. 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 $V_{cap}(ETi)$) ii) V_{cap} per acre in t1 and t2) iii) the average V_{cap} and average acres iv) degradation/enhancement as changes in V_{cap} multiplied by respective acres v) conversions as changes in acres multiplied by average V_{ap}. [6]

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[4] It is assumed that condition is a vector i.e. it has values (for all ES_j at time t_1 and likewise at t_2).

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

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

We observe that as expected we see differences between V_{act} and V_{cap}. A key difference can be seen regarding the degradation of our water/lake ecosystem. We have assumed that the water quality has improved (e.g. as its condition characterized by its metal contents has improved, but we assumed a drop in demand). V_{act} shows a decrease due to a drop in ES flows, but V_{cap} increases as higher sustainable flows are possible reflecting the improved condition.[7]

The example can be easily expanded to take revaluation or changes in management regime/obsolescence into account. It illustrates the possibility of integrating the notion of extent, condition, capacity, degradation/enhancement/conversion.

Overall, the advantages of defining degradation as change in capacity are as follows:

- Empirically it may be easier to estimate V_{cap} than V_{act}, as we do not need to model / project demand: we only need an estimate of the current capacity i.e. set of sustainable yield given the current regime / condition
- Using V_{cap} to estimate degradation ensures that a direct connection is made with the extent and condition accounts. If there is no change in condition, there is no degradation/enhancement., which is not the case in V_{act} description, which is focused on expected ES flows.
- Defining degradation as a change in capacity, has a clear intuition, given that these assets are renewable.

Additional considerations

A note on terminology. Degradation is here defined as change in capacity, which can be expressed in monetary and in physical terms. We may also need terminology for changes in condition itself (i.e. in the set of condition variables). This could be called a <u>deterioration</u> of the condition of the asset.[8] Some people may wish to see ecosystem conversions as degradation as well (at least in case of changes in value).[9]

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 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. When valuing the ES flows, it is hence important to assess them as value added not as outputs (to avoid double counting).

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.

[7] NB: the ES here should be some sort of quality adjusted liters of water abstracted.

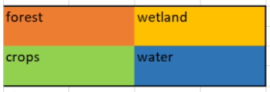
[8] Or alternatively, we call the change in condition degradation, and call the change in capacity value consumption of natural capital of renewable assets. The key thing is that we need different terms to distinguish the two.

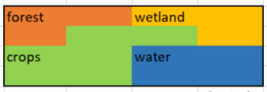
[9] This is the approach at least of the definition of SDG indicator 15.3.1 – land degradation. This indicator combined 3 sub-indicators on 1) land cover change 2) land productivity and 3) carbon stocks. The land cover change sub-indicator captures essentially ecosystem conversions, with a default interpretation 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.

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 would be sufficient to have at least one condition variable that is indicative to assess the sustainability for each individual ES. This would place a demand on the contents of the condition account. Further discussion on the connections between the measurement of condition and capacity therefore will be required.

Table 4: Estimating degradation and enhancement (mock-up example)





t1					t2			physical	physical	monetary	monetary	monetary				
ET	ES	actual	unit	condition		area	price	capacity	actual	sust	tot_act	tot_sust	NPV act	NPV sust	act_acre p	sus_acre p
Forest	timber	10	tons	age		4	1	8	10	8	40	32	$246	$320	$61	$80
	carbon sequestratior	12	tC	biomass		4	1	12	12	12	48	48	$295	$480	$74	$120
	nature based recreat	20	visitors	shannon		4	1	16	20	16	80	64	$492	$640	$123	$160
Agricultur	crops	8	tons	soil depth		4	1	6	8	6	32	24	$197	$240	$49	$60
Wetland	fishing	5	tons	BOD		4	1	6	5	6	20	24	$123	$240	$31	$60
Water	provisioning of wate	4	m3	PB		4	1	4	4	4	16	16	$98	$160	$25	$40
													$1,450	**$2,080**		
		actual	**unit**	**condition**			**price**	**capacity**	**actual**	**sust**	**tot_act**	**tot_sust**	**NPV act**	**NPV sust**	**act_acre p**	**sus_acre p**
Forest	timber	10	tons	age	down	3	1	7	9.8	6.5	29.4	19.5	$181	$195	$60	$65
	carbon sequestratior	12	tC	biomass	equal	3	1	12	12	12	36	36	$221	$360	$74	$120
	nature based recreat	20	visitors	shannon	down	3	1	14	20	14	60	42	$369	$420	$123	$140
Agricultur	crops	8	tons	soil depth	up	6	1	7	8	7	48	42	$295	$420	$49	$70
Wetland	fishing	5	tons	BOD	up	3	1	6	5	6	15	18	$92	$180	$31	$60
Water	provisioning of wate	4	m3	PB	down	4	1	4	3	5	12	20	$74	$200	$18	$50
													$1,231	**$1,775**		
		average acres		forest		3.5			Opening stock				1450	2080		
				agriculture		5				degradation forest			-4	-123		
				wetland		3.5				degradation water			-25	40		degradatic
				water		4				enhancement agriculture			0	50		
										enhancement wetland			0	0		
		average price			act	sust				conversion forest			-257	-343		
				forest	$257.46	$342.50				conversion water			0	0		
				agriculture	$49.16	$65.00				conversion wetland			-31	-60		
				wetland	$30.72	$60.00				conversion cropland			98	130		
				water	$21.51	$45.00			Closing stock				1231	1775		

Balance sheet implications

Now that we have defined ecosystem degradation, the main question is what we now want to show in the balance sheet? V_{act} would be consistent with common National accounts conventions, however degradation – because of the way it has been defined above - only occurs in the decomposition of V_{cap}. Both decompositions contain relevant information (e.g. obsolescence in V_{act}). One option may be to introduce a liability in the balance sheet as difference between both types of valuations (As in Table 5). The net worth would correspond with the V_{act} – the value as currently managed based on ES flows. The liability would indicate for instance the difference between the ecosystem asset as currently managed and if sustainably managed.

Table 5: Balance sheet (mock-up example)

		Asset	Liability	Net
Opening balance		2080	-630	1450
	Degradation	-123	118	-4
	Enhancement	50	-50	0
	Conversions	-273	83	-190
	Obsolescence	40	-65	-25
Closing balance		1775	-544	1231

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. Annex 2 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).

4. 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.

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.

Four cases are therefore considered concerning increases in asset value (referring here to nominal values at 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, 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. Set aside 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 rather than ecosystem accounting specific issue 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 concerning case (iii) below.

For case (iii) where there is activity undertaken by economic units to improve ecosystem condition the treatment in accounting terms is less clear. The challenge involves reconciling the reality in the SNA that the economic activity of restoration can be considered to result in a produced asset and the extension of the SNA production boundary to encompass ecosystem services within the SEEA EEA. Two main alternatives appear possible:

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 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 creates an operating surplus for 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 a produced asset. While this may sound a more unusual alternative, it is likely 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. 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 biodiversity.

5. Recording liabilities related to ecosystem assets

Examples of approaches to recording liabilities related to ecosystem assets

The notion of recording ecological liabilities (and the associated concept of ecological debt) has been proposed by a range of people. The general idea is to make explicit that current economic activity is degrading the environment and leaving future (and current) generations with a cost that must be paid. While this general idea is potentially compatible with standard accounting treatments, the various proposals cover a range of different interpretations of the concept of liabilities. This section aims to describe the alternatives and discusses the extent to which they may be aligned to 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. 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.

6. Integrated accounting for the use of ecosystem services and ecosystem assets

Introduction

As noted before, accounting for the production and use of services, or benefits, derived from ecosystem assets, and the accounting for the monetary value of stocks of ecosystem assets, including the recording of the various changes, among which the degradation of the relevant assets, that drive the developments in the values of the relevant stocks, require an extension of the production boundary and the asset boundary as currently applied in the international standards for compiling national accounts, the 2008 System of National Accounts (2008 SNA). Below, first issues around the extension of the current production boundary are discussed, with a focus on the similarities and differences between goods and services currently recorded in the system of national accounts and ecosystem services. Subsequently, the extension of the asset boundary with ecosystem assets will be discussed, again focusing on similarities and differences with the assets, which are recognised in the 2008 SNA.

Understanding the production boundary of the SNA

The 2008 SNA defines a general production boundary, and a more specific boundary to be applied in the actual compilation of national accounts. The general boundary is defined in § 6.24 as follows:

> *"Economic production may be defined as an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital, and goods and services to produce outputs of goods or services. … A purely natural process without any human involvement or direction is not production in an economic sense. For example, the unmanaged growth of fish stocks in international waters is not production, whereas the activity of fish farming is production".*

According to this general production boundary, it is clear that a variety of goods and services, among which most prominently unpaid household activities, such as preparing meals, taking care of children and elderly, and cleaning, are part of production. However, the 2008 SNA prescribes a more restrictive boundary, with specific reference to unpaid household services. The production of goods within households, the main example of which relates to subsistence farming, should always be included, while the production of unpaid services is excluded with the exception of owner-occupied housing and the production of domestic and personal services by employing paid domestic staff.

The main reasons for the exclusion of the main part of unpaid household services produced within households are summarised in § 6.30:

> *"…, the reluctance of national accountants to impute values for the outputs, incomes and expenditures associated with the production and consumption of services within households is explained by a combination of factors, namely the relative isolation and independence of these activities from markets, the extreme difficulty of making economically meaningful estimates of their values, and the adverse effects it would have on the usefulness of the accounts for policy purposes and the analysis of markets and market disequilibria".*

Some may consider the argument regarding the problems of making meaningful estimates of unpaid household services slightly exaggerated, as at the same time national accounts also include estimates for substantial amounts of informal, hidden and illegal activities. More important are the concerns around the usefulness of the accounts and the analysis of markets. One could add that the inclusion of unpaid household activities also leads to a concept of household income that is likely considerably different from the perception that households have of their income at the micro-level.

Quite close to the concept of services provided by ecosystem assets, at least when it comes to provisioning services, concerns the recording of agricultural products. As these products are goods, the production of these products, including the gathering of berries or other uncultivated crops; forestry; wood-cutting and the collection of firewood; hunting and fishing are always considered as part the SNA production boundary. However, the recording will differ depending on the particular circumstances surrounding the relevant activity. As stated in § 6.136 of the 2008 SNA, "*the growth and regeneration of crops, trees, livestock or fish which are controlled by, managed by and under the responsibility of institutional units constitute a process of production in an economic sense*". Often, for example in the case of crops, the growth and harvesting take place in the same year, and the output value can be put on a par with the value of the harvested products. However, "*some plants and many animals take some years to reach maturity. In this case, the increase in their value is shown as output and treated as increases in fixed capital or inventories, depending on whether it concerns plant or animals that yield repeat products or not"* (§ 6.138 of the 2008 SNA). A good example regarding the latter distinction between fixed capital and inventories concerns fruit trees versus trees grown for one-off wood production. The growth of fruit trees is to be considered as gross fixed capital formation, and the use of these trees in the production of fruits is to be recorded as depreciation, while the growth of trees for wood production is to be recorded as positive changes in inventories, the felling of which is to be accounted for as negative changes in inventories.

An important criterion applied in the above is that the growth and regeneration process is "controlled by, managed by and under the responsibility of" an economic agent. If the above is not the case, and the growth relates to a purely natural process without any human involvement, in line with the definition of the SNA production boundary in § 6.24, the growth is not production in an economic sense. Examples relate to the unmanaged growth of fish stocks in international waters, the growth of trees in "uncultivated" forests. Only goods produced by catching the fish, felling the trees, or picking berries, etc. enter into the production boundary.

However, it should be noted that the 2008 SNA is not that unambiguous. For example, in § 1.43, it is stated that *"… the natural growth of stocks of fish in the high seas* ***not subject to international quotas*** (bold inserted by the author) *is not counted as production: the process is not managed by any institutional unit and the fish do not belong to any institutional unit*". This can be interpreted as if the presence of international quotas can be regarded as a sufficient condition for the natural growth to be considered as part of the production boundary, while in the case of truly open access to fish in international waters only the catching of fish is entering the production boundary. The latter interpretation considering the presence, or not, of international quota, also makes one wonder about the recording of uncultivated forests, which are often under some form of control by the national government and cannot be used for e.g. wood production without an explicit permission provided by government.

Recording imputed output in the SNA

The above distinction may be less relevant for the recording of ecosystem services as such, but it matters when it comes to linking ownership of ecosystem assets to the benefits derived from them. It may also matter for the interpretation of the 2008 SNA and the SEEA Central Framework. Anyhow, it is clear that the inclusion of ecosystem services leads to an extension of the production boundary, as defined in the 2008 SNA[10]. But then again, that is the whole idea of accounting for ecosystems. However, to include ecosystem services in line with the main accounting principles, more conditions need to be met.

This can be illustrated by looking at other imputations of output in the SNA. The 2008 SNA includes such imputations for own account production of goods and services for own final use, be it final consumption expenditure or gross fixed capital formation. As noted before, unpaid household services are not included here, with the major exception of owner occupied housing. Another imputation for output concerns the production of government services, where output is put on a par with the sum of costs for producing these services.

In all these cases, the producer coincides with the user. For each relevant economic agent, the imputation of the benefits in the form of additional output is equal to the imputation of the use of these benefits, as a consequence of which the imputations balance out, resulting in a zero impact on net lending/net borrowing. The latter is necessary to arrive at a consistent recording in which the budget identity from double entry bookkeeping, according to which the balance of current and capital transactions needs to be equal to the balance of financial transactions, is respected. There is however one exception to this equality of output and use. Although in the case of government services, the use

[10] There is a discussion, however, on whether the natural growth of biological resources already accounts for provisioning services, and that the addition of the relevant ecosystem services, including their use, leads to double-counting. Here it is assumed that the ecosystem services are distinct from the natural growth, in the sense that the relevant services provide an input to the growth of biological resources.

of the imputed services is first allocated to government by convention, there is an alternative recording in the 2008 SNA in which the individualised government services (health, education, etc.), as distinct from collective government services, are also allocated to the households benefiting from them. To arrive at a consistent recording, an additional recording of social transfers in kind, from government to households, is applied to balance the imputation of the reallocation of the use of the individualised government services to household consumption.

Allocations for ecosystem services

In the case of ecosystem services, the benefits and their uses are much more mixed. Looking at a forest, for example, some of the services may be related to provisioning services, such as the production of timber, while another part may be consumed by the public at large in providing cultural services in the case of non-extractive recreation.

There are various solutions to this problem, which coincide directly with the question on how to account for the ecosystem assets from which these services are derived. The simplest solution is to allocate both the benefits and the uses to a separate sector, called “ecosystem”, thereby making a distinction between intermediate use for the part that is used in the production of goods and services, and final use for the part that is consumed by households. Another solution would be to partition the benefits (and the uses), and allocate them to the relevant economic agents, in line with their use.

In Table A6.1 of the SEEA 2012 EEA, two different models have been presented for the allocation of the benefits and uses of ecosystem services. According to Model A, the benefits are allocated to the separate sector “ecosystem”, while the uses have been attributed to the relevant economic agents, with an equivalent flow of transfers to off-set the use. In model B, the “ecosystem”-sector has been combined with the sector of the farmer who presumably owns the ecosystem (thereby cancelling out the output and intermediate consumption of the ecosystem services). Both models have their problems. Although in model A disposable income and saving is unaffected because of the off-setting flow of transfers, operating surplus and primary income are affected. The latter seems to be unjustified, as the use of the ecosystem services by the farmer does not involve a monetary payment that has an actual negative impact on his operating surplus. In model B, the simpler solution might have been to also allocate benefits to the households, in line with their final consumption of ecosystem services.

Another solution would be to consider the part of ecosystem services, which cannot be allocated to a specific group of economic agents, as a public good, and to allocate the output and use of them to government. This may work quite well in the case ownership of the underlying assets is less clear, and the benefits are used by the public at large, and not by a very specific group of economic agents. The use can subsequently be transferred to the households, enterprises and non-residents[11] benefiting from these services, while in other cases it is “simply” considered as collective consumption. The various types of ecosystem services may actually coincide with the different ways of recording in the above. Provisioning services could probably be attached to a specific group of economic agents (e.g. agriculture and fishing), while in the case cultural services such as those related to tourism and recreation one may prefer to apply the second way of recording. Regulating services, such as for example flood protection services have a clear resemblance with water protection services produced by government, and similar to the latter services they could be recorded as collective consumption. Proposals for the recording of ecosystem services in the sequence of accounts will be put forward later

[11] In the 2008 SNA, the imputation of such transfers, i.e. social transfers in kind, are limited to transfers to households. Having transfers to enterprises and non-residents would entail a considerable change to the recording, as it would also involve an imputation of final consumption by enterprises and, for the part allocated to non-residents, an imputation of exports. It should be noted however that there is also discussion of broadening such imputations for social transfers in kind benefiting non-resident households, and for free services provided by the digital economy.

in this paper, after a more in-depth discussion of the accounting for ecosystem assets, including the costs of degradation of these assets.

Accounting for (the degradation of) ecosystem assets

In SEEA EEA, the (imputed) output of ecosystem services is directly linked to the underlying ecosystem assets from which these services are derived. As such, accounting for the benefits and uses of ecosystem services has a direct relationship with the recording of ecosystem assets, including the way in which degradation of ecosystem assets is accounted for. Looking at the asset boundary according to the 2008 SNA, an asset is defined, in § 3.5, as follows: "*An asset is a store of value representing a benefit or series of benefits accruing to the economic owner by holding or using the entity over a period of time"*. Central to this definition are that the entity, or asset, is being owned by an economic agent, and the entity represents a store of value for the owner.

In the system of national accounts, ownership is defined in terms of economic ownership, not legal ownership. Economic ownership refers to "… the *institutional unit entitled to claim the benefits associated with the use of the entity in question in the course of an economic activity by virtue of accepting the associated risks"* (§ 3.26 of the 2008 SNA). Usually legal and economic ownership coincide, but there are exceptions. One of those exceptions concerns financial lease, where the lessor is the legal owner, but the lessee takes all the risks and rewards related to the use of the asset in question. Public Private Partnerships (PPPs), for example in the case of developing and subsequently operating major infrastructural projects, may also lead to a disconnect between legal and economic ownership. However, for the more fundamental discussion in this section, this distinction is less relevant.

What is relevant for the discussion on broadening the asset boundary with ecosystem assets is what is being stated in § 3.22 of the 2008 SNA, "*sometimes government may claim legal ownership of an entity on behalf of the community at large. No entity that does not have a legal owner, either on an individual or collective basis, is recognized in the SNA*". In the case of ecosystem assets, legal ownership is often not the problem, apart from the high seas. Ecosystem assets are defined as spatial areas on the economic territory of a country, and one can thus assume that there usually is some kind of legal ownership, if only exercised by government in the case of public areas. More problematic is the economic ownership of these assets, which is very much related to the question of who claims the benefits and who runs the associated risks from these assets. Only when it comes to the valuation of these assets, which is directly linked to the (imputed) presence of benefits, one can observe a clear extension of the asset boundary as currently defined in the 2008 SNA.

So, all in all, from a purely technical point of view, the imputation of benefits through the production of ecosystem services leads to a recognition of ecosystem assets representing a store of value from which future benefits can be derived. However, this leads us back to the question of whose store of value, of who is the (economic) owner of these assets. A comparison with some of the assets that are currently recognised in the 2008 SNA may shed some more light on this issue. The answer to this question is also critical when it comes to the attribution of the costs related to the degradation of ecosystem assets.

Before describing some relevant SNA examples, it is relevant to note that determining, potentially by convention, the links between owner and asset may not fully resolve issues around the recording of degradation, at least not from a policy perspective. In addition, it is necessary to recognise that activities by the owner of one ecosystem may have detrimental effects on other ecosystems (and their owners). In this case, following a polluter pays principle, the degradation of the second ecosystem might be attributed to the income earned by the owner of the first ecosystem. It will be necessary determine whether and how accounting principles and recording approaches can be best adapted to accommodate this reality.

Biological resources

The asset type which has the closest resemblance to ecosystem assets is what in the 2008 SNA is referred to as “biological resources”, i.e. “*naturally occurring assets in the form of biota (trees,* vegetation, animals, birds, fish, etc.)” (§ 10.169 of the 2008 SNA). When these assets are taken place under the direct control, responsibility and management of institutional units, they are treated as “cultivated biological resources”, and the activity is treated as falling within the production boundary of the SNA. The assets therefore fall within the category of “produced assets”. § 10.169 of the 2008 SNA goes on with stating that:

> “*The growth of animals, birds, fish, etc., living in the wild, or growth of uncultivated vegetation in forests, is not an economic process of production so that the resulting assets cannot be classed as produced assets. Nevertheless, when the forests or the animals, birds, fish, etc. are actually owned by institutional units and are a source of benefit to their owners, they constitute economic assets. When wild animals, birds, fish, etc. live in locations such that no institutional unit is able to exercise effective ownership rights over them they fall outside the asset boundary. Similarly, the forests or other vegetation growing in such regions are not counted as economic assets. On the other hand, fish stocks in the high seas which are subject to international agreement on how much may be caught by individual countries may be counted as falling within the asset boundary”.*

As stated before, the latter could be interpreted in such as a way that vast areas of forests which are regulated in one way or another by governments, if only by controlling the cutting down of trees by way of granting permissions, are to be considered as produced assets.

In relation to fish stocks in open seas, § 17.334 of the 2008 SNA goes on to say: *“Fishing quotas may be allocated in perpetuity or for extended periods to particular institutional units, for example, where fishing is an established way of life and there may be little alternative economic employment. In such circumstances the quotas may be transferable and if so, there may be a well developed market in them. Fishing quotas may therefore be considered as permits to use a natural resource that are transferable. They are thus assets in the SNA”.* Whether or not such permissions are actually being granted, the limitation in the use of these stocks leads, from an economic perspective, to a resource rent, and thus to a monetary exchange value. In the case where the permission does not come for free, both the legal owner granting the permission and the economic owner who exploits the resources holds an economic asset in SNA-terms.

The latter obviously mainly relates to the provisioning services provided by the fish stocks, In the case of e.g. agricultural land and forests, other ecosystem services may be playing a role as well. It is important to note, however, that in the case there is completely free access to using the available resources and competitive markets, one may assume that the resource rent related to the provisioning services will be close to zero, and the value of the relevant assets will also fall down to zero. As such, the monetary exchange value will not give a fair representation of issues around the sustainability of the resources. In such situations the use of physical indicators may best allow consideration of t these concerns.

Mineral and energy resources

Another asset type worth considering in respect of the above is mineral and energy resources. This class of non-produced assets has a clear ownership. The limitation in the exploitation of these resources, be it for economic reasons or because of technical capabilities, results in a resource rent which may or may not be shared between the legal owner and the exploiter of the reserves. In both cases, biological resources as well as subsoil assets, the ownership, or the restrained use, and the resulting resource rent, also make it possible to allocate the costs of degradation or depletion to the owner/user of the resources. This economic agent clearly bears the related costs. This is much more difficult in the case there is no such thing as economic ownership, as a consequence of which the assets and the related costs of degradation cannot be allocated unambiguously.

Public assets of government

Before considering further the allocation of ecosystem assets and related costs of degradation, for which there is no clear ownership, it is good to also discuss some of the public assets of government. Some of the items that fall within the asset boundary of the 2008 SNA are also quite problematic in terms of economic ownership and valuation. This concerns, for example, public infrastructure and public R&D. In the former case, there may be clarity on the legal ownership of these assets, but given frequently occurring economic arrangements in which the roads are toll-free, the value of these assets on the market would be close to zero. The benefits derived from these assets are, by convention, set equal to the depreciation costs and expenditures for maintenance, and allocated to government as part of collective consumption, but in reality they are being used by the people driving on the roads.

An even more problematic area, which still raises question whether or not it is appropriate to record them as assets, concerns public R&D. In this case, quite a substantial part of these latter type of assets relates to freely available and publicly accessible knowledge, which on the market would have no value at all. Yet, because they provide benefits for the community at large, they are considered as government assets by convention. Adding to this problem is the intangible nature of these assets, as opposed to public infrastructure whose physical presence makes it easier to look upon them as assets. Infrastructure also has the advantage of generating a market exchange value under changing economic arrangements, which is not the case for freely available knowledge.

The important conclusion to derive from this discussion is that in the current system of national accounts some public assets do not exhibit a clear ownership. Furthermore, in these and other cases, the benefits that can be derived from them may be imputed and not "proven" by market revenues, while the users of these benefits may only coincide with the imputations by convention. However, it should also be noted that in the case of public R&D, and also in the case of public infrastructure, balancing items such as net operating surplus, net disposable income and net saving are not affected by this way of recording, because the additional depreciation also leads to additional output. The latter is not the case for the costs of ecosystem degradation; see below.

Considerations and proposals for integrated accounting

From the above discussion, it will be clear that ownership of the ecosystem assets, and the related ownership of the costs of degradation, is central to the discussion on the consistency with and the integration into the system of national accounts. Where ownership is undisputed, for example in the case of provisioning services which benefit a specific economic agent, or group of agents, the benefits derived from the ecosystem asset and the use of these benefits can be attributed to the relevant industry or sector. The same holds for the relevant part, in this case the net present value of the provisioning services, of the ecosystem assets, and the (user) costs related to the degradation of the relevant assets. As stated before, one should realise however that the resource rent and the value of the ecosystem asset are strongly correlated with the ownership, or the exclusive use, of the asset. If there is completely open access to the asset, and the ownership becomes more blurred, the resource rent will be close to zero, as will be the value of the asset and the costs of degradation.

The issue of ownership also becomes much more blurred in the case of regulating services and cultural services. When looking at regulating services, some of these services have a clear spatial, regional or national, component, such as, for example, the contributions of the ecosystem assets to flood protection or the lowering of local pollution. One could look upon this part of the ecosystem assets, including the related services, as the provision of a public good, similar to the investments in public infrastructure (e.g. investment in water defence structures). The same holds for many of the cultural services, although in these cases it may be easier to determine the beneficiaries of some of these services, e.g. in the case of recreation and tourism. More difficult to allocate are the services which benefit the world as a whole, the obvious example being carbon sequestration services.

From an accounting perspective, the most convenient solution for the above issue of allocating the relevant parts, i.e. those related to regulating and cultural services, of (the costs degradation of) the ecosystem assets is to account for them in a separate sector, "ecosystems", which may or may not be consolidated with the government sector. The allocation of the use of the benefits derived from the ecosystem assets could then be done in the use of income accounts, with compensating transfers in kind, to avoid an impact on net lending/net borrowing. In the current system of national accounts, these re-allocations of the use of services is limited to transactions between government and households, but there is much to say in favour of extending this approach to especially non-residents[12]. In the case of, for example, carbon sequestration services, one would then observe, in accounting terms, a transfer from a country to the rest of the world.

However, the recording of the ownership of the ecosystem assets, and the related attribution of degradation costs, remains quite problematic. The costs of degradation feature as a component that negatively affects net saving, while in economic reality these costs are not internalised in an economic sense, as they do not involve a monetary payment, or they do not affect (the perception of) future income levels.

Another, more generic, issue with the proposals in the above concerns the splitting of the ecosystem assets, including the benefits and uses derived from them, and the costs of degradation. One may prefer an accounting for the whole asset, but that would go along with several disadvantages, as mentioned in the above, such as the misalignment of benefits and uses, and an incorrect allocation of (the costs of degradation of) the ecosystem assets. The complete sequence of accounts of the accounting proposals presented here is illustrated in Table 6 below. This table is a reconfiguration of Table A6.1 of the System of Environmental-Economic Accounting (SEEA) 2012 Experimental Ecosystem Accounting. In the example, total ecosystem services amount to 110, of which provisioning services of 80 are used by agriculture, and 30 of other ecosystem services are used by the "public sector". Degradation amounts to 15, distributed across provisioning services (10) and other services (5). In the example, it is assumed that the ecosystem services other than the provisioning services are consumed by domestic households, but one could easily attribute some of them to the rest of the world, with an equivalent change in the transfers.

Accounting for liabilities related to the degradation of ecosystem assets

As mentioned in section 5 of this discussion paper, proposals have also been made to account for the degradation of ecosystems through the recognition of a build-up of ecological debt, a debt of society towards nature; see e.g. Vanoli (2015). In short, Vanoli (2015) proposes to add the monetary value of (net) degradation of ecosystems as "unpaid ecological costs" to the final expenditure categories, thus arriving at final consumption and gross fixed capital formation at "total costs". The unpaid costs would feed as a negative into saving, which would subsequently add to the increase of a new liability category, "ecological debt of the economy". Table 7 provides an example of the way in which such an accounting for ecological debt would affect the standard national accounts, in addition to the inclusion of output and use of ecosystem services. In the table it is assumed that the degradation costs are equal to 15, as in Table 6, and that all these costs can be attributed to domestic final consumption.

Apart from the problems related to the estimation of this degradation, which are being addressed in section 5, it may be a viable alternative recording, which may help to address some of the issues around the attribution of degradation costs, although – again – it may not align very well with the perception

[12] See the previous foot-note.

of consumers, as they are not directly confronted with the actual monetary payments, as a consequence of which they may not internalise the negative impact on their saving. In addition, it should be noted that this way of recording does not align very well with the accounting for the value of ecosystem assets, as in that case the degradation would be accounted twice, once as a decrease in the monetary value of the assets, and another time as an increase in ecological debt. Furthermore, one still will be confronted with difficulties in estimating the contributions of the various final expenditure categories to environmental degradation. On the other hand, recording the degradation of ecosystems in such a way would make the accounts very transparent in showing the externalities caused by economic expenditures.

Table 6: Simplified sequence of accounts for ecosystem accounting

	SNA 2008			Including ecosystem services			
	Farmer	Household	Total	Farmer	Household	Ecosystems (public sector)	Total
Production and generation of income accounts							
Output—products	200		200	200			200
Output—ecosystem services				80		30	110
Total output	200		200	280			310
Intermediate consumption—products	0		0	0			0
Intermediate consumption—ecosystem services				80			80
Gross value added	200		200	200		30	230
Less consumption of fixed capital (SNA)	10		10	10			10
Less ecosystem degradation (non-SNA)				10		5	15
(Degradation-adjusted) net value added	190		190	180		25	205
Less compensation of employees—SNA	50		50	50			50
(Degradation-adjusted) net operating surplus	**140**		**140**	**130**		**25**	**155**
Allocation/use of income accounts							
(Degradation-adjusted) net operating surplus	140		140	130		25	155
Compensation of employees		50			50		50
Ecosystem transfers					30	-30	0
(Degradation-adjusted) disposable income	140	50	140	130	80	-5	205
Less final consumption—products		200	200		200		200
Less final consumption—ecosystem services (non-SNA)					30		30
(Degradation-adjusted) net saving	**140**	**-150**	**-10**	**130**	**-150**	**-5**	**-25**
Capital account							
(Degradation-adjusted) net saving	140	-150	-10	130	-150	-5	-25
Plus consumption of fixed capital (SNA)	10			10			10
Plus ecosystem degradation (non-SNA)			10	10		5	15
Net Lending/Net Borrowing	**150**	**-150**	**0**	**150**	**-150**	**0**	**0**
Changes in balance sheets							
Changes in fixed capital (SNA)	-10			-10			-10
Changes in ecosystems (non-SNA)			-10	-10		-5	-15

Table 7: Simplified sequence of accounts for ecosystem accounting, including ecological debt

	SNA 2008			Including ecosystem services			
	Farmer	Household	Total	Farmer	Household	Ecosystems (public sector)	Total
Production and generation of income accounts							
Output—products	200		200	200			200
Output—ecosystem services				80		30	110
Total output	200		200	280			310
Intermediate consumption—products	0		0	0			0
Intermediate consumption—ecosystem services				80			80
Gross value added	200		200	200		30	230
Less consumption of fixed capital (SNA)	10		10	10			10
Net value added	190		190	190			220
Less compensation of employees—SNA	50		50	50			50
Net operating surplus	**140**		**140**	**140**		**30**	**170**
Allocation/use of income accounts							
Net operating surplus	140		140	140		30	170
Compensation of employees		50			50		50
Ecosystem transfers					30	-30	0
Disposable income	140	50	140	140	80	0	220
Less final consumption—products		200	200		200		200
Less final consumption—ecosystem services (non-SNA)					30		30
Less unpaid ecological costs of degradation (non-SNA)					15		
(Degradation-adjusted) net saving	**140**	**-150**	**-10**	**140**	**-165**	**0**	**-25**
Capital account							
(Degradation-adjusted) net saving	140	-150	-10	140	-165	0	-25
Plus consumption of fixed capital (SNA)	10			10			10
Net Lending/Net Borrowing	**150**	**-150**	**0**	**150**	**-165**	**0**	**-15**
Financial accounts							
Changes in cash	150	-150	0	150	-150		0
Changes in ecological debt (non-SNA)					15		15
Net Lending/Net Borrowing	**150**	**-150**	**0**	**150**	**-165**	**0**	**-15**
Changes in balance sheets							
Changes in fixed capital (SNA)	-10			-10			-10
Changes in ecological debt (non-SNA)					15		15

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 paper on the valuation of ecosystem assets, there is much commonality among accounting and economic approaches but there are important differences 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.

- Determining 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.
- Establishing an agreed use of the terms: depreciation, depletion and degradation
- Clarifying the scope of degradation with regard to human activity and unforeseen events
- Mapping out the link 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
- Understanding the extent to which general equilibrium effects can and should be considered in the valuation of assets and hence the definition and measurement of ecosystem degradation (Commonly for non-market valuations only information about the specific context for the environmental asset is taken into account)
- 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
- Assessing the merits of the various approaches to recording ecosystem related liabilities, especially in the context of the overall balance sheet.
- Determining appropriate approaches to the allocation of degradation, in particular taking into account the interest in understanding approaches to attributing the costs of degradation to the economic units that are considered to cause the degradation as distinct from attribution of the cost to the owner of the ecosystem asset.
- Establishing a sequence of accounts capturing flows of ecosystem services and changes in ecosystem assets.

Annex 1: Selected excerpts from SEEA EEA and the Technical Recommendations

Technical Recommendations: Defining ecosystem capacity

7.33 SEEA-EEA describes three main ecosystem asset concepts: ecosystem extent, ecosystem condition and expected ecosystem service flows. Ecosystem capacity was recognized to be central to making the connection between ecosystem assets and ecosystem services in accounting terms, but the nature of that connection was not articulated in SEEA-EEA for two reasons:

- First, it was recognized that the link between ecosystem assets and ecosystem services is hard to define and measure in ecological terms, particularly in terms of the link between changes in overall ecosystem condition and the supply of individual ecosystem services. It was deemed important to consider threshold effects, resilience, ecosystem dynamics and other non-linear factors;
- Second, since the concept of ecosystem capacity was considered to be related to the overall ecosystem asset, measuring capacity was understood to require the definition of an expected basket of ecosystem services. However, discussions on how to formulate such a definition have been inconclusive.

7.34 Since the publication of SEEA-EEA in 2014, it has become increasingly apparent that the concept of ecosystem capacity is central to explaining the ecosystem accounting model and applying that model in practice. That is especially the case with respect to development of information sets that can support the discussion of sustainability. It is thus clear that further research is needed on how to capture the key aspects of ecosystem capacity and the nature of their interrelationships, together with practical examples. Utilizing recent research findings as presented in Hein and others (2016), the present section marks the beginning of a discussion on this topic.

7.35 Ecosystem capacity for accounting purposes may be defined initially as the ability of an ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum yield or use level that does not negatively affect the future supply of the same or other ecosystem services (Hein and others, 2016).

7.36 An extended discussion of the issues relevant to development of the definition of ecosystem capacity is provided in Hein and others (2016). The paper also examines challenges associated with applying the concept of capacity to the three main types of ecosystem services, that is, provisioning, regulating and cultural services; and provides several real-world examples of capacity assessment. Consideration of ecosystem capacity requires a joint discussion of ecosystem condition, ecosystem services and measurement, which were discussed in earlier chapters. That explains why the subject of ecosystem capacity, whose measurement is relevant in both biophysical and monetary terms, is being analysed later in the *Technical Recommendations*.

7.37 Development of the definition of ecosystem capacity has been supported by the following key insights:

(a) Capacity needs to be analysed for specific ecosystem services. The capacity of a forest to supply wood is different from its capacity to capture air pollutants or sequester carbon. The nature of capacity varies, depending on the type of services—provisioning, regulating and cultural—to which it is applied;

(b) There is a temporal dimension to the analysis of capacity. Whereas the harvest or use of provisioning services generally occurs at specific moments in time, regeneration of ecosystems is a continuous process. In other words, measures of capacity must reflect the stock of ecosystem assets and the ecosystem asset's ability to supply individual services as a flow over time. In general terms, capacity entails estimation of the sustainable use level of an ecosystem, based on whether there is sufficient regeneration of that ecosystem (growth less natural losses) to offset its use by economic units;

(c) Using one ecosystem service can reduce the ecosystem's capacity to supply other ecosystem services. For example, harvesting wood in a forest may reduce opportunities for nature-based tourism. Capacity therefore needs to be assessed in the context of the actual use of the ecosystem, for example, carbon sequestration by a forest ecosystem must be considered in the context of actual rates of timber harvesting in that forest. It is also relevant to consider competing uses of ecosystems when considering the future flows of ecosystem services;

(d) Capacity is a measure that should be related to both the supply and the use of ecosystem services. Analysing capacity requires understanding the demand for the services generated by an ecosystem asset. If there is no demand for a service, the ability of an ecosystem to generate that service is not relevant for assessing ecosystem capacity. That could be the case for, say, a flood control service provided in an area without people. Hence, a meaningful connection between capacity and sustainable use levels is conditional on there being a demand for the service involved;

(e) Generally, the application of the definition of capacity is appropriate at more aggregated scales, in particular the landscape scale and above. If capacity is assessed over too small an area, signals regarding changes in capacity may be misleading because the influence exerted by natural fluctuations or ecosystem use on the ecosystem's state will be stronger than their influence in the case of assessment of larger areas (Hein and others, 2016). For example, timber harvesting generally occurs in rotation periods; hence, the capacity to generate timber would logically be assessed for a complete forest asset rather than for individual stands.

7.38 For ecosystem accounting, capacity is related to the actual basket of ecosystem services supplied and thus requires the presence of users of ecosystem services. Capacity therefore differs from the ability of an ecosystem asset to supply ecosystem services independently from the potential use of those services by beneficiaries, which has been labelled potential ecosystem service supply (see, e.g., Bagstad and others, 2014; Hein and others, 2016). It could also be labelled "the capability of an ecosystem to supply services", that is, the optimal ecosystem management under which the basket of ecosystem services would be obtained (Hein and others, 2016). While both potential supply and capability are relevant concepts for ecosystem management, they would not necessarily underpin ecosystem accounting estimates, although they may be derived from a common underlying information set covering, for example, measures of extent and condition.

7.39 In cases in which there are high levels of use of the ecosystem asset (e.g., through high levels of extraction) it is expected that the actual flows of ecosystem services will be higher than the sustainable flow and hence the condition of the asset will fall. That set of circumstances would reflect ecosystem degradation.

7.40 Capacity may be monetized on the basis of the NPV of the sustainable flow of ecosystem services. A choice may need to be made when there are trade-offs between services. For example, sustainable timber logging may not be compatible with provision of maximum recreational opportunities or air filtration services by the ecosystem. For accounting purposes, the basis for this choice should be the actual or revealed patterns of use and any associated legal or institutional arrangements. Thus, if the forest is currently used primarily for timber logging, then sustainable timber logging rates should be calculated and estimates for other ecosystem services (e.g., air filtration or recreation) should be made with the same logging rates in mind, instead of there being estimates of capacity for each service based on alternative patterns of use. At the same time, greater consideration must be given to the question how that may apply in practice. One outcome, for example, may be that the unit values of ecosystem services estimated with respect to actual use are different from unit values estimated within the context of sustainable use.

7.41 Even without that consideration, it is to be noted that the NPV of ecosystem use at capacity may be lower than, higher than or equal to the NPV of actual use of the ecosystem. The selected discount rate and discounting period exert a major influence on the various valuations.

7.42 To consider capacity as being measurable in terms of individual ecosystem services is an important step forward in an accounting context, since this establishes a direct link with discussions of sustainable yield and flow, which are well established in biological models and resource economics. However, there remain significant challenges with respect to understanding the links between measures of capacity for individual services and overall ecosystem condition.

7.43 Capacity is also relevant for policymaking on ecosystems. For example, the difference between valuation of an ecosystem asset in terms of its capacity and valuation in terms of its current use provides an indication of the relative costs or benefits of unsustainable ecosystem use. Sustainable ecosystem management ultimately requires management of ecosystems at or below capacity.

7.44 Further details on analysis of capacity are provided in Hein and others (2016). Additionally, La Notte and others (2017b) have undertaken a case study on nitrogen retention services in Europe. Insights derived from recent studies such as these could serve as the basis for further discussions on how capacity may be integrated in SEEA-EEA.

Technical Recommendations: Linking ecosystem capacity and ecosystem degradation

7.45 From an accounting perspective, an important emerging dimension of ecosystem capacity measurement encompasses the link between ecosystem capacity and ecosystem degradation. In SEEA-EEA (para. 4.31), ecosystem degradation is defined in relation to the decline in condition of an ecosystem asset as a result of economic and other human activity. That aligns with the approach taken in the SEEA Central Framework with regard to the definition of depletion of natural resources and in the SNA with regard to the consumption of fixed capital (depreciation) of produced assets.

7.46 The emerging idea is that while ecosystem degradation is clearly related to declining condition, it can be defined more specifically as reflecting a decline in the value of an ecosystem asset as measured in relation to the change in that asset's NPV, based either on the expected flow of services, or on the ecosystem asset's capacity. In either case, only the part of the decline that can be attributed to human activity should be considered degradation, in line with the accounting definition of degradation. Note that that implies that changes in NPV due solely to changes in prices should not be considered part of degradation.

7.47 Both approaches to measuring degradation, based either on expected flows or on capacity, result in different metrics, since the NPV of expected use is different from the NPV of capacity, unless the ecosystem is used sustainably. Similarly, annual changes in the NPV of actual use and the NPV of capacity are generally different, even though the directions of change will often be related.

7.48 Within the context of that discussion, there are several approaches to measuring degradation:

(a) In physical terms, through changes in ecosystem condition indicators;

(b) In monetary terms, through changes in the NPV of the expected use of ecosystems;

(c) In monetary terms, through changes in NPV of capacity;

(d) Through changes in the NPV of the potential supply; however, this may require attributing monetary values (i.e., option values) to potential ecosystem services;

(e) In principle, through the relationship of degradation to changes in the NPV of capability, that is, of optimal use of an ecosystem, provided that such an optimal use pattern can be defined.

7.49 However, for any given ecosystem asset, there may be several ways to estimate potential supply and capability, entailing different use patterns. Thus, the last two approaches to defining degradation are unlikely to be relevant for accounting.

7.50 At present, further testing is required to assess if and when it is more appropriate to define degradation in relation to the NPV of expected use as opposed to the NPV of capacity, or whether both approaches should be considered simultaneously. It is to be noted that each approach to measuring degradation has its own specific policy-related implications: changes in the NPV of expected use reflect impacts on the economy, while changes in the NPV of capacity reflect changes in the window of opportunities for the present and future generations to manage ecosystems sustainably.

7.51 Ecosystem degradation can be examined not only in the context of the NPV of ecosystem assets but from another perspective as well: ecosystem degradation occurs when actual ecosystem service flows, in particular provisioning services, exceed the ecosystem's capacity to supply that service. Therefore, in cases in which capacity can be quantified and mapped, in particular when a fully spatial approach to ecosystem accounting is pursued, it may be used as a measure for analysing whether flows of ecosystem services in specific areas can be sustained in the future (see Schröter and others, 2014).

7.52 While ecosystem degradation may be measured most appropriately in terms either of (a) changes in the ecosystem monetary asset account or (b) capacity, degradation is also reflected in measures of changes in ecosystem condition and, depending on how the ecosystem is used, in flows of ecosystem services, since the expected flows ultimately decrease over time as a result of ecosystem degradation. As research on degradation advances, it is important to ensure coherence of approaches across the various components of ecosystem accounting.

SEEA EEA: Allocation of ecosystem degradation to economic units

6.40 Whatever approach taken to the measurement of ecosystem degradation, there may be interest in understanding the relationship between ecosystem degradation and specific economic units – enterprises, households, and governments. In this regard a choice must be made as to whether the measures of ecosystem degradation in monetary terms are allocated to economic units in terms of the ecosystem degradation they cause through their economic and human activity (activity based allocation), or the costs they incur (in terms of lost income) as a result of degradation (receiver based allocation).

6.41 Allocation of ecosystem degradation to economic units on a receiver basis requires assumptions concerning the relationship between economic units and their use of flows of ecosystem services. Allocation to economic units on an activity basis will require assumptions about the relationship between the causes of degradation and economic units. These allocations may be difficult because there will not be a neat spatial relationship between the location of an ecosystem asset, the location of the economic units that cause the degradation, and the location of the users of the ecosystem services. Further, it may be necessary to understand and account for differences between the time at which ecosystem degradation occurred and the time at which the impacts of the degradation were felt by the various economic units.

Technical Recommendations: Allocation of ecosystem degradation to economic units

7.58. Allocation of ecosystem degradation represents one of the longest-standing challenges to the development of fully integrated environmental-economic accounts. The SEEA Central Framework proposes a treatment through which the depletion of natural resources can be incorporated within the standard sequence of accounts of the SNA. That treatment recognizes that the "using up" of natural resources is a capital cost against the future income of the extractor, and one that should be attributed to the extractor.

7.59. A number of alternative approaches to the allocation of degradation have been suggested. What is perhaps the most obvious approach entails attribution of degradation to the economic unit that caused the degradation, assuming that this can be determined. Determining the relevant economic unit may be difficult owing to the factors of distance, that is, when impacts are felt in neighbouring ecosystems, and time, that is, when the impacts become evident after the activity occurred. As a result of either of these factors, the relevant economic unit, that is, the unit that should be presented as bearing the capital cost, may not be the manager or owner of the particular ecosystem asset suffering the degradation. Further, attributing the overall impacts may be a complex issue, since the physical degradation of an ecosystem is likely to exert an impact on the supply of multiple ecosystem services that are received by different users.

7.60. The estimation of depreciation (or consumption of fixed capital) for produced assets entails a different approach that does not involve such factors. Depreciation can be attributed directly, since there is only one owner/user who receives all of the benefits/services of the asset in the generation of output and income. Thus, while the national accounting framing of ecosystem assets and the conceptualization of degradation are clear, there still remain practical measurement challenges, including related choices, which require further discussion and research.

Technical Recommendations: Integrated sequence of institutional sector accounts

8.28. As discussed, for certain purposes, it may be relevant to integrate ecosystem information into the broader sequence of institutional sector accounts and balance sheets of the SNA. The general underpinning logic and the structure of the sequence of accounts is described in detail in the SNA and is summarized in SEEA Central Framework, chapter VI. The informational focus in these accounts shifts from production and consumption towards the institutional sector level (i.e., corporations, governments, households) and measures of income, saving, investment and wealth.

8.29. One of the main functions of the sequence of accounts is to demonstrate the linkages among incomes, investment and balance sheets. In that regard, a key feature of the standard SNA sequence of accounts is the attribution of consumption of fixed capital (depreciation) to economic activities and institutional sectors as a cost against income.

8.30. The type of presentation that emerges from such integration is shown in table 8.2, which is taken directly from SEEA-EEA, annex A6. Table 8.2 presents two models (A and B) for a simplified example. In the example, presented for a farm, a single ecosystem asset provides a mix of ecosystem services (a total of 110), of which 80 are used by the farmer and 30 are final consumption of households. The allocation is based on the assumed composition of the ecosystem services. Thus, the value of 80 for ecosystem services may be considered inputs to agricultural production and the value of 30 may be considered regulating services, such as air filtration, used by households.

8.31. All SNA production of the farmer (200) is recorded as final consumption of households. For simplicity, no other production, intermediate consumption or final consumption is recorded. It is to be noted that in the generation of ecosystem services, table 8.2 does not show any "inputs" from the ecosystem (i.e., intermediate ecosystem services). Recording these flows is not required for the purposes of developing a sequence of accounts focused on economic units.

8.32. As shown in table 8.1, the rise in gross value added (GVA) occurs only in relation to the final consumption of ecosystem services that are related to non-SNA benefits (the air filtration services of 15 units in that table). In the following example, shown in table 8.2, final consumption of 30 units is attributed to households and contributes to a final measure of GVA of 230. In model A, GVA is allocated between the value added of the farmer (120) and the value added of the ecosystem asset (110). In model B, all of the value added is attributed to the farmer based on the assumption that it is the economic unit that manages the ecosystem asset and hence the generation of ecosystem services.

8.33. Having derived extended measures of GVA, these measures can now be adjusted for the cost of capital in the derivation of that GVA. This includes the deduction of depreciation of produced assets (consumption of fixed capital), depletion of natural resources and ecosystem degradation. In the SNA, only depreciation is deducted to provide a measurement of net value added (NVA). Deduction of all costs of capital provides a measure referred to as degradation-adjusted NVA. In table 8.2, total depreciation is 10 units, and ecosystem degradation is 15 units.

8.34. At an economy-wide level, the resulting measure of degradation-adjusted net value added (205 units)—assuming no cross-border flows in relation to ecosystem services—are the same irrespective of the choice of model A or B. However, when compiling institutional sector accounts in the case in which the economy-wide results are allocated between, for example, corporations, governments and household sectors, in order to move forward, a choice is required regarding whether ecosystems should be treated as (a) producing units in their own right (model A) or (b) assets owned and managed by existing economic units (model B).

8.35. In the *Technical Recommendations*, no explicit recommendation regarding model A versus model B is provided. However, discussions on other ecosystem accounting-related issues, particularly recording of the supply of ecosystem services, suggests that treatment of ecosystem assets as distinct producing units accords neatly with the measurement logic applied in other parts of the ecosystem accounting framework.

8.36. The significant implication of recognizing ecosystem assets as constituting a distinct sector is that all ecosystem degradation are deducted from the value of the ecosystem services generated by those assets. That is to say, the degradation is allocated to the ecosystem assets as the producing units in the model. Thus, in table 8.2 under model A, degradation-adjusted net value added for ecosystems is 95 units.

Table 8.2: Simplified sequence of accounts for ecosystem accounting

	Model A				Model B		
	Farmer	Household	Ecosystem	Total	Farmer	Household	Total
Production and generation of income accounts							
Output—products	200			200	200		200
Output—ecosystem services			110	110	30		30
Total output	200		110	310	230		230
Intermediate consumption—products	0		0	0	0		0
Intermediate consumption—ecosystem services	80		0	80	0		0
Gross value added	120		110	230	230		230
Less consumption of fixed capital (SNA)	10			10	10		10
Less ecosystem degradation (non-SNA)			15	15	15		15
Degradation-adjusted net value added	110		95	205	205		205
Less compensation of employees—SNA	50			50	50		50
Degradation-adjusted net operating surplus	**60**		**95**	**155**	**155**		**155**
Allocation and use of income accounts							
Degradation-adjusted net operating surplus	60		95	155	155		155
Compensation of employees		50		50		50	50
Ecosystem transfers	80	30	-110	0	-30	30	0
Disposable income	140	80	-15	205	125	80	205
Less final consumption—products		200		200		200	200
Final consumption—ecosystem services		30		30		30	30
Degradation-adjusted net saving	**140**	**-150**	**-15**	**-25**	**125**	**-150**	**-25**

Source: United Nations, European Commission, FAO, OECD and World Bank (2014), table A6.1.

8.37. That issue is resolved, at least in principle, in model B, since it does not introduce an additional sector for ecosystem assets but, instead, allocates each ecosystem asset to a specific institutional sector. The cost of capital for each ecosystem asset owned and managed by each sector is then directly attributed in the accounting structure. Thus, ecosystem degradation of 15 units is allocated to the farmer, whose adjusted net value added is recorded as 205 units.

8.38. The challenge presented by application of model B in practice is related to the extent to which individual ecosystem assets can be attributed to individual economic units and sectors. While this may be clear-cut in those cases in which a unit is a direct user of specific ecosystem services, in cases where the supply of public services (e.g., water regulation) comes from private landholdings, complete allocation of an asset and its value to a single institutional sector may not be appropriate.

8.39. In this example, within the context of a full accounting system approach, allocating all of the ecosystem asset to the farmer could imply that the ecosystem asset's full value to the farmer should be recorded on the farmer's balance sheet, including both the ecosystem services used as input to farm production and the publicly consumed air filtration services. However, that may not provide a suitable recording on the balance sheet of the allocation of assets.

8.40. The issue to be resolved is that of the balance between the allocation of the costs of degradation to an appropriate economic unit and the attribution of the ecosystem assets' value to the economic unit to the appropriate user of the services. The same accounting challenge was confronted with respect to the allocation of depletion of mineral and energy resources in the SEEA Central Framework. The resolution in that case entailed showing a series of transfers whereby the depletion cost was attributed to the unit extracting the resources and the balance sheets reflected the future income streams attributable to two sectors, the mining and general government units. Similar transfers could be envisaged for ecosystem accounting purposes, but such recording has not yet been developed.

8.41. It is to be noted that the approach to the allocation of degradation may in some cases be relatively straightforward. However, in many other cases the impacts of economic activity on the environment are of a complex nature. For example, the impacts may be experienced well away from their source or well after they arose, or they may not be felt by the relevant units. In addition, it is not necessarily clear how the loss of benefits incurred by the impacted sectors should be related to the income of the sector exerting the impact. Those matters have been debated at length in the national accounting community without any clear resolution. Thus, while an appropriate accounting treatment may be determined, the application of the treatment in practice and recommendations on a preferred approach requires further discussion of that treatment over a range of cases in which economic and human activity leads to degradation of ecosystem assets.

8.42. The final section of table 8.2 presents the allocation and use of income accounts. The aim of those accounts is to provide a measure of saving for the economy as a whole and for each sector. Under model A, that requires recording an adjustment entitled "ecosystem transfers", which reflects the need of the farmer and household sector for resources with which to purchase ecosystem services from the ecosystem assets. Recording those transfers enables the saving of the three sectors in model A to reflect the actual cash positions, which, it is to be recognized, are not affected by flows of depreciation or degradation.

8.43. Under model B, ecosystem transfers are not required, since there is no stand-alone ecosystem sector. The difference between net saving for farmers under model A and net saving under model B reflects the simple allocation in model B of ecosystem degradation (15 units) to the farmer, thus reducing the farmer's net saving from 140 to 125 units.

Technical Recommendations: Extended and integrated balance sheets

8.44. On balance sheets, which are the second type of integrated accounts, the opening and closing values of ecosystem assets in monetary terms, as recorded in the ecosystem monetary asset account, are integrated with the values of asset and liabilities recorded on the standard balance sheet of the SNA. Such an integration would lead to the derivation of extended measures of national and sector net wealth.

8.45. The integration of ecosystem asset values may appear to constitute a relatively straightforward step. However, it is likely, for a variety of reasons, to exhibit a high degree of complexity, entailing two main challenges, which are described at greater length in SEEA-EEA, chapter VI. First, in a full SNA and SEEA Central Framework balance sheet, there are already values recorded for natural resources, such as timber and fish. Since the value of these resources is embedded in the value of ecosystem assets, through the valuation of provisioning services, it is necessary to ensure appropriately that the value of natural resources is not double-counted. That issue pertains to various cultivated biological resources, such as orchards and vineyards.

8.46. Second, in many countries, the value of land, as recorded on the SNA balance sheet, is estimated in terms of its market price. Since there is a generally well-established market in land, balance-sheet values may be obtained more directly than by using net present value techniques as applied in resource accounting. It is likely to be the case that the market values of land, particularly agricultural land, will capture the value of some ecosystem services, at least to a certain extent. However, they are unlikely to capture a full basket of ecosystem services, particularly those that have clear-cut public-good characteristics and longer-term benefits. Also, land value may well reflect dimensions that are not of an ecosystem services character—for example, the location and the value of alternative uses (e.g., urban development). Adjusting market values of land based on these considerations therefore requires careful consideration.

8.47. Recognition of the differences in underlying scope among environmental assets is important when comparing the values of ecosystem assets with values currently incorporated in SNA balance sheets. In broad terms, the SNA balance sheets have lower values for environmental assets as a result of the inclusion by SEEA-EEA of the values of additional ecosystem services. At the same time, the SEEA-EEA values of ecosystem assets do not cover all environmental assets, most notably subsoil mineral and energy resources.[13] The effects of those two types of differences on the total value of environmental assets vary from country to country.

8.48. Integration of the accounts poses a final challenge, which arises when the accounting approach is applied at the level of an individual ecosystem asset. It should be recalled that the valuation of an ecosystem asset is directly related to the basket of final ecosystem services that are expected to be generated from that asset. At the level of individual ecosystem assets, however, there are cases in which an asset supplies few, or no, final ecosystem services (e.g., a forest on a high mountain) but, instead, plays a supporting role in supplying intermediate services to neighbouring ecosystems. In that situation, an ecosystem asset may be recorded as having zero monetary value, and its value becomes embodied in the value of the neighbouring ecosystems. While at an aggregate national level that may not be a significant issue, it is likely to be of concern if attribution of value is being examined, or accounting is being undertaken, at smaller subnational scales. Resolution of the issue requires the incorporation of intermediate services into the ecosystem accounting model in an explicit manner and related work on recording dependencies between ecosystem assets.

8.49. From a national accounting perspective, the development of a sequence of accounts and balance sheets represents an important objective that helps motivate the development of other parts of the ecosystem accounting framework. At the same time, it is clear (a) that work is needed to ensure progress in the development of the ecosystem accounts that must underpin the integrated accounts described here; and (b) that further research and testing are needed to meet the challenges posed by integration. Consequently, it is recommended that countries focus their efforts on developing ecosystem extent and condition accounts and ecosystem services supply and use accounts, which possess tremendous value in their own right.

Technical Recommendations: Alternative approaches to integration

8.50. The preceding sections describe integration as achieved through institutional sector accounts and balance sheets, following standard SNA measurement definitions and boundaries. That is a logical approach for the SEEA and is important when data already published in the national accounts—for example, on national wealth and saving—are to serve as the starting point for extension using ecosystem accounting data. However, there are other integrated measurement approaches that do not apply SNA standard measurement definitions and boundaries and hence offer alternatives to the integration of ecosystem and economic data. Three such alternative integrated approaches are summarized in the following paragraphs.

8.51. A well-developed approach, usually referred to as wealth accounting, has been developing as a branch of economics since the mid-1970s. Wealth accounting seeks to aggregate the value of all relevant capitals, including produced, natural, human and social capital. The most prominent work

[13] Accounting for these environmental assets is described in the SEEA Central Framework.

in this regard has been accomplished by the World Bank (2011) and UNU-IHDP/UNEP (2015). While varying in their details, those methods are nonetheless broadly similar in their approach.

8.52. In concept, wealth accounting aims at valuing each form of capital in terms of its marginal contribution to human welfare (Dasgupta, 2009; Arrow and others, 2012). Achieving that aim entails estimation of shadow prices for each type of capital. From a national accounting perspective, the focus on marginal contributions is appropriate. However, the national accounts focus on estimating contributions to market-based income, which requires the estimation of exchange values rather than shadow prices.

8.53. Given the purpose of wealth accounting, the conceptual basis for the approach to integration is highly appropriate. However, in practice, estimates for produced capital from the standard national accounts, based on exchange-value concepts, are often combined with estimates for other types of capital based on shadow prices. Hence, there may be a lack of alignment among the valuation concepts used to estimate various capitals. With regard to natural capital, it is clear that the use of exchange values for ecosystem services would not fulfil the conceptual requirements of wealth accounting, although there will be strong connections between the two approaches.

8.54. A second approach to integration, which builds on the use of restoration costs as a measure of ecosystem degradation, entails recording corresponding ecological liabilities on the national balance sheet. That is, unpaid restoration costs, which arise when an ecosystem declines in condition, are treated as a liability. This approach is described as a possible extension in the ENCA-QSP and has also been suggested for use at the corporate level by the Natural Capital Committee (United Kingdom). From a national accounting perspective, there are a number of difficulties associated with this approach:

- First, there is the question of whether restoration costs is a suitable estimate of ecosystem degradation, as discussed in chapter VII;
- Second, there is a question of when liabilities should be recognized. If there is no expectation that the restoration will occur, then, at least for accounting purposes, no liability should be recognized. In effect, recognizing these liabilities represents, in the first instance, a social or analytical choice rather than an application of accounting principles;
- Third, if a liability is recognized, then, all else being equal, net wealth should fall by that amount. However, since the recognition of the liability reflects the degradation of an asset, there is both a fall in an asset and an increase in a liability for the same event, which implies a double-counting on the balance sheet in terms of the impact on net wealth. That issue does not arise in the integrated accounting approach, as already described in the present chapter, since the only balance-sheet change is the fall in the asset value due to degradation. An alternative solution to the double-counting issue is to record the liability but keep the ecosystem asset value unchanged, although that seems counter-intuitive.

8.55. Overall, while recording ecological debts may appear to be an attractive objective and may be a useful tool in communicating the extent of ecosystem degradation, it has some deficiencies in terms of its consistency with national accounting principles.

8.56. The final integration approach to be described here is full-cost accounting, which has been developed in corporate accounting. The aim in full-cost accounting is to estimate and record the broader costs of a company's impacts on the environment as part of its ongoing operating costs, which thus results in an adjusted profit and loss statement. For example, the costs of greenhouse gas emissions and the release of pollutants are common areas of interest. Such information may be helpful in a range of management situations.

8.57. From an ecosystem accounting perspective, a few points may be highlighted. First, the approach largely excludes consideration of ecosystem services as inputs to the production process. Hence, in the full cost accounting approach, there is no change in the standard production or income boundaries.

8.58. Second, there is no recognition of ecosystem assets as part of a company's capital base and hence no impact of those assets on the company's balance sheet or recording of ecosystem degradation as a capital cost. Such degradation would be included implicitly in the adjusted profit and loss statement to the extent that it was part of the derivation of costs associated with the specific impacts assessed, but that would not be a specific focus.

8.59. Third, the incorporation of costs associated with residual flows (emissions, pollutants, etc.) is not undertaken directly in ecosystem accounting. In broad terms, a focus on residual flows reflects the valuation of a company's negative externalities, and externalities are specifically excluded from the national accounts. It may be that, in fact, the attribution of those costs can be part of a measure of ecosystem degradation. Further work is required to build an understanding of the links between the valuation of externalities and ecosystem accounting, with the understanding that those links may be different for different types of externalities.

8.60. Overall, while full cost accounting does represent a form of integration, it is somewhat different in scope and intent relative to the concepts and intent of ecosystem accounting.

Annex 2: Other approaches to measuring ecosystem degradation

SEEA 1993 approaches

The main objective of the SEEA 1993 was to develop measures to assess degradation, leading to a number of headline indicators – the well-known green GDP indicators. The SEEA 1993 provided unique recommendations for the measurement of degradation based on the so-called maintenance costs approach (MC), defined as "those costs that are required to prevent or mitigate a deterioration of the natural environment" (para 257).

"The rationale of the approach is based on two criteria:

> 1) "application of the sustainability concept" (57) – which "reflects the requirements for achieving a country's economic development under the constraints of maintaining the natural environment quantitatively and qualitatively intact" (257).
>
> (2) "extension of the national accounts concept of consumption of fixed capital (CFC) to the use of non-produced assets in production." (50).

The SEEA 1993 hence claims that the MC approach is similar to the CFC concept, as it is a measure of the current costs to maintain the level of fixed assets (54). These costs are deemed hypothetical (55) and considered as "prevention costs". As in the case of fixed assets, if there is no wear and tear there would be no degradation. It is stated that "neither concept has a welfare orientation".

Later on, in Chapter 4, the SEEA 1993 introduces as key concepts <u>costs caused</u> and <u>costs borne</u>: (253).

> *Costs caused* are "costs associated with economic units actually or potentially causing environmental deterioration by their own activities".
>
> *Costs borne* are "borne by economic units independent of whether they have actually caused or might potentially cause environmental deterioration". (254)

These two concepts correspond to two possible questions regarding the impacts of economic activities on the environment:

> (a) Should the analysis focus on the immediate environmental impacts of economic activities of a specific country in a specific time-period independently of the question at which time and in which country those impacts will cause environmental deterioration;
>
> (b) Should the analysis focus on the state of the environment and its effects on human well-being in a specific country in a specific time-period independently of the question which economic activities have caused environmental deterioration and when.

The MC approach follows the first approach, applying the concept of costs caused. But the SEEA 1993 argues that there is also a lot of interest in costs borne estimates, which would have a welfare focus to the extent that they take impacts on households into account (258, 259). The SEEA 1993 eventually proposes 3 different valuation versions/concepts (see also Annex with Table 4.1 with an example):

> *(a) Version IV. 1: costs borne valued at market values.*
>
> *(b) Version IV.2: costs caused valued at maintenance costs.*
>
> *(c) Version IV.3: costs borne valued at market and contingent values.*

It seems questionable to sum market values and contingent values (although this concern apparently is not raised in the SEEA 1993), the SEEA 1993 does consider the use of contingent values within an accounting framework as "controversial" (278).

The distinction between caused and borne is however relevant for the discussion around the attribution of degradation costs in the sequence of accounts (as highlighted in the distinction between Model A and Model B in the SEEA EEA Chapter 6) – as well as issues around temporal and spatial attribution. The proposal to have different versions of degradation is not unlike the requests for bridge table for the “family of values” as expressed during the meeting on valuation and accounting held in Bonn in April 2018. It is also worth pointing out that the intuition behind the MC approach contains parallels to the ideas around capacity discussed before, although the SEEA 1993 operationalization through restoration costs is very different than current thinking that links condition, capacity and ecosystem services.

Table 4.1 Imputed and actual environmental costs of economic activities in the SEEA: numerical example
(Monetary units)

		Imputed environmental costs		Actual environmental costs	
		Production activities of industries	Household consumption activities	Production activities	Household consumption activities
		1	2	3	4
	Costs caused	59.9	17.1	54.1	8.8
1	Depletion costs a/	17.5	0.7	0.0	0.0
	Degradation costs				
	Prevention costs a/				
2	Use of land etc.	9.0	0.8	0.0	0.0
	Discharge of residuals				
3	Current activities	33.3	13.3	47.7	7.7
4	Use of produced assets	5.1	2.3	6.4	1.1
5	Restoration costs b/	-5.0	0.0		
	Costs borne	20.5	75.6	78.7	21.5
6	Depletion costs a/	11.3	0.3	0.0	0.0
	Degradation costs				
	Prevention costs b/				
7	Use of land etc.			0.0	0.0
	Discharge of residuals				
8	Current activities			47.7	7.7
9	Use of produced assets			6.4	1.1
	Repercussion costs b/				
10	Use of land etc.	1.1	12.3	0.0	0.0
11	Discharge of residuals	10.1	63.0	19.6	12.7
	Restoration costs a/				
12	Non-market producers	0.0		5.0	
13	Others	-2.0		0.0	0.0

a/ Caused by own economic activities.
b/ Caused by own and other economic activities.

While the SEEA 1993 does not speak about ecosystem services specifically, it does consider at some length the concept of environmental services. This includes mention of the idea to expand the production boundary:

> *The production boundary of the economy can also be extended by introducing the concept of environmental services produced by nature (for example, Peskin, 1989; Vanoli, forthcoming). Those services describe qualitative (including spatial) functions of natural non-produced assets of land (including ecosystems), water and air. As environmental services often compete with other economic functions and with each other, a value could be imputed to them (Hueting, 1980, chap. 4; OECD, 1989, chap. 3; Pearce, Markandya and Barbier, 1989, chap. 3; Peskin, 1989). Services provided by the different natural assets could be treated as production activities of the natural environment.* (Para 356).

Three types of environmental services are distinguished: (a) disposal services, which reflect the function of the natural domestic environment (land, air, water) as an absorptive sink for residuals of domestic and foreign economic activities; (b) productive services of land, which reflect the spatial and economic functions of land (including water areas) for production purposes including the use of soil for agricultural purposes; and (c) consumer services of the natural environment, which encompass the elementary functions of the environment in providing for physiological as well as recreational and related needs of human beings

The SEEA 1993 included all sorts of possible adjustments to National Accounts tables in various versions. In so-called version V.5, consumer services of the natural environment are introduced in terms of their (negative) value of output, by adding up the actual repercussion costs borne by households and the imputed repercussion costs that those households are willing to bear. It is explained that both cost elements acquire a negative sign because the description of consumer services is limited to recording the decrease of these services corresponding to (negative) eco-value added (EVA).

SEEA 2003

SEEA 2003 discusses degradation in Chapters 9 and 10, but the focus is mostly on degradation due to residuals such as air emissions. Compared to the SEEA 1993 which advocated for the maintenance costs, it takes a step back and no longer recommends a unique treatment of degradation. The key distinction made is between cost-based and damage-based approaches, and it provides typology of approaches, with pros and cons.

It is instructive to quote how the SEEA 2003 explains the difference:

> "10.133. <u>Damage-based estimates</u> answer the question how much damage is caused by environmental degradation. <u>Cost-based estimates</u> answer variations on the question of how much would it cost to avoid environmental degradation. Both questions have their foundation in the Hicksian concept of income as being dependent on preserving the value of one's wealth but one estimate is formed by looking at what has happened to the stock of assets (the damage-based estimates) and the other is based on a measure of income (the cost-based estimates). Both types of estimates incorporate hypothetical valuations into the economic accounting system and thus are less firmly based than measures depending solely on observation.
>
> 10.135. The cost-based alternative is more like an extension of defensive expenditure and is essentially an income approach. When this is associated with the notion of maintaining environment services within the existing economic structure this is called the maintenance cost approach."

The cost versus damage distinction resembles the distinction in the SEEA 1993 between costs caused and costs borne (in terms of attribution of costs/damages), but it is in many ways also different (e.g. income versus stock dimension). Regarding the cost-based approaches, SEEA 2003 makes a helpful distinction between various approaches (that sometimes were used interchangeable in the SEEA 1993), see Box 9.1.

Box 9.1 Taxonomy of cost-based estimates

Avoidance costs
Structural adjustment costs
Reduction of activities or complete abstention
Changes in production and consumption patterns
Abatement costs
Input substitution and changes in technology to achieve the same output
Treatment costs (end-of-pipe, safe disposal, etc.)
Restoration costs

Avoidance costs are hypothetical costs that would have to be made to avoid the degradation of the environment. They fall into several categories. Abatement costs approaches which estimate hypothetical costs of say installing scrubbers etc. The problem with these estimates is that if they are non-marginal and change behaviour, the structure of the economy would change. Structural adjustment costs (e.g. greened economy models) essentially try to model what would happen if we internalize all externalities (with well-known examples such as Hueting's Sustainable National Income etc.). This is usually done by constructing CGE models, with abatement costs curves etc. Something like the social cost of carbon, would likely fall in the category of structural adjustment costs.

Box 9.2 sums up the main techniques when it comes to damage based approaches.

Box 9.2 Taxonomy of benefit/damage valuation techniques

Revealed preferences
Direct
Market prices
Indirect
Hedonic price analysis
Travel cost method
Stated preferences
Direct
Contingent valuation
Indirect
Conjoint analysis

The SEEA 2003 does not really take a stance in these debates. For instance, it notes that "a popular view amongst environmental economists is that it is (relatively) straightforward to make estimates of the economic costs of avoiding particular categories of damage or natural resource depletion but it is much more speculative to obtain monetary estimates for the benefits of such action" (paragraph 9.138). This seems to suggest a preference for using cost-based approaches. On the other hand, the SEEA 2003 states clearly "the size of the value obtained by the cost-based method does not represent the severity of environmental problems; rather, it represents the effort, in terms of costs, of taking measures to rectify the environmental problems. Measuring the severity of the problem depends on an assessment of the significance of the environmental function affected".

On damage / benefit based estimates, SEEA 2003 states these would be "major innovations to the SNA as presently articulated" (paragraph 10.147). It opens the door however to include such estimates by focusing on changes in stocks rather than in estimating absolute values.

> "The benefits we receive from a good state of health are not recorded in NDP, yet we suggest recording a decline in those benefits due to environmental degradation as a decline in NDP. If we were to suppose that a (restricted) value of welfare could be estimated as being the sum of NDP plus a health benefit H, then we could more easily say that the decline in welfare due

to environmental degradation was the decline in the original sum NDP+H. This is not possible as long as we have no robust estimates of H. However, it means that in looking at the impact of degradation it is advisable to relate it to year to year changes (when the unknown value of H may be fairly constant) rather than to just a simple comparison with the absolute level of NDP" (paragraph 10.147)

The SEEA 2003 also discusses the concepts of environmental debt and land improvement.

> 10.162. In making adjustments to current period production or income measures for degradation it is clearly only appropriate to adjust for degradation caused in the present period. This should include an allowance for pollutants generated this period even though the effects may not be felt until later. It should not include the costs of restoring damage caused in an earlier period. As noted earlier, unremedied degradation which carries forward to a future period is sometimes referred to as environmental debt. Knowing the extent of this debt is obviously useful, but it is a stock value rather than a flow. As with asset accounts it is possible, in theory at least, to track this through time, seeing how much debt is ameliorated in a year and how much is added to the debt. As with other entries in the balance sheet, the costs of restoration are likely to increase over time also so there is a type of holding loss associated with environmental debt.
>
> 10.53. A particular case of interest is that of land improvements. … It is assumed here that it is the excessive generation of residuals which impairs the quality of environmental media and hence of the environmental functions they provide. Unfortunately the exact link between specific residuals and a given environmental function are not always established and seldom precisely quantified.

To complete this summary of past literature it is useful to quickly note the summary of these earlier SEEAs in the 2008 SNA. The relevant passages are:

> 29.122 One approach is to focus on maintenance costing. (This is the approach taken in the 1993 version of the *SEEA*.) The object of the exercise is to answer the question: *What would the value of net domestic product have been if hypothetical environmental standards were met using current costs and current technologies?*
>
> 29.123 The problem with this approach is that if the question is posed in respect of significant changes in environmental standards, the resultant price rises involved are likely to bring about a change in behaviour that would affect the level of demand for those products. In turn this would show up either as a change in the level of output of those products or a change in the technology of production to reduce dependence on the newly expensive products. Nevertheless, for marginal changes in standards, this technique may be used to give an upper bound on the impact on NDP from moving to more rigorous environmental standards. The aggregates from such an exercise are referred to as "environmentally adjusted".
>
> 29.124 A second type of cost-based estimates, known as "greened economy modelling" attempts to resolve the problems raised by maintenance cost approaches for the nonmarginal cases of changes in environment standards. They attempt to answer the question: *What level of GDP could be achieved if steps were taken to internalize maintenance costs?*
>
> 29.125 A particular application of greened economy models aims not just to determine a set of values for output, demand and so on which satisfy the national accounting balances but to determine levels of output which lead to levels of income that are sustainable over a given time period. It attempts to answer the question: *What level of income and environmental functions can be sustained indefinitely?*
>
> 29.126 Damage-based measures derive from the impact of actual residual generation. The biggest impact is on human health. They attempt to answer the question: *What is the impact on the level of NDP of environmental impacts on natural and man-made capital and on human health?*

29.127 "Damage-adjusted income" is thus a first step on the way to converting GDP-type measures to welfare indices but many other aspects of welfare are deliberately ignored.

Current reflections on the earlier SEEA approaches

On damage based and cost based approaches

As described above, one distinction among ecosystem degradation measurement approaches that can be made is between damage-based and cost-based valuations of the effects of ecosystem degradation. Chapter 6 of the SEEA EEA summarises this distinction in the following way.

6.37 Historically, the discussion on the measurement of ecosystem degradation in monetary terms has revolved around whether the matter should be approached from the perspective of "how much damage is caused by ecosystem degradation"[14] – so-called damage-based estimates; or whether it should be approached from the perspective of "how much would it cost to avoid ecosystem degradation" – cost-based estimates. There was no expectation that estimates obtained from the different perspectives should align although the extent of ecosystem degradation in physical terms was assumed to be the same in each case. The differences and the relevant accounting implications are described in detail in Chapters 9 and 10 of the SEEA-2003.

6.38 Consideration of ecosystem degradation in the context of ecosystem services does clarify the scope of damage-based and cost-based perspectives to a significant degree. Thus damage based assessments should focus on the value of the reduction in the capacity to generate ecosystem services, and cost-based assessments should focus on the cost of avoiding or modifying the human activity that is causing the ecosystem degradation (avoidance costs). These two values may be quite different although having both may be useful for informing policy options.

6.39 Damage-based assessments are likely to include changes in the value of other assets (e.g. buildings) that may be due to a degraded environment. In theory, these declines in value should have already been accounted for in the standard SNA asset accounts as either consumption of fixed capital or other changes in volume. In practice, ensuring that extent of damages is appropriately attributed to assets such that they are only recorded once is likely to be a complex accounting exercise. It is necessary to consider (i) whether the changes in the ecosystem are normal and long lasting, (ii) the linkages to related effects such as productivity and human health which may or may not be captured in the SNA, and (iii) the relationship between the value of an ecosystem service and the value of the benefits to which an ecosystem service contributes. Overall, integration of damage-based measures of ecosystem degradation within standard national accounting requires a careful articulation.

Building on this final paragraph, it seems a particular feature of damage-based approaches is that they can be quite broad ranging and may tend to focus on wider socio-economic impacts rather than the direct loss of future flows of ecosystem services that is the focus of measurement from an accounting perspective. In this regard, damage-based approaches are likely to have stronger conceptual connections to welfare-based valuations of ecosystem services. As this topic is a feature of discussion in Discussion paper 5.1, the distinction between welfare and exchange value-based measures of degradation are not considered further here. It is simply noted that there will be connections between these different valuation concepts to be considered and explained with regard to degradation.

[14] Note that a more accurate framing might be a focus on the damage caused by residual flows (e.g. pollutants).

On the use of the restoration cost approach to valuing ecosystem degradation

Given the challenges of non-market valuation and determining the scope of damage-based assessments, the use of restoration costs to value ecosystem degradation is commonly proposed. The following text from the SEEA EEA Technical Recommendations (section 7.4.3) is relevant as background.

7.61. A commonly discussed alternative approach to valuing ecosystem degradation—that is, other than in relation to the change in the NPV of ecosystem assets—entails the use of estimated restoration (and maintenance) costs. Such an approach was initially suggested in the original SEEA (United Nations, 1993). Under that approach, an estimate is made of the expenditures that would be required (i.e., not actual expenditures) to restore an ecosystem to its condition at the beginning of the accounting period. That line of thinking is sometimes extended to include the notion that the accumulated unpaid restoration costs represent a liability—an ecological debt (Weber, 2011). It is assumed that if the estimated restoration costs were in fact made, then there would be no recorded decline in condition, that is, there would be no degradation.

7.62. In the environmental-economic community (see, e.g., Barbier, 2013), restoration cost approaches are not the approaches of choice since (a) they do not reflect the change in the value of the associated services resulting from the loss of condition and (b) the restoration costs are not revealed (i.e., actually paid) costs. In recent work on the subject (Obst and Vardon, 2014; Obst, Hein and Edens, 2016), it has been observed that, in accounting terms, restoration costs are not equivalent to those associated with estimating depreciation, or with consumption of fixed capital. That is, in the estimation of consumption of fixed capital, the terms “replacement cost” and “restoration cost” refer to the expenditure required to replace an asset in its depreciated condition, not to return it to an “as new” condition. Finally, it is also to be noted that the extension of the accounting framework to integrate the value of ecosystem services allows a different perspective on degradation to be supported within that framework.

7.63. An alternative approach to the use of estimated restoration costs in the valuation of ecosystem degradation might involve examining whether, between the beginning and end of an accounting period, there has been a significant change in the estimated restoration costs. Thus, a rise in the estimated restoration costs in real terms might be an indicator of the cost of a decline in condition between those two points in time. Another approach might entail considering not the cost of restoring an ecosystem to an earlier condition but rather the cost, including time, of “building” the ecosystem, starting from a zero base, up to its currently observed condition. That could be considered equivalent conceptually to the replacement cost approach within the context of measuring consumption of fixed capital. The change in total restoration cost between two points in time might be an alternative measure of the valuation of degradation.

7.64. The general conceptual issue here is whether, for a basket of ecosystem services from a given ecosystem asset, the estimated restoration costs can be related to a least cost (purchase price) for the supply of that basket of services and hence provide an estimated value of the ecosystem services for accounting purposes. The underlying logic is akin to that of the standard approach in national accounts for the estimation of government services such as health and education, which are measured at cost. While that conceptual issue is somewhat different from the challenge of measuring ecosystem degradation, it is not unrelated. In any case, it is clear that further discussion on the appropriate accounting interpretation of estimated restoration costs is required.

7.65. Notwithstanding the issues surrounding the use of restoration cost approaches for the valuation of degradation, the estimation of potential restoration costs can provide valuable information for policy purposes. For example, estimation of costs can provide a discussion of ecosystem degradation with a sense of economic scale, especially where that discussion revolves around the issue of the resources required to maintain condition, that is, where government establishes upfront charges or bonds in relation to business use of ecosystem assets or associated spatial areas such as mining sites. It may also be useful from an analytical perspective to compare the estimated restoration costs with the actual expenditures on ecosystem maintenance. When those costs and expenditures are tracked against actual changes in ecosystem condition, it is likely that some useful information for policy purposes will emerge.

These paragraphs highlight a range of issues that should be the focus of further discussion. In particular, it would be useful to understand to what extent and under what assumptions the following alternative applications/definitions of restoration costs (noted in the text above) might be considered consistent with the concept of ecosystem degradation as defined in the previous section, and taking into consideration the discussion of costs and degradation in the 1993 SEEA and the SEEA 2003.

a. costs required to restore an ecosystem asset to its condition at the beginning of the accounting period;

b. costs required to restore an ecosystem asset to a previous (potentially "natural") condition or target condition (e.g. a condition consistent with sustainable supply of the current basket of ecosystem services);

c. change in the cost required to restore an ecosystem asset over an accounting period (i.e. estimate the cost required at the beginning and end of the period); and

d. costs (or change in costs) required to "build" an ecosystem asset (including time) to its current condition.

An initial proposal is that options (a) and (b) do not seem to meet the requirements concerning the concept of degradation for accounting purposes but, under certain assumptions, the changes in costs suggested in options (c) and (d) might be appropriate. This issue is examined in much more depth in the companion (discussion paper 5.1) on the valuation of ecosystem services.

Significantly, there seems little doubt that estimation of restoration and maintenance costs is an important undertaking, irrespective of the nature of the connection to the measurement of degradation. This is reinforced in the discussion in the next section on the recording of liabilities related to ecosystem assets.

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