ESA/STAT/AC.301
UNCEEA/10/Bk10b

DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
STATISTICS DIVISION
UNITED NATIONS

Tenth Meeting of the UN Committee of Experts on Environmental-Economic Accounting
New York, 24-26 June 2015

SEEA Experimental Ecosystem Accounting: Technical Guidance

(for information)

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DRAFT

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Version: 3.0 (Draft for review, 03 April 2015)
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This work was undertaken as part of the project Advancing the SEEA Experimental Ecosystem Accounting. The project is led by the United Nations Statistics Division in collaboration with United Nations Environment Programme through its The Economics of Ecosystems and Biodiversity Office, and the Secretariat of the Convention on Biological Diversity. It is funded by the Norwegian Ministry of Foreign Affairs.

[1] *The views and opinions expressed in this report are those of the authors and do not necessarily reflect the official policy or position of the United Nations or the Government of Norway.*

Background

This document has been prepared to support discussion at the forthcoming Expert Forum on ecosystem accounting. It has been prepared on the basis of a range of materials but has not been subject to substantial consultation at this point. It should therefore be considered an initial draft and not circulated broadly at this stage. It is intended that following discussion at the expert forum a revised document taking on board the inputs from the experts will be prepared for circulation.

The content builds on the SEEA Experimental Ecosystem Accounting initially released in 2013 and provides updates and further clarification. It is hoped that the summary and overview style of this document can provide a relatively common understanding of ecosystem accounting for the participants in the Expert Forum and hence aid discussion and exchange at the meeting.

A particular note is that the referencing in the document is incomplete and needs substantive work. Advice on amend or additional references would be welcome.

Also, most chapters have final sections outlining conclusions and recommendations for compilation, testing and further research. These sections have not yet been drafted, in large part pending the discussion at the Expert Forum. The text generally provides a good indication of the types of conclusions and recommendations that may emerge.

Acknowledgements *(to be completed)*

Contents

1. Introduction

1.1. Definition and role of ecosystem accounting

1.1. Ecosystem accounting is a coherent and integrated approach to the measurement of ecosystems and measurement of ecosystems and the flows of services from them into economic and other human activity. Ecosystem accounting complements and builds on the accounting for environmental assets as described in the SEEA Central Framework. In the SEEA Central Framework environmental assets are accounted for as individual resources such as timber resources, soil resources and water resources. In ecosystem accounting the accounting is for these individual resources operating in combination as an ecosystem.

1.2. A prime motivation for ecosystem accounting is that a separate analysis of ecosystems and the economy does not reinforce the vital nature of the relationship between humans and the environment in which we live. In this context, the SEEA EEA provides a platform for the integration of relevant information on ecosystem extent condition, capacity and services with information on economic and other human activity.

1.3. The accounting approach outlined in SEEA EEA extends and complements a range of other ecosystem and biodiversity measurement initiatives in a number of important ways.

- First, the SEEA EEA framework includes accounting for the changes in ecosystem condition and function (including changes in biodiversity) and the flows of ecosystem services. Often measurement of these two aspects of ecosystems are separate fields of research.
- Second, the SEEA EEA framework encompasses measurement in both biophysical terms (e.g. in hectares, tonnes) and in monetary terms where flows of ecosystem services are ascribed monetary valuations through various non-market valuation techniques.
- Third, the SEEA EEA framework is designed to facilitate comparison and integration with the economic data prepared following the System of National Accounts (SNA). This leads to several design elements concerning valuation and measurement boundaries that are not systematically applied traditionally in ecosystem measurement but, at the same time, facilitates the mainstreaming of ecosystem information with standard measures of income, production and wealth that is required for analysis of, for example, sustainability and green economy.
- Fourth, the aim of the SEEA EEA framework is to provide a broad, cross-cutting perspective on ecosystems at a country or large-sub-national level. While in principle many of the concepts can be applied at a detailed level the intent is to provide a broad picture to enable integration with the broad picture of the economy from the national accounts. Since many ecosystem measurements are conducted at a detailed, local level there is an important methodological challenge to utilize these data to provide a national view.

1.4. In this context, ecosystem accounting does not represent a competing measurement approach. Rather it is hoped that the benefits of building an integrated set of information concerning ecosystem condition, ecosystem services and economic activity can provide a basis for discussion and integration between the various perspectives, disciplines and related initiatives that are involved in this area of work.

1.5. The SEEA EEA has emerged from work initiated by the international community of official statisticians and their development of the SEEA Central Framework. While there has long been recognition of ecosystems in the context of environmental-economic accounting and of the need to account for the degradation of ecosystems the approach described in the SEEA EEA has only emerged in recent years. Its design is attributable to the relatively recent development of concepts of ecosystem services. With these concepts it has been possible to incorporate accounting for ecosystems using the accounting approaches that have been developed for recording economic activity and individual environmental stocks and flows (water, energy, timber resources, GHG emissions, etc).

1.6. One result of this bringing together of traditional national accounting and newer concepts of ecosystem services is that ecosystem accounting is considered to be an emerging and still developing area of work. Thus, while it shows considerable potential as an integrating framework, there remain a number of areas that require much further discussion and testing. In addition, it is by nature an inter-disciplinary undertaking and, since each discipline (statistics, economics, national accounts, ecology, geography, et al) brings its own perspective and language, all involved must recognize the additional effort required to respect and understand the other perspectives.

1.2. Scope and purpose of SEEA EEA Technical Guidance

Connection to the SEEA EEA

1.7. The SEEA Experimental Ecosystem Accounting: Technical Guidance (EEA TG) provides a range of content to support the testing and implementation of ecosystem accounting at national level. It complements SEEA Experimental Ecosystem Accounting (SEEA EEA) released in 2013 that described a framework for ecosystem accounting and provided an initial foundation for discussion and collaboration on ecosystem and biodiversity measurement issues.

1.8. EEA TG uses the SEEA EEA as its starting point and basis for conceptual discussion. However, since its drafting in 2012, there has been further discussion and testing of concepts and engagement with a broader range of interested experts. The core conceptual framework remains solid but some additional issues, interpretations and approaches have arisen and EEA TG seeks to introduce those new topics and thoughts into the discussion on ecosystem accounting.

1.9. EEA TG should not be considered to reflect the definitive word on the issues of ecosystem accounting since further testing and discussion in this emerging field is required. Thus, it provides additional background, context and clarification to the concepts outlined in SEEA EEA with the intent of increasing understanding of the ecosystem accounting approach and its potential. Where relevant, advances in thinking on specific topics, for example on the topic of ecosystem capacity, have been introduced to ensure that the content is as up to date as possible in this rapidly developing field.

Connection to other materials

1.10. The EEA TG also aims to place in context a range of other materials on ecosystem accounting that have developed over the past few years. Examples include the CBD's "Ecosystem Natural Capital Accounts: A Quick Start Package" (ENCA QSP); UNEP's "Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States"; the World Bank WAVES' "Designing

Pilots for Ecosystem Accounting"; and the EU's "Mapping and Assessment of Ecosystems and their Services (2nd report)". These materials have been developed by different agencies and for different contexts but have an important role to play in the testing of SEEA EEA and communicating the potential of a national accounting approach to ecosystem measurement. A short overview of these different documents is provided later in this chapter.

1.11. As described in SEEA EEA, there are often strong connections between accounting for ecosystem condition and ecosystem services, and accounting for individual ecosystem components such as water and land. Consequently, work on ecosystem accounting should take advantage of the range of materials that have been developed relating to the measurement of water resources (including SEEA Water), forests and timber, fisheries, and land. While these materials have not generally been developed with ecosystem accounting in mind, they nonetheless support the development of relevant estimates and accounts. As well, these document often point to potential applications of ecosystem accounting which can provide a useful focus for compilers.

1.12. Throughout the EEA TG, references to these documents and other relevant material are included as appropriate. Consequently, EEA TG should reflect somewhat of a reference guide in addition to being an up-to-date description of the state of ecosystem accounting.

The audience for EEA TG

1.13. The primary audience of the EEA TG are those people working on the compilation and testing of ecosystem accounts at national level and those providing data to those exercises, perhaps as part of separately established ecosystem and biodiversity monitoring and assessment programs. The content should also assist those who may use the information that emerges from sets of ecosystem accounts but the potential applications of ecosystem accounts is not the focus of this document.

The scope of EEA TG

1.14. All aspects of ecosystem accounting as described in SEEA EEA are within scope of EEA TG. However, far more emphasis has been placed on measurement in biophysical terms than on issues concerning valuation and integration into the standard national accounts. This balance reflects that work over the past few years in the context of SEEA EEA has tended to focus on biophysical measurement in terms of land and ecosystem condition accounting. It also reflects a pragmatic view that the valuation of ecosystem services and ecosystem assets requires a strong grasp of the relevant stocks and flows in biophysical terms. Consequently, resolving the accounting issues in biophysical terms can be considered a necessary first step.

1.15. It is recognized that there is a substantial field of expertise and experience on the valuation of ecosystem services but it is less clear that there have been significant advances in linking this knowledge to the challenge of valuation for SEEA EEA based accounting purposes – a challenge raised substantively in the SEEA EEA Chapter 5. While some developments will be reported on in this document, This area requires further work both in testing valuation approaches in an accounting context and in discussion among relevant experts (mainly in accounting and economics) to broaden the understanding of the valuation of ecosystem services for accounting purposes.

1.16. Since the field of ecosystem accounting is quite new and is likely to advance quickly given the range of testing underway, the EEA TG cannot be considered a definitive document but rather a summary at a point in time. However, it is intended that in the coming 3-5 years a process will be undertaken to update the SEEA EEA, taking advantage of all relevant conceptual and practical development, and put in place an international statistical standard for ecosystem accounting. Through this process it is also proposed that relevant guidance be updated and shared on an ongoing basis with the EEA TG providing the structure.

1.3 Links between EEA TG and other initiatives

1.17. As noted in Section 1.2, the content of EEA TG is based on the conceptual ecosystem accounting model described in SEEA EEA. In turn, the conceptual model complements the accounting for environmental assets in the SEEA Central Framework and the accounting structures themselves are applications of the principles and structures described in the System of National Accounts (SNA). Thus, the EEA TG is firmly rooted in national accounting conventions and approaches to the organization of information.

1.18. At the same time, the ongoing testing and development of ecosystem accounting as reflected in the EEA TG continues to demonstrate that this area of accounting is not a straightforward application of national accounting principles. The primary driver for this is that ecosystems are not standard assets in the ways generally conceived by traditional economic accounting. Instead they are characterized by having multiple owners, generating multiple services and have the potential to regenerate themselves in the future.

1.19. The second key driver is that the information set required for the compilation of a full set of ecosystem accounts is very diverse and not generally coordinated at national level. Economic statistics are, on the whole, quite well coordinated by a small number of leading institutions (e.g. national statistics office, central bank, taxation office). The lack of co-ordination of the underlying information needed for ecosystem accounting has meant that ecosystem accounting is one among a number of information integration initiatives concerning environmental data. For the EEA TG and those compiling ecosystem accounts, it means that connections can and should be made to a variety of information and data projects across a number of agencies.

1.20. Finally, since ecosystem accounting is a relatively new field it is natural that different approaches and perspectives are developing. There are thus a range of documents describing approaches that are essentially ecosystem accounting even if not fully aligned with the conceptual model described in the SEEA EEA. Since these documents provide useful information for SEEA based ecosystem accounting purposes, the following paragraphs provide a short summary of some key documents of this type.

a. CBD Ecosystem Natural Capital Accounts: Quick Start Package (ENCA QSP) (October 2014)

The ENCA QSP is a detailed technical document aimed at supporting countries in the implementation of Aichi Biodiversity Target 2 on the integration of biodiversity values in national accounting systems. Using techniques developed in a European context (European Environment Agency, 2011) and applied in Europe and in Mauritius, the ENCA QSP gives practical guidance on establishing detailed spatial datasets on land cover, carbon, water, species diversity, and various landscape level indicators (e.g. on fragmentation and ecotones).

The two key strengths of the ENCA QSP are its demonstration of the potential to integrate large volumes of data at country level, often using global level datasets;

and its demonstration of a national accounting approach to ecosystem measurement wherein data are scaled up and down as required to provide an overall picture of change for a country as a whole. The ambition to provide a broad picture for a country as distinct from a precise estimate for a specific ecosystem is an important distinction of ecosystem accounting.

The focus of the ENCA QSP is on the measurement of ecosystem extent and condition. It does indicate a link to the measurement of ecosystem services but this is done only via an assumption that for a given ecosystem condition there will be a specific basket of ecosystem services. Ecosystem services are not measured directly. A consequence is that the measurement scope of ENCA QSP is narrower than the SEEA EEA.

With regard to the measurement of ecosystem condition the ENCA QSP proposes an approach that uses indicators of a limited number of ecosystem characteristics that are applied to all ecosystem types. This broad brush approach may well seem inappropriate from an ecological perspective but the intention is to provide a quick and broad assessment.

ENCA QSP does proceed to valuation but does so in a limited way via the use of restoration costs as a measure of ecosystem degradation. There is no valuation of ecosystem services nor valuation of ecosystem assets as outlined in the SEEA EEA. Concerns about the use of restoration cost approaches are discussed in Chapter 8 of EEA TG.

Overall, its detailed proposals for the estimation of accounts with national coverage for land, carbon and water and various high-level indicators concerning ecosystem function are important contributions and should be of direct support to compilers of ecosystem accounts as described in the SEEA EEA.

b. World Bank WAVES Designing Pilots for Ecosystem Accounting (May 2014)

This guidance material provides a summary of the key features of ecosystem accounting and how a country or region might work towards developing a set of ecosystem accounts. Its coverage includes discussion on the types of issues that might benefit from the compilation of ecosystem accounts, the selection of a case study area/site, assessment of the relevant ecosystem services, guidance on the biophysical mapping and analysis of ecosystem services, and shows an application of the approach to a study area in Peru.

The focus of the material is on providing appropriate context and criteria / factors that are relevant for making decisions in respect to ecosystem accounting. While there is some mention of the measurement of ecosystem condition and somewhat more discussion on the issue of ecosystem capacity, on the whole the primary focus of the material concerns ecosystem services. Methods for the valuation of ecosystem services are mentioned.

This material should provide a useful complement to other materials, such as those focused on ecosystem condition (ENCA QSP, above) and those focused on valuation (UNEP SIDS Guide, below). Indeed, this presence of complementarity speaks to the breadth of the requirements for ecosystem accounting.

Since the focus of the guidance is on the practical implementation and testing of ecosystem accounting there are no specific departures from the SEEA EEA concepts. Of course, the precise manner and methods by which ecosystem accounts should be compiled remain the object of the testing and in this regard the WAVES guidance material should usefully complement the EEA TG as well.

c. *UNEP Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States (SIDS) (January 2015)*

This manual was prepared in the context of the particular imperatives for SIDS to manage their development in the context of climate change and recognizing the particularly strong link between SIDS economies and their natural environment.

The first part (chap. 2 - 4) of the guidance is focused on the measurement and valuation of ecosystem services and a thorough overview of relevant concepts and methods is provided with a particular focus on measurement in the context of SIDS. Step by step guides to the most relevant methods are also provided. The coverage of this discussion is not solely on valuation for accounting purposes since there are other reasons for valuation other than accounting (e.g. cost benefit analysis, program evaluation, etc).

Chapter 5 describes two aspects of "ecosystem service accounting. The first is a summary of work in Mauritius that is an application of the methods described above in the ENCA QSP. In effect this work does not reflect accounting for ecosystem services but rather accounting for ecosystem condition. The second aspect outlines some steps to the valuation of ecosystem services for inclusion in the standard national accounts. The use of a production function approach is summarized for a small set of provisioning and cultural services.

The guidance does not cover the valuation of regulating services in an accounting context and while pointing towards the integration of ecosystem services into the national accounts, it does not discuss the relevant measurement issues or mention issues such as the valuation of ecosystem degradation.

This Guidance Manual should provide useful information for those wishing to undertake the valuation of ecosystem services as part of implementation of work on SEEA EEA however care is needed on the discussion of the integration of ecosystem services value within the standard national accounts since some of the important integration issues are not considered.

d. *EU Mapping and Assessment of Ecosystems and their Services (MAES)*

The EU's MAES project is a large measurement project working towards completion of Action 5 of the EU Biodiversity Strategy to 2020. The MAES framework encompasses the two key dimensions of measurement that are also in the SEEA EEA namely ecosystem condition and ecosystem services. In that sense, the developments in the MAES provide a relevant example of the types of measurement issues likely to arise in ecosystem accounting. Indeed, part of the MAES project is the development of a methodological approach to natural capital accounting.

To date the main output from the MAES project is its report (February 2014) on "Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020". In this report it documents the establishment of six pilots across Europe and the results from assessing ecosystem condition and an array of ecosystem services in different ecosystem types (forests, cropland and grasslands, freshwater, and marine).

The document is useful in highlighting measurement possibilities and challenges in a summary manner thus providing insights for those aiming to establish ecosystem accounting projects. Particularly useful are the listings of (and recommendations regarding) potential indicators for different ecosystem services across the range of provisioning, regulating and cultural services. Such listings are particularly useful in trying to understand the type of information that might be relevant.

In the context of ecosystem accounting the approach taken is particularly appropriate since it is working form the intent of measuring ecosystems and their services at a national and pan-European level. This type of broad assessment and the use of relevant frameworks and classifications is well aligned with the intentions of ecosystem accounting.

A draft reference document on natural capital accounting has also been released for consultation (January 2015). Largely it is a description of the various approaches to natural capital accounting, including the SEEA and includes discussion of natural capital itself, and the role of natural capital accounting in policy. The document discusses also the role of valuation, in both monetary and non-monetary terms. The document does not provide methodological guidance but is useful in providing background material to SEEA EEA based accounting exercises.

1.21. In addition to these documents, there is an increasing body of work developing that is testing the conceptual model for ecosystem accounting as described in the SEEA EEA. Projects are taking place at national level and sub-national level, and being undertaken as part of international initiatives, by national and provincial governments, by non-government organisations and by academia. Chapter 14 of EEA TG provides some brief summaries of relevant work to give a sense of the directions being pursued. Links to relevant outputs and documentation from these projects will be of value to those seeking to establish ecosystem accounting projects.

1.22. Also, there are an increasing number of examples of projects and initiatives focused on particular components relevant to ecosystem accounting. Work on biodiversity, soil, land cover, water, carbon in the context of accounting is proceeding, sometimes in awareness of the SEEA EEA framework, sometimes not. It is very likely that the learnings from these component based studies can be integrated into the SEEA EEA and hence discussion with those undertaking these studies is particularly important for the compiler of ecosystem accounts. While it is likely that results may need to be tailored to suit the particular requirements of integration with the national accounts, this step is more straightforward than the gathering of specific intelligence and knowledge on ecosystems and their components.

1.4 Links to corporate accounting initiatives

1.23. In parallel with the work on developing environmental-economic accounting as a complement to the SNA, there is an equally long history of work on the integration of environmental information into corporate accounting. By and large, these two streams of accounting have not interacted in a significant way. While there are differences between national and corporate accounting, there appear more similarities than differences and a joining of efforts in this space would be a positive step forward.

1.24. To this point however, the integrated ecosystem accounting approach described in SEEA EEA has not been applied in corporate accounting. Efforts at environmental or natural capital accounting have either focused on integrating the costs of residual flows (emissions, pollutants, etc) into current accounting structures or focused on a more generic reporting on environmental and natural capital issues as a complement to the standard suite of accounts.

1.25. The second approach has developed considerable momentum via the Global Reporting Initiative (GRI) and the International Integrated Reporting Council (IIRC but neither of these approaches yet incorporates an integrated approach to accounting.

1.26. Work on integration into standard accounting structures is being developed via the Natural Capital Protocol (NCP) by the Natural Capital Coalition and the work on the Natural Capital Declaration being co-ordinated by the UNEP-Finance Initiative. However, at this stage whether ecosystem accounting type approaches will be incorporated is unclear.

1.27. Research funded by the UK Government's Natural Capital Committee has proposed a corporate natural capital accounting model whereby the value of ecosystems is incorporated on a company's balance sheet using the net present value of ecosystem services – thus following the logic of SEEA EEA. However, measures of ecosystem degradation are then estimated using a restoration cost approach and further, no alteration to the company's income or production boundary is developed. These two matters are inconsistent with the direction of the SEEA EEA. (Further discussion on these issues is in section 9.6.)

1.28. Notwithstanding the current lack of overlap between the natural capital accounting work at national and corporate levels, in relation to the testing and development of ecosystem accounting at a national level there are a number of reasons for establishing a relationship between these two branches of accounting. First, in many cases understanding the environment-economic relationship requires assessment of public goods. Consequently, the development of corporate accounting requires information beyond their own operations. Second, there may be a good opportunity for the public sector to improve their collection of data on the environment through appropriate coordination with the business community. Third, the business community relies on public data, such as the national accounts, to understand its wider operating environment both nationally and globally. Widely developed ecosystem accounts should be able to offer similar advantages in terms of standardised approaches to assessing operational risks and opportunities. Fourth, joint development and exchange should help to more quickly advance the research agenda especially via a common understanding of terms and concepts.

1.5 Structure of EEA TG

1.29. EEA TG Chapter 2 covers the general principles of ecosystem accounting with a summary of the ecosystem accounting model described in SEEA EEA and a discussion of key boundary issues.

1.30. Chapter 3 summarises the various accounting units and classifications used in ecosystem accounting.

1.31. Chapter 4 describes the main types of ecosystem accounts.

1.32. Chapter 5 introduces accounting for flows of ecosystem services with a description of some of the key boundary and classification related issues and the relationships to other concepts such as benefits and well-being.

1.33. Chapter 6 provides an introduction to accounting for various components of ecosystems namely land, carbon, water and biodiversity.

1.34. Chapter 7 considers the issue of accounting for ecosystem assets in a holistic way which, in particular, involves dealing with the aggregation of information and the measurement of condition, capacity and degradation.

1.35. Chapter 8 summarises the important and often controversial topic of monetary valuation from an ecosystem accounting perspective. The aim is to support a considered discussion of the role and relevance of valuation rather than provide detailed guidance on the application of particular valuation techniques.

1.36. Chapter 9 updates the discussion in the SEEA EEA Chapter 6 on the integration of ecosystem and economic information via the accounting framework. Since the release of the SEEA EEA there have been some additional insights that take forward discussion in this area although there remain outstanding issues from a conceptual and practical perspective.

1.37. To support the discussion in the EEA TG and also to assist in advancing the research agenda for ecosystem accounting, a series of ANCA Research Papers has also be released covering a range of topics in much greater depth than conveyed in this document. The list of ANCA Research Papers is provided in Annex 1.

2. Main aspects of ecosystem accounting

2.1 Introduction

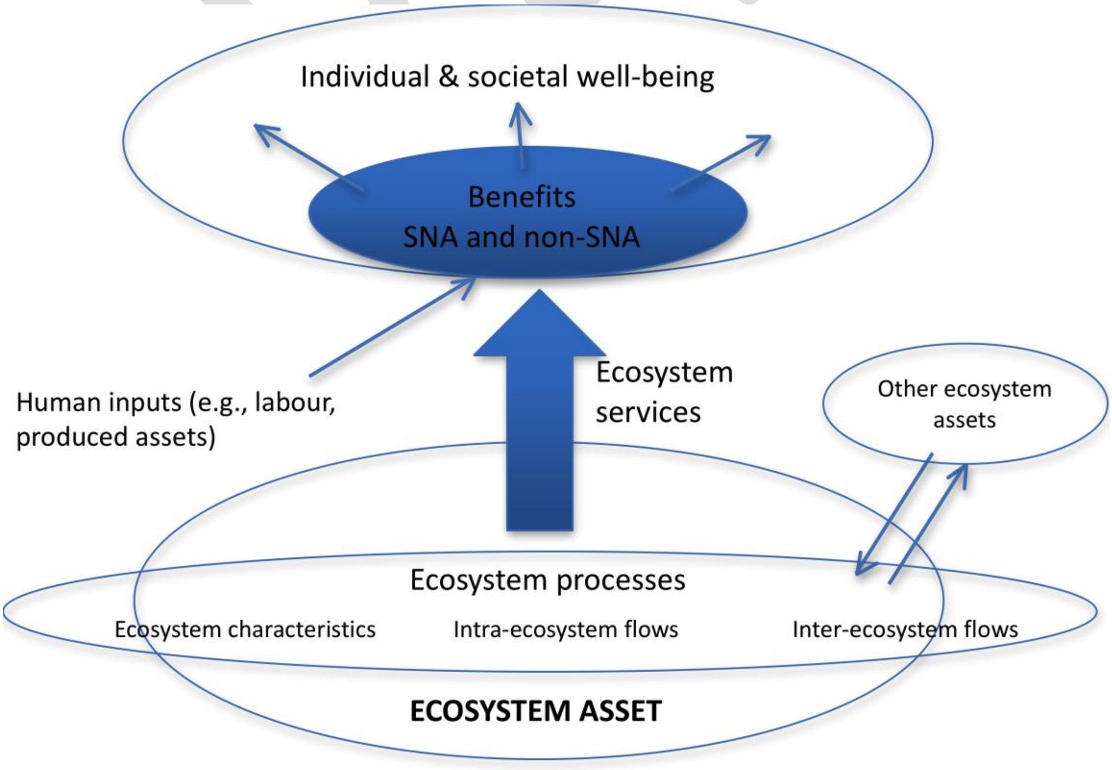
2.1. This section complements the text in SEEA EEA Chapter 2 by providing additional descriptions of key elements of the SEEA ecosystem accounting model. In doing so the section also provides some additional material to reflect the ongoing discussion of the ecosystem accounting model. This particularly relates to a discussion on the concept of ecosystem capacity and the treatment of inter-ecosystem flows. First though a quick summary of the ecosystem accounting model is presented.

2.2 The SEEA EEA ecosystem accounting model and key accounting principles

2.2.1 The Ecosystem Accounting Model

2.2. The SEEA EEA ecosystem accounting model has 6 main components that are reflected in figure 2.1 below. Starting at the bottom of Figure 2.1 the model is based around accounting for an ecosystem asset that is defined spatial area. Each **ecosystem asset** has a range of relevant **ecosystem characteristics and processes** that together describe the functioning of the ecosystem. The accounting model proposes that the stock and changes in stock of ecosystem assets is measured by considering the ecosystem asset's **extent and condition** which can be done using indicators of the relevant ecosystem's area, characteristics and processes.

Figure 2.1 Ecosystem accounting model (SEEA EEA Figure 2.2)



2.3. Each ecosystem asset generates a set of **ecosystem services** which, in turn, contribute the production of **benefits**. Benefits may be goods or services currently included in the economic production boundary of the SNA, SNA benefits, or they may be benefits received by individuals that are not produced by economic units (e.g. clean air). These are non-SNA benefits. Benefits, both SNA and non-SNA, contribute to individual and societal **well-being** or welfare.

2.4. The chain of relationships from ecosystem assets to well-being is at the core of the SEEA EEA. While there remain some important issues of definition in terms of the boundaries between different components, and there remain significant measurement challenges in both physical and monetary terms, the core model reflecting the relationships between ecosystem assets, ecosystem services and individual and societal well-being remains strong.

2.2.2 Assets and services

2.5. At the core of the ecosystem accounting model of the SEEA EEA is the distinction between ecosystem assets and ecosystem services. The former are the stocks within the accounting system and the latter are the flows. The distinction is an application of the separation in standard accounting between capital and income.

2.6. By accounting for both of these components and presenting both in a single integrated model, two key advantages accrue

- First, a significant amount of data can be integrated in both bio-physical and monetary terms
- Second, issues of sustainability can be considered since the capacity of the ecosystem asset to deliver services can be considered separately from the flows of ecosystem services themselves.

2.7. There are a number of approaches in the field of ecosystem measurement that focus on either the assessment of ecosystem assets or on the flows of ecosystem services. Those that focus on ecosystem assets tend to work in bio-physical terms and while this information is undoubtedly of value and relevance, the issue of why ecosystem assets are important is not addressed. That is, the information does not directly highlight the connections between ecosystem assets and economic and human activity.

2.8. On the other hand, approaches that focus on ecosystem services, particularly those targeting monetary valuation of ecosystem services, can tend to infer or assume a connection to the underlying ecosystem assets which generate the services. This is consistent with standard accounting and economics where the value of an asset is considered to be equal to its discounted future income stream. However, using this assumption in ecosystem accounting puts to one side significant issues of the multi-faceted connection between ecosystem assets and the services they generate.

2.9. The significance of the SEEA ecosystem accounting model thus lies in requiring consideration of both assets and services and in the recognition of the connection between the two key components.

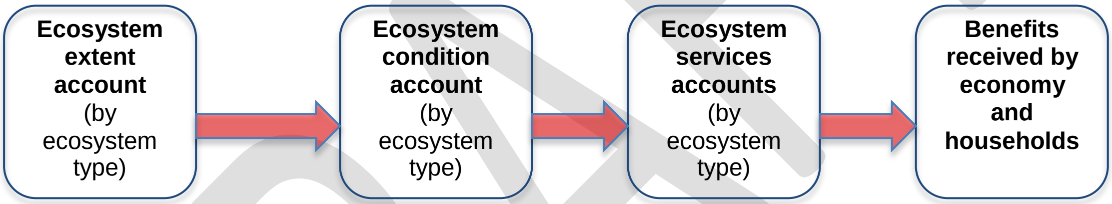
2.3 The steps in compiling ecosystem accounts

2.10. While the conceptual model for ecosystem accounting in Figure 2.1 provides a general description of the relationships between the different stocks and flows, it does not provide a sense of how a compilation of ecosystem accounts might proceed. This section provides a broad overview of the steps involved in compiling ecosystem accounts. Later chapters in the EEA TG provide more detail on the various types of accounts and the related measurement issues and recommendations.

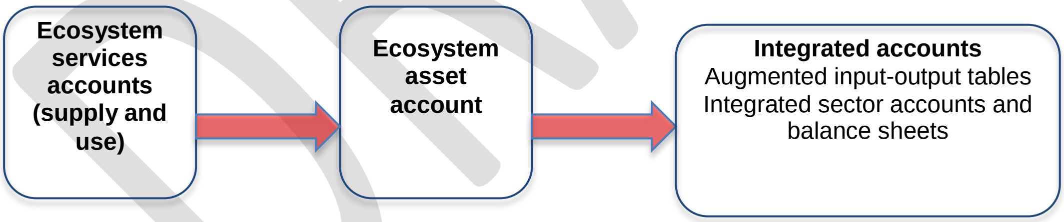
2.11. In broad terms the compilation of ecosystem accounts will proceed from basic physical measures of ecosystem assets to the measurement of ecosystem services in physical terms and, from there, to valuation and integration with standard economic accounts. This broad sequence is shown in Figure 2.2 where the first series of steps is in physical terms and the second series of steps is in monetary terms. This logic might be circumvented somewhat by first measuring physical flows of ecosystem services but without a clear articulation of the ecosystem assets of interest this task is likely to be somewhat more challenging. Further, it is noted that since ecosystem services are not traded on markets, then valuation must follow measurement in physical terms.

Figure 2.2 Basic steps in developing ecosystem accounts

a. Steps in physical terms



b. Steps in monetary terms



2.12. <u>Step 1:</u> For ecosystem accounting, as for national accounting, the first important step is to delineate the spatial areas that are to be the focus for the accounts. In principle, these areas should cover the entirety of a country's terrestrial area and as appropriate, relevant marine areas – perhaps extending to a country's EEZ. As a first step, information on the total area should be classified by type of land cover/marine area thus providing a very broad approximation of ecosystems. More detailed classifications of total areas will also be appropriate. Chapter 3 discusses at more length the issues of delineating and classifying spatial areas for ecosystem accounting purposes.

2.13. Information on the total area, generally in hectares, is presented in an **ecosystem extent account**. This account presents an opening and closing area by type of land cover or more detailed classification, together with information on the additions and reductions in area. The structure of the ecosystem extent account mirrors that of the land cover account described in the SEEA Central Framework noting the likely incorporation of more detailed classes of spatial areas for ecosystem accounting purposes. The compilation of the ecosystem extent account is described in Chapters 4 and 7 with relevant information also in the discussion of land accounts in Chapter 6.

2.14. Step 2: Using the breakdown of ecosystem assets determined for the ecosystem extent account, the next step is to compile the **ecosystem condition account**. This account records information on the various characteristics that reflect the condition or quality of an ecosystem. This may include information on water, carbon, biodiversity, and soil. The set of relevant characteristics will depend both on the type of ecosystem (i.e. indicators for forests will likely be different indicators for coastal ecosystems) and on the use of the ecosystem since the way in which an ecosystem is used will usually have a direct effect on the way in which its condition may change.

2.15. Chapters 4 and 7 discuss the compilation of ecosystem condition accounts in more detail. Chapter 6 discusses the compilation of information on carbon, water and biodiversity using accounting approaches since these data are likely to be highly relevant in monitoring the condition of most ecosystems.

2.16. Step 3: The next step involves the measurement of ecosystem services in physical terms. This measurement is completed by considering each ecosystem in turn and determining the relevant ecosystem services and appropriate indicators. This task should be conducted by using a classification of ecosystem services such as CICES. In effect a classification can provide a checklist to ensure appropriate coverage in measurement. This work should lead to the compilation of an **ecosystem services supply account**. The possible approaches to measurement are discussed in Chapter 5.

2.17. Still on ecosystem services, the next aspect is understanding the link between the supply of ecosystem services and the beneficiaries who use those services. To support integration with the national economic accounts the beneficiaries in ecosystem accounting are grouped in the same way as for the economic accounts – i.e. by industry group and by institutional sector. This information on the types of ecosystem service used by different beneficiaries is contained in an **ecosystem services use account.** The compilation of this account is also discussed in Chapter 5.

2.18. Step 4: Although there are differing views on the merits of monetary valuation (see Chapter 8 for a discussion), it is the case that there are many examples of the valuation of ecosystem services and it is a necessary step for the integration of ecosystem measures into the standard national accounts. There are two main parts to valuation in ecosystem accounting. First, the valuation of ecosystem services by applying relevant prices to the physical flows of ecosystem services measured in Step 3. This permits the compilation of **ecosystem service supply and use tables in monetary terms**.

2.19. Second, the valuation of ecosystem assets and measurement of ecosystem degradation. This is done by estimating the net present value of each future flow of ecosystem service from each ecosystem. There are, of course, many challenges in this step (discussed further in chapter 8) but a particularly important one is assessing the extent to which current ecosystem services supply can be maintained. This requires an assessment of ecosystem capacity – in essence the connection between ecosystem condition and ecosystem services. Information on ecosystem capacity can be presented in an **ecosystem capacity account**, although this area of work is less developed than other aspects of ecosystem accounting. Using the change in the net present value of ecosystem assets, a value for ecosystem degradation can be determined. Opening and closing values for ecosystem assets and changes in those values over an accounting period can be presented in an **asset account for ecosystems**.

2.20. The final part of step 4 is the use of information on the value of ecosystem services, ecosystem assets and ecosystem degradation to augment the current, standard national accounts. This may be done in a number places including (i) the input-output table where ecosystems can be incorporated to show the supply of additional services and the extension of the supply chain; (ii) the sequence of accounts where measures such as GDP, national income, and saving are adjusted for the cost of ecosystem degradation; and (iii) the national balance sheet where the value of ecosystem assets is incorporated to derive extended measures of national wealth. There are challenges in all of these areas that are discussed at more length in Chapter 9 on **integrated ecosystem accounts**.

What constitutes ecosystem accounting?

2.21. A reasonable question, in light of the lengthy list of different accounts just described, is which accounts constitute ecosystem accounting? Further, do all of the accounts need to be compiled? The response to these questions has two main aspects. First, ecosystem accounting is as much an approach to measurement as it is a set of accounts. As outlined further in Section 2.5 ecosystem accounting embodies important underlying aspects of national accounting by establishing broad and comprehensive boundaries and standardised relationships between different stocks and flows. In this context, ecosystem accounting is an approach to measurement that goes well beyond the measurement of individual ecosystems or the valuation of individual ecosystem services. It is the bringing together of a variety of information that is the feature of ecosystem accounting.

2.22. Second, in the context of this comprehensive approach, it must be accepted that all of the accounts described above cannot be completed at once and there is a quite natural progression through the accounts. As the progression takes place ecosystem accounting becomes more advanced but at each point along the way the completed accounts will be relevant for particular policy purposes and analysis. That is, it is not necessary to complete the full series of accounts for the information to become relevant.

2.23. Based on current experience a reasonable first level of attainment in terms of ecosystem accounting would be the compilation of accounts for ecosystem extent, ecosystem condition and ecosystem services supply, all in physical terms. These three accounts form the basis for all accounts beyond and in their own right comprise a coverage of the key elements of the ecosystem accounting model in Figure 2.1. It is also likely to be the case that in compiling these accounts it is relevant to compile several component accounts such as accounts for land cover, carbon, water resources and biodiversity. These accounts will organise data of value in their own right but will also directly support the compilation of the primary ecosystem accounts.

2.24. In compiling these first three accounts (extent, condition and ecosystem services supply) the largest gap lies in the lack of meaningful aggregates that permits broad assessment across ecosystems (aside from aggregation in terms of total hectares in the extent account). One path toward aggregation is the use of monetary valuation and it is in this context that the drive towards valuation and ultimately towards integration with the standard economic accounts has most relevance. Some may argue that without this objective being obtained then ecosystem accounting is a "detour" (Bartelmus, 2015) and lacks real meaning. However, the SEEA perspective is that all of the accounts described embody national accounting principles and structures and hence work towards the meaningful mainstreaming of environmental information into economic and other decision making which is the overriding objective of this work.

Further advice on implementation strategies

2.25. To be completed: could include here reference to national work plans, advice from WAVES document and CBD QSP, reference to the SEEA Implementation Guide and any other implementation materials

2.4 Key boundary and conceptual issues

2.4.1 Introduction

2.26. Within the context of the conceptual model for ecosystem accounting just outlined there are many measurement challenges. This section is aimed at highlighting five key aspects of ecosystem accounting that should be considered in advancing work in this area. Further discussion of these aspects is presented in the remaining chapters, sometimes in the form of recommendations for compilation and testing and sometimes in the form of issues requiring further research and discussion.

2.4.2 The spatial approach to ecosystem accounting

2.27. The ecosystem assets that are the basis for ecosystem accounting are spatial areas. Consequently, the delineation of spatial areas within a country is a fundamental part of ecosystem accounting. To support the process of delineation the SEEA EEA describes a units model in which different types of spatial areas (units) are related to each other. The units for ecosystem accounting are described in SEEA EEA section 2.3 and the logic is summarized briefly in EEA TG Chapter 3 together with an introduction to the related issues of classification of units.

2.28. The delineation of units is important for ecosystem accounting since the ultimate intent is to provide a comprehensive picture of ecosystem assets and the services they supply across a country without gaps and overlaps in measurement. Thus defining the units appropriately and consistently in relation to each and over time is a central feature. An analogous approach is taken in economic measurement where individual economic units (businesses, households, governments) are classified to mutually exclusive classes of industries to provide a better understanding of the changing structure and performance of the economy.

2.29. As discussed in Chapter 3 there remain a number of issues to be resolved in applying the broad units model to ecosystem accounting. These issues include (i) determining the appropriate scale for analysis, (ii) defining the relationship between the delineation of spatial areas (and hence ecosystem assets) and the generation of ecosystem services since ecosystem services, particularly regulating services, which may be generated over spatial areas that cross ecosystem asset types; and (iii) connecting the spatial areas relevant for measuring the generation of ecosystem services with the location of beneficiaries of those services.

2.30. Another role of the units model is to facilitate the upscaling and downscaling of information. Since so many different data are likely to be required from national level production data to site specific condition data, an important challenge in ecosystem accounting is the integration of information to a common scale, using scaling techniques, and then re-presentation of the data to the relevant level for aggregation and communication. Chapters 5 and 7 provide a summary of possible approaches to scaling and the related issues that arise in the context of biophysical modeling of ecosystem services and indicators of condition.

2.4.3 The treatment of final and intermediate ecosystem services

2.31. The explicit focus of accounting in SEEA EEA with regard to ecosystem services is final ecosystem services – i.e. the contributions of ecosystems to benefits used in economic and other human activity. The word "final" was deliberately dropped in the drafting of SEEA EEA with the intention of making it clear that those flows that were not considered final were also not considered to be ecosystem services.

2.32. While this choice was clear and internally consistent, subsequent discussion and explanation of the ecosystem accounting model suggests that use of the word "final" as appropriate would help considerably in explaining the model, especially to those already in the field of ecosystem measurement.

2.33. A primary reason for this change is the increasing recognition of the need to incorporate into the ecosystem accounting model flows between ecosystems that can be explicitly linked to the generation of final ecosystem services. A fairly standard example concerns the soil retention and water purification services provided by upstream forests to downstream surface water resources from which water is abstracted for irrigation or household consumption.

2.34. Further discussion on the issue of final and intermediate services is presented in Chapter 5.

2.4.4 Distinguishing final ecosystem services from benefits

2.35. The SEEA EEA ecosystem accounting model has a clear distinction between final ecosystem services and benefits. From an accounting perspective the distinction is meaningful since it facilitates the integration of final ecosystem service flows with existing flows of goods and services, it recognizes the role of human inputs in the production process and especially the fact that the relative share of final ecosystem services may change over time, and it helps in identifying the appropriate target of valuation since final ecosystem services that contribute to marketed products (e.g. crops, timber, fish, tourism services) will have a different (lower) price than the corresponding benefits.

2.36. For these reasons the principle of distinguishing between ecosystem services and benefits is appropriate. It is also consistent with the approach taken in TEEB (2010), Boyd and Banzhaf (2007), Haines-Young and Potschin (20xx) and the UK NEA (2011) although the precise definitions and terms applied for ecosystem services and benefits varies in the different cases.

2.37. In practice however, particularly at large scales, the explanation and application of this principle can be challenging. The issues arise differently in the context of provisioning services and regulating services. For provisioning services, the difficulties lie in fully describing the various ecosystem services involved in generating, so-called, cultivated biological resources. Thus for crops, including plantation timber, and aquaculture, the treatment is that these outputs are benefits produced as a combination of ecosystem services and human inputs. Further, since the balance of inputs between ecosystem services and human inputs will vary by production process, this means that the using the measure of output/benefits as a measure of the ecosystem service may be misleading.

2.38. For regulating services there are generally no human inputs in the production of benefits and consequently the quantity of ecosystem service will be equal to the quantity of the benefit. The challenge however is to appropriately describe the benefit and the ecosystem service such that the focus of measurement is appropriate. The focus in describing the ecosystem service should be a description of ecosystem processes or characteristics rather than on why the ecosystem services is a good thing. For example, in the case of air filtration services the benefit is reduced risk (to the local population) of respiratory diseases. Or, in the case of the service of soil retention the benefit is reduced risk of landslides. Focusing on this distinction enables a clearer description of what the ecosystem is actually doing to be established.

2.4.5 Ecosystem degradation and enhancement

2.39. The measurement of ecosystem degradation is one of the key drivers of ecosystem accounting and for the SEEA more generally. Indeed, without a concern for a falling ability of the environment to provide ecosystem services it would be possible to continue to view the environment as infinitely capable of regeneration and of supporting economic and human activity.

2.40. While the general idea of ecosystem degradation as reflecting a fall in the capacity of ecosystems to supply ecosystem services is well accepted – there remains debate about how this concept should be defined for measurement purposes. The alternatives are described in SEEA EEA Chapter 4 and are summarized in EEA TG Chapter 7.

2.41. The related concept is ecosystem enhancement which arises when there is an increase in the capacity of an ecosystem to supply ecosystem services. Again, there are some alternative concepts that can be used and also some interesting connections to the recording of investment in ecosystems which should be recorded as a standard entry in economic accounts.

2.42. The measurement of degradation and enhancement is closely tied to the definition of the concept of capacity, which as noted earlier, is a topic of ongoing discussion. This issue is also picked up in Chapter 7. Ecosystem degradation related issues also arise in the context of valuation, discussed in Chapter 8, and in terms of how degradation costs may be allocated across economic units, discussed in Chapter 9.

2.43. In the context of describing general principles for ecosystem accounting the most relevant observation is that ecosystem degradation is not something that can be directly measured. It requires consideration of changes in overall ecosystem condition, in the capacity of the ecosystem and in the overall basket of ecosystem services. Given that the relationships between these elements are many and varied then, depending on the assumptions used, different measures and interpretations of ecosystem degradation will arise. Careful consideration of the relevant building blocks is required.

2.4.6 Valuation in ecosystem accounting

2.44. Valuation is commonly one of the most controversial issues in ecosystem accounting. Given this reality, the intent of discussion of this topic in the SEEA EEA and in EEA TG is to provide a broad base for discussion by articulating the different elements of the debate and the key conceptual points from a national accounting perspective. The general conclusion to date is that effective valuation in monetary terms requires careful consideration of the *purpose* of the valuation – for example for accounting purposes or for the assessment of trade-offs between alternative scenarios. Once the purpose is defined the appropriate valuation *concept* can be selected and from these relevant valuation *methods* and techniques can be applied. Often the focus moves directly to methods and techniques but it is simply not the case of one size fits all. Chapter 8 provides a description of the relevant issues.

2.45. A fundamental aspect of valuation in an accounting context is that the first step required is the valuation of individual ecosystem services. In general this will mean finding an appropriate price to apply to an imputed exchange of ecosystem services between a given ecosystem asset (e.g. a forest) and an economic unit or individual (e.g. a forester). Valuing this imputed exchange is the starting point for broader valuation.

2.46. Valuing ecosystem assets requires considering the future flows of ecosystem services that are expected to be generated by the ecosystem asset. Generally, this will mean that a basket of ecosystem services needs to be forecast and priced with the value of the ecosystem asset then equal to the net present value of the future flows of expected ecosystem services. Recognising the steps that are required to move from the valuation of ecosystem services to the valuation of ecosystem assets is important in making decisions about the nature of implementation of ecosystem accounting.

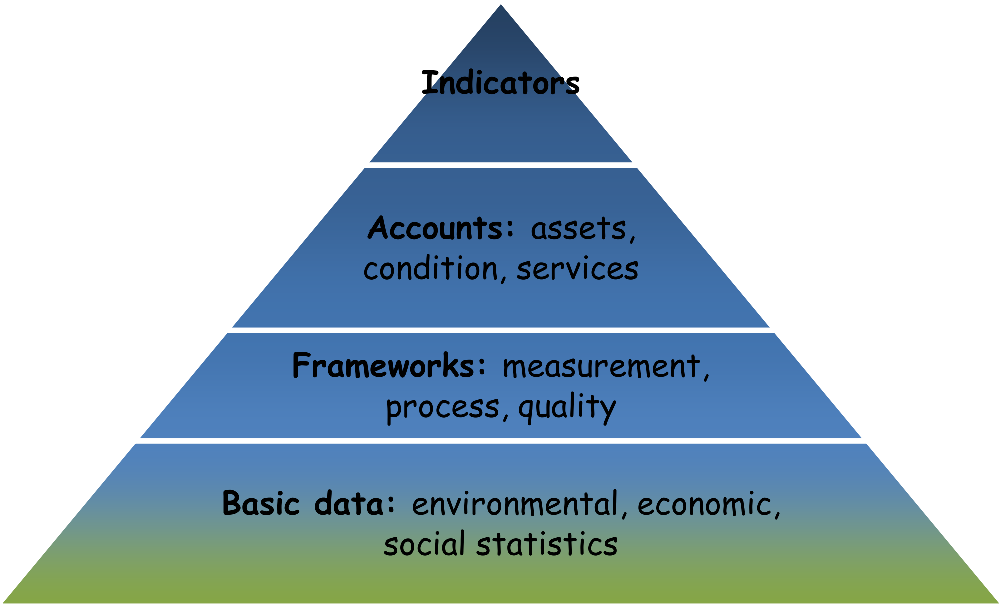
2.5 Key features of a national accounting approach to ecosystem measurement

2.5.1 Introduction

2.47. Given the focus of ecosystem accounting in the SEEA is predominantly on the organisation of biophysical information pertaining to ecosystems, it may be reasonable to conclude that there is little connection to the standard approaches to national accounting which focuses on the integration of monetary measures of stocks and flows of goods, services and assets. This section is aimed at explaining the key features of a national accounting approach and why it provides a distinct measurement discipline that works very effectively towards the mainstreaming of environmental information into economic measures.

2.48. First, to place accounting frameworks in context it is relevant to consider the information pyramid (Figure 2.3). This pyramid has as its base a full range of basic statistics and data from various sources including surveys, censuses and administrative sources. Generally, these data will be collected for various purposes with the use of different measurement scopes, frequencies, definitions and classifications. Each of these data sources will be relevant to analysis or monitoring of specific themes.

Figure 2.3 Information pyramid



2.49. The role of accounting frameworks (at the middle levels of the pyramid) is to integrate these data to provide a *single best picture* of a broader concepts or set of concepts – for example economic growth or ecosystem condition. The compiler of accounts must therefore reconcile and merge data from various sources taking into account differences in scope, frequency, definition and classification as appropriate.

2.50. Finally, having integrated the data within a single framework, indicators can be derived that provide insights into the changes in composition, changes in relationships between stocks and flows, and other features taking advantage of the underlying relationships in the accounts between stocks and flows, between capital and labour, between production and consumption, etc. Indicators such as GDP, national saving, national wealth, terms of trade and multi-factor productivity all emerge from the one national accounts framework.

2.51. This section focuses on the approach that national accountants take to providing the single best picture in the middle section of the pyramid.

2.5.2 Key features of a national accounting approach

2.52. For those not familiar with the way in which national accountants work through measurement issues there are two key aspects that should be understood. First, national accounting approaches generally always commence using data from multiple sources that has already been collected. National accounting is therefore not a challenge in defining questions, determining sample sizes, collecting and processing data, etc. Those tasks are assumed to be completed by experts in specific subject matter areas or those in charge of administrative data. Ideally, there would be a close relationship between the national accounts compiler and those collecting the data but this can take time to evolve and in any event the national accountant will always remain one step removed from the source data.

2.53. Second, in part as a result of not collecting data but largely as a result of the underpinning conceptual framework, national accountants work "from the outside in". National accounting is not a "bottom up" measurement approach whereby aggregates are formed by summing available data. Rather, most effort goes into ensuring that the estimates that are compiled appropriately reflect the target concept, for example, economic growth or fixed capital formation or household consumption. Generally, it will be the case that no single data source can fully measure a single concept and hence the role of the national accountant is to meld, integrate and otherwise combine data from multiple sources to estimate the concept as best as possible.

2.54. Further, on this same point. It is not sufficient to obtain the best estimate of each concept in isolation. Rather the measurement of each concept must be considered in the context of the measurement of other concepts following national accounts identities. Thus, for example, total supply and total use of each product must align. Ultimately it is the ambition to produce, at a single point in time, the single best picture, of the concepts in scope of the national accounts framework. This cannot be achieved by relying on a bottom up strategy where the micro builds neatly to the macro. Instead, a top down or working from the outside in approach must be applied.

2.55. Building on these two key aspects there are some related national accounting approaches that should be recognised.

- The maintenance of time series is fundamental. In creating the "single best picture" it is not sufficient for each data point to stand alone and hence movements and levels must both be considered. Often national accounts time series extend for over 30 or 40 years and there are few if any data sources that are maintained consistently over these time frames. Indeed, generally data sources will improve their methods and coverage over time. Consequently, a key role in national accounts in linking information from different sources and over time, various methods may need to be applied to consistently measure the same concept.

- Prices, quantities (volumes) and values are all relevant. While the vast bulk of the national accounts framework is presented in terms of relationships in value terms (i.e. in terms of the actual monetary amounts transacted); the most significant proportion of resources on compiling national accounts are targeted at decomposing the changes in value between changes in prices or changes in underlying volumes. Generally, most analysis of the national accounts, e.g. growth rates, productivity, investment levels, are conducted in volume terms (i.e. after removing price effects). Again the single best picture ambition requires balancing these different perspectives at an aggregate level.

- Focus on the aggregate and then the allocation. Although an iterative approach is necessary at the final stage decisions must be made on the aggregate measure and then the impact of this decision filtered through the underlying data to various levels in the classifications – either by product, industry or institutional sector. This final process of allocation is the means by which the national accounts approach ensures consistency and coherence between the various concepts within the framework. It cannot be assured through coordination of the underlying data.

- The need for revisions. Without a time constraint on the integration of data and the release of results it is likely that the national accounts would never be completed. Given their scope there is always new information that might be considered or new methods that might be adopted to refine the single best picture. National accounting thus works by ensuring the release at regular intervals of the best picture with the knowledge that it will be revised in due course and additional information comes to hand.

The reality of revisions is an important feature of national accounting approaches.

- Accounting is iterative. Fundamentally, the process of integrating data is not a once through process. Each time a set of accounts is compiled different integration issues will arise and will generally only be resolved through attempting integration, understanding the reasons for imbalances, and implementing possible solutions. Gradually, a single best picture emerges. Ideally, resolving these integration issues is a task that involves both accountants and data supplying areas – often this joint level of operation is not a feature of accounting in practice.

2.56. One overall consequence of a national accounting approach to estimation is that comparability between different estimates is not assessed primarily on the basis of method. In the first instance, comparability is based on the extent to which different estimates accurately reflect the target concept. Indeed, since each national accountant will be faced with the integration of different source data a focus on comparability of methods is likely not a helpful starting point although it must be accepted that not all methods will produce estimates of equal quality.

2.57. One benefit of a focus on concepts is that countries will tend to focus their resources on measuring those aspects that are of most relevance to them. For example, in a country in which agriculture is a dominant activity, resources should be allocated to measurement of this activity. In a different economic structure, for example a country with a large finance sector, the balance of resources and the associated accuracy of methods will and should be different. Since economic structures changes over time, methods will also need to adapt. The development of services statistics and associated measurement methods in the past 25 years is a good example of this process.

2.5.3 Applying the national accounting approach to ecosystem accounting

2.58. For those not of a national accounting background, this description of the national accounting approach may seem overly loose and lacking in rigour. While it is certainly the case that national accounting entertains a different approach, it must be recognised that the ambition in national accounting is different from the objectives of most statistical or database managers. In most cases, including in the datasets that underpin ecosystem accounting, the ambition is to generate databases pertaining to a single theme or topic and to provide the best estimates based on the selected methods and resources available. While this may well and should involve comparison with other datasets as part of editing the dataset, it generally does not involve full integration with those datasets.

2.59. A national accountant is not compiling such a dataset but rather is seeking to undertake the integration. In many respects this is a role that must be undertaken by an analyst or decision maker – i.e. making tradeoffs between different data sources that may suggest different trends. Within the scope of economic analysis, national accountants have been making these tradeoff decisions about relative data quality (for example between quarterly and annual data) within the rigour of the national accounting framework, rather than a situation where each economic analyst was required to make their own tradeoffs and likely to different definitions of economic aggregates.

2.60. The application of a national accounting approach within ecosystem accounting thus extends this approach to the consideration of biophysical and scientific data. That is, within ecosystem accounting the ambition is to integrate the various sources of information on ecosystem condition, ecosystem services, economic production and consumption, etc. and to present the single best picture, based on the available data.

2.61. One consequence is that for ecosystem accounting it is necessary but not sufficient to have data for a particular ecosystem type (e.g. forests) or for a selected set of ecosystem services. Rather, effort must be made to obtain information that permits assessment of the whole area of interest or full scope of supply of ecosystem services. Certainly it would be relevant to place most resources into measuring those ecosystems and their services that are considered most relevant but this should not detract from the ambition to measure the whole.

2.62. In putting these estimates together it means that data that may be regarded as of good quality are adjusted to ensure an integrated picture. As well, since the emphasis is on the measurement of a defined framework, some data sources may not be used, whatever their quality, since they are not defined following the required concepts.

2.63. While these statements are somewhat stark, in practice, a national accounts approach is very reluctant to ignore any information. Rather, efforts are generally made to examine all relevant data and where necessary make adjustments to concepts to permit integration.

2.64. Further, in the area of ecosystem accounting, work is ongoing to define the final integrated framework. In this context, there remains considerable scope for an active dialogue between those managing the underlying data sets and those designing the ecosystem accounting framework. This dialogue is essential for the generation of high quality information.

2.5.4 Principles and tools of national accounting

2.65. In this final part of section 2.5, discussion focuses on the main aspect of the national accounting framework that underpin the design and application of the ecosystem accounting model described in section 2.2. The focus here is on the main principles and tools that national accountants apply to ensure coherence in the integration of data from multiple sources.

2.66. The following paragraphs present a brief description of the relevant principles. An extensive discussion of the principles is contained in the SNA 2008 and an extended overview is provided in SEEA 2012 Central Framework.

2.67. <u>Accounting identities.</u> The accounting system relies on a number of identities – that is, expressions of relationships between different variables. There are two of particular important in ecosystem accounting. First, there is the supply and use identity in which the supply of a product (or in this case ecosystem service) must balance with the use of that same product. This identity applies in both physical and monetary terms. Often information on the supply and use of a product will be from multiple sources and hence this identity provides a means by which data can be reconciled.

2.68. Second, there is the relationship between balance sheets and changes in assets. This identity is that the opening stock plus additions to stock less reductions in stock must equal the closing stock. Again, this identity applies in both physical and monetary terms. Without this identity there would be no particular reason to ensure that observed changes in ecosystem assets aligned with the series of point in time estimates of ecosystem condition that underpin the balance sheets.

2.69. Time of recording. In order to provide a single best picture across multiple data sources it is essential that there is a common reference point referred to in accounting terms as the accounting period. Generally, it is recommended that the accounting period used in the SEEA is one year thus permitting alignment with economic data that are usually compiled on this basis. Flows are measured in terms of recording all that takes place during the selected accounting period and stocks are measured at the opening and closing dates of the accounting period.

2.70. Commonly, different data sources will have different reference periods and thus adjustments will be required to allow appropriate integration. For example, flows may cover a date range that is not aligned with the selected accounting period and/or stock information will relate to a non-opening or closing period date. Where adjustments are made these should be made explicit or if no adjustments are made then the implicit assumptions should be described.

2.71. In addition to these key principles there are a few common tools and methods that national accounts apply. These are

2.72. Benchmarking, interpolation and extrapolation. Among the range of different data sources there will usually be a particularly sound source in terms of coverage and quality. Commonly such a source will provide a benchmark at a point in time or for a given accounting period. Using this information as a base it is then common to apply indicators to extrapolate this information to provide more up to date estimates and also to interpolate between benchmarks, for example in cases where the best data are collected every 3 years but annual estimates are required for accounting purposes. Generally, these techniques are applied to generate the first estimates for a particular variable and may be subsequently adjusted through the balancing and integration process.

2.73. In some respects these types of benchmarking and interpolation/extrapolation techniques may be regarded as a form of modelling. The extent to which this is the case will depend on the sophistication of the technique that is used. Generally, regressions and the like are not utilised since maintaining these models across the full gamut of a national accounts framework would be very resource intensive. Further, since the outputs are eventually integrated within a series of accounting identities it may be difficult to rationalise the statistical advantage of applying detailed modelling approaches for individual series.

2.74. Modelling. Where modelling does become more in evidence is when there is a clear shortage of data for particular variables – i.e. there are no direct estimates or benchmarks that can be used to provide a starting point. In this case, modelling may be required. An example in standard national accounts is the estimation of estimates of consumption of fixed capital (depreciation) which are commonly estimated using the so-called perpetual inventory model (PIM) that requires estimates of capital formation and assumptions regarding asset lives and depreciation rates.

2.75. In the context of ecosystem accounting, the spatial detail required is likely to considerably increase the need for modelling and this will be new ground for many national accountants. Later sections in this EEA TG consider the role of biophysical modelling in ecosystem accounting and the general issue of benefit transfer where information from one location is applied in other locations is one that confronts all those involved in larger scale ecosystem measurement. While these may not be traditional sources of information for national accounts type work, there is no particular reason that such modelled data cannot be directly incorporated. It remains the task of the accountant to integrate all available data as best as possible.

2.76. A general issue that crosses all of the discussion through this section is that of data quality. Unlike many of the source data that feed into the national accounts it is not usually possible to give a precise estimate of common measures of data quality such as standard errors. The melding and synthesis of multiple data sources makes this task relatively intractable. In the same context it is challenging to measure the significance of the application of accounting principles. While clearly these principles lead to coherence in the final data – it is often unclear how much adjustment might have been required in order for the coherence to be enforced.

2.77. Ultimately it will often be the case that accounts are considered of a relatively good quality if the picture that they present is broadly considered a reasonably accurate one. This may emerge from consideration of (i) how well the accounts reflect and incorporate data that are considered to be of high quality; (ii) in commentary by accountants as to the extent of adjustment required (noting that in a number of situations accounts may be left unbalanced and the size of the discrepancy may be a measure of quality); (iii) the size of revisions to the estimates where a consistent pattern of large revisions to initial estimates either up or down would give an indication as to the relative quality of the source and methods; and (iv) the usefulness of the data from the accounts to users. At the end of the day if the data from the accounts do not support meaningful decision making or analysis then the quality of the accounts must be questioned.

2.78. A final area of mention concerns the treatment of uncertainty in accounting contexts. SEEA EEA Chapter 5 provide an overview of several areas of uncertainty that may affect information used in ecosystem accounting. These include By its nature, accounting aims to provide a single best picture and in this context would seem to ignore issues of uncertainty. Two points should be noted. First, to the extent that the inputs into an accounting exercise are subject to uncertainty then this should be taken into consideration in the compilation of the accounts themselves. Ideally, degrees of concern about the data would be the subject of description in the reporting of accounting outputs. The same holds true for any assumptions that are applied in the construction of accounting estimates – for example in terms of estimating future flows of ecosystem services in net present value calculations.

2.79. Second, while not generally undertaken, it would be plausible to consider publishing some ecosystem accounting aggregates within sensitivity bounds. The challenge of course is to ensure that a balance in the accounting identities would be meaningfully maintained but some further consideration of how uncertainty can be usefully reflected within an accounting context would be welcome.

2.80. Third, accounting does not represent a model for estimating future changes in systems. The national accounts therefore, organise information about the composition and changes in economic activity but do not purport to provide future estimates of economic growth. Economic models, generally using time series of national accounts data, perform this role.

2.81. In the same way, ecosystem accounting is not designed to provide a model of how the ecosystem behaves. It records, ex post, measures of changes in ecosystem condition and flows of ecosystem services. How this information might be combined to support estimates of future flows or changes in condition is a separate issue and likely subject to considerable uncertainties. This distinction between creating a structured set of information and modelling future states is often not made in scientific discourse and usually forgotten by economists. However, it is fundamental to understanding the role that accounting may be able to play in supporting the mainstreaming of environmental information into decision making.

3. Ecosystem accounting units of SEEA EEA

3.1 Introduction

3.1. The starting point for ecosystem accounting is the delineation of spatial areas that represent ecosystem assets. The focus on spatial areas enables the application of accounting approaches since it means that all areas within a country or region can be considered in a mutually exclusive manner. The challenge for ecosystem accounting however is that delineating spatial areas for ecosystems is not a straightforward task and is certainly not equivalent to using existing administrative or political boundaries as would normally be applied in socio-economic statistics.

3.2. An initial challenge is that ecosystems are not easy to define spatially. In ecological terms, ecosystems may be very small or very large and hence determining the appropriate scale for measurement and analysis is the main requirement. The SEEA EEA applies the definition of ecosystems from the Convention on Biological Diversity – "ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (CBD, 2003, Article 2, Use of Terms).

3.3. From this starting point the SEEA EEA describes a units model that provides a hierarchy of units at different spatial scales. While the definitions may appear prescriptive it is recognised that the precise application of the units model will require testing and application before more definitive guidance can be provided.

3.4. This chapter summarises the units model developed in SEEA EEA. An extended discussion on the units model and the approaches to delineating relevant spatial units is provided in ANCA Research Paper #1 (Bordt 2015).

3.2 The SEEA EEA units model

3.5. The role of the units model is two fold. First it allows the organization of information into separate entities that can then be compared and aggregated. This is akin to the role of a units model in economic statistics where different types of economic units (businesses, households and governments) are distinguished by their types of economic activity and legal structure. Second, the units model and the associated classifications provide a basis for the structuring of data for ecosystem extent, condition, and services.

3.6. Generally, the scale imagined for ecosystem accounting relates to broad types of land cover such as forests, wetlands, grasslands or urban areas. Where these types of land cover are quite mixed, the scale considered is more at a landscape level. While land cover is a primary driver of the types of ecosystems considered in ecosystem accounting, it is recognised that this should not be the only consideration and hence the SEEA EEA has developed the notion of Land Cover Ecosystem functional Units (LCEU). An LCEU, in most terrestrial areas, is defined as those areas that satisfy a pre-determined set of factors relating to the characteristics of an ecosystem. Examples of these factors include land cover type, water resources, climate, altitude and soil type (SEEA EEA 2.57).

3.7. To support measurement and recognizing that spatial areas often change incrementally overtime, the second component of the units model has been defined as the Basic Spatial Unit (BSU). A BSU is a small spatial area (say $1km^2$) often formed by overlaying a grid on a map of a larger area or country. Each BSU can be attributed a basic set of information (e.g. on land cover, soil type, elevation, land ownership, etc) and then, using selected characteristics, BSU with common features can be grouped together. In this sense, LCEU may be formed by combining contiguous BSU that have the same characteristics to form a relatively homogenous spatial area which in terms may be considered to constitute an ecosystem for accounting purposes. Generally, BSUs will be useful for some data integration and modelling but will be too small to operate as units for national level accounting purposes.

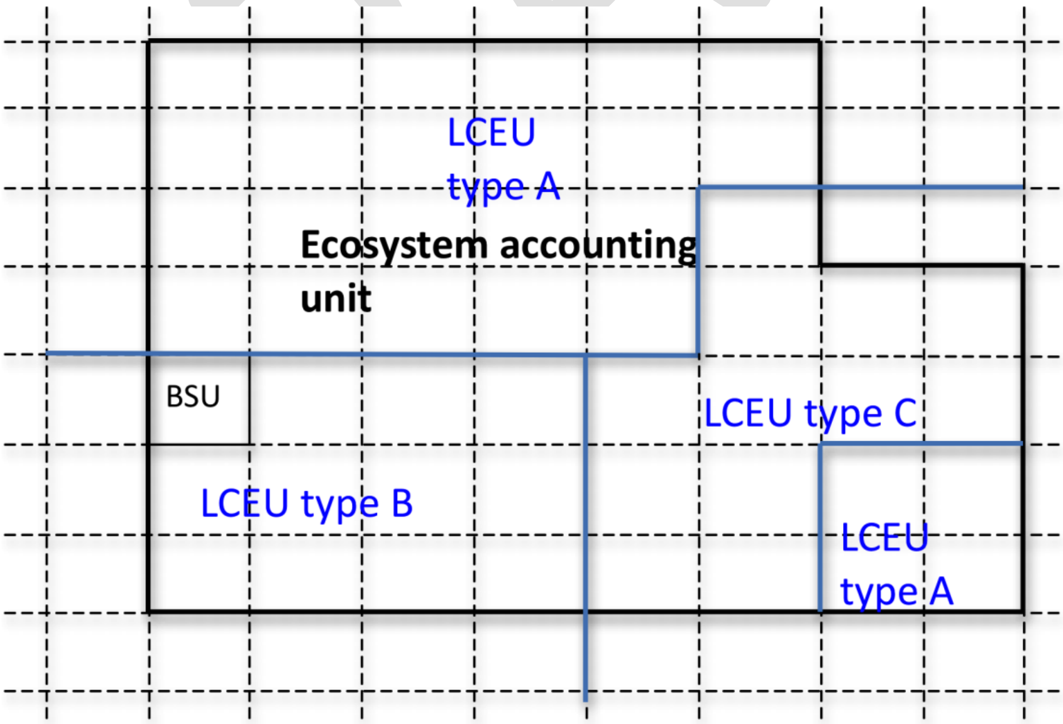
3.8. Since the general ambition of ecosystem accounting in the SEEA is to account for all ecosystems across a country, it is necessary to have a national level ecosystem accounting unit or EAU. At this level, information on, for example, the generation of ecosystem services may be integrated with the estimates of national level economic activity and income. Using a national level accounting unit also aligns with the general intent of accounting to ensure coverage of all components, without exception, and from that basis assess materiality (or relative importance) and changes in structure over time.

3.9. While the idea of a national EAU is appropriate, in practice it is also very relevant to consider sub-national level EAUs that may be aggregated to form a national perspective. Indeed a number of levels in a hierarchy of EAU may be envisaged, possibly aligned with level of administrative boundaries. Alignment with administrative boundaries would facilitate connecting ecosystem information with socio-economic information.

3.10. EAUs may also be delineated according to other spatial boundaries such as hydrological zones/river catchments. Areas such as these will generally encompasses a number of different ecosystem types and in that context the EAU represents an aggregate reporting level for information on the relevant constituent ecosystems.

3.11. The conceptual links between BSU, LCEU and EAU are shown in Figure 3.1.

Figure 3.1 (SEEA EEA Figure 2.4)



3.12. In the SEEA EEA there was not a great deal of clarity on the relationship between LCEU and EAU. Further discussion and consideration of the practical application of the spatial units model has led to the following conclusions.

- That LCEU, being defined as areas that are relatively homogenous in their characteristics, should be considered ecosystem assets for the purposes of ecosystem accounting.
- That LCEU should be delineated such that no LCEU is larger than an EAU in which it is located. Thus combinations of homogenous and contiguous BSU may need to be split to not cross the relevant EAU boundaries.
- EAU should not be considered ecosystem assets but rather as higher level reporting units.
- While at the most aggregated level of a classification LCEU may be delineated solely on the basis of land cover, it is likely that finer level classes will need to be used in which case factors other than land cover will be needed to delineate LCEU.

3.13. Given these conclusions the delineation of LCEU and hence of ecosystem assets is a fundamental step in ecosystem accounting. A balance must be struck between providing a highly detailed typology of ecosystem assets and providing more aggregated information that can be more readily translated to providing information about trends at an aggregate level. Approaches to delineating LCEU and the other elements of the units model are described below.

3.3 Data sources, classifications and methods for delineating spatial units

3.14. The delineation of spatial units will involve the use of a range of information. Typical of the type of data are those relating to:

- The physical topography of the country (coastline, digital elevation model(DEM), slopes, river basins and drainage areas)
- Land cover
- Soil resources
- Meteorological data
- Bathymetry (for marine areas)
- Administrative boundaries
- Population
- Transport and communication (roads, railways, power lines, pipelines)

3.15. Using these types of information it is possible to construct maps for a given country outlining different spatial units. In practice, to integrate information from these different data sources it will be necessary to put in place a standardised grid that can be used to provide a stable working base for the data. Further, a projection system that permits translation of information into a flat, two dimensional structure will be needed. And finally assimilation grids will be needed.

3.16. With these data source and tools in place there are a range of choices available for delineating the spatial units needed for ecosystem accounting. The following considerations are relevant.

3.17. For BSUs. Most commonly in ecosystem accounting discussion, BSUs are conceptualised as reflecting individual grid squares or rasters/pixels. This question is not whether such a concept is appropriate but rather what size the squares should be for ecosystem accounting purposes. This may, at least at present, be a limited choice depending on what data are currently available. Generally, information at the level of 1km2 would be considered to be the largest BSU that was appropriate. BSUs down to 5m2 or 10m2 are now possible for some countries, but whether delineation at that level of detail is required or appropriate for ecosystem accounting remains to be tested. Another alternative is to define BSUs based on the delineation of cadastres that are available in some countries. A concern for this approach is that the resulting characteristics of the BSU may be too heterogeneous to be aggregated meaningfully.

3.18. For LCEUs. There as yet no standardised method for delineating LCEUs and the approaches for delineating LCEUs depend in part on the amount of information available that can be attributed to the BSU level and hence be grouped to form LCEUs.

3.19. At a minimum information on land cover by BSU can be used as a basis for forming LCEU. An example of this approach is described in the CBD ENCA QSP (chapter 4) where land cover data, classified using the FAO LCCS v3, is used to form LCEUs aligned with the proposed LCEU classes in the SEEA EEA. (See table 3.1 below). Depending on the size of the BSUs being used, it may be necessary when attributing a BSU to a land cover class, to determine the dominant land cover for each particular grid cell.

Table 3.1 Provisional Land cover/ Ecosystem functional unit (LCEU) classes

Description of classes
Urban and associated developed areas
Medium to large fields rainfed herbaceous cropland
Medium to large fields irrigated herbaceous cropland
Permanent crops, agriculture plantations
Agriculture associations and mosaics
Pastures and natural grassland
Forest tree cover
Shrubland, bushland, heathland
Sparsely vegetated areas
Natural vegetation associations and mosaics
Barren land
Permanent snow and glaciers
Open wetlands
Inland water bodies
Coastal water bodies
Sea

Source: SEEA EEA Table 2.1

3.20. Other approaches have used a broader range of characteristics to delineate LCEU. These include the approach of the MEGS project in Canada and the work in Victoria, Australia. Work by SANBI also shows how the same principles of using multiple characteristics can be applied in the case of marine ecosystems. These various methods are described in ANCA Research Paper #1.

3.21. Another consideration is that accounting may be possible without delineating LCEUs as such and rather ensuring that all information on ecosystem condition and ecosystem services is attributed to the BSU level. If this can be done then accounting may take place at any aggregated scale – i.e. there is no specific requirement to enforce LCEU classes.

3.22. For EAUs. The most obvious choices of delineation for EAUs relate to administrative boundaries. These boundaries correspond best to the level of coverage of government decision making and hence to a range of other socio-economic data. Depending on the decision making context however other boundaries may be relevant including river basins, landscapes and viewscapes, and protected areas. In line with the conclusions above EAUs should reflect an aggregation of both BSU and LCEU.

3.4 Key issues and challenges in delineating spatial units for ecosystem accounting

3.23. As approaches to delineating the SEEA EEA's units model are developing there are a number of considerations that should be kept in mind. These issues are considered in more detail in ANCA Research paper #1.

3.24. First, it is likely that there is no perfect set of spatial units that can deal with all of the ways in which data might be integrated. Consequently, it is likely to be useful to develop approaches that permit a degree of flexibility in the delineation of spatial units.

3.25. Second, the standard model of BSU, LCEU and EAU has been developed to deal with terrestrial units. Although some work has commenced on the application of the model to marine areas (South Africa, Mauritius) and to river systems (South Africa), more work is needed to appropriately incorporate the atmosphere and airsheds, to deal with linear features such as coastlines and hedgerows, and to account for the zones between different ecosystem types – known as ecotones – since it is in these zones that concentrations of ecosystem functions and processes are at their highest.

3.26. Third, ideally the delineation of spatial units should consider issues of upward and downwards scaling of information particularly the attribution of information to the BSU level. Delineating units in a manner that requires a heavier burden of assumptions to permit scaling would likely reduce the general quality of the accounts.

3.27. Fourth, it is likely to be the case that delineation of spatial units will involve the use of satellite and remote sensing data. This is an important step forward but is not without its challenges particularly in the context of maintaining a consistent time series for accounting purposes. Particular care is needed in the organisation of satellite based data since higher resolution is not necessarily the most important factor for accounting purposes.

3.28. Fifth, particularly for LCEU the choice of classification and the associated level of detail is particularly important for the preparation of accounts. As explained further in Chapter 4, the accounts to be compiled in the first stage of ecosystem accounting – the ecosystem extent account, ecosystem condition account and the ecosystem services supply account – are all structured based on data at the LCEU level. Since each LCEU represents an ecosystem asset, measures of condition should be able to be developed at the LCEU level which in turn should require an understanding of the relevant characteristics in the supply of ecosystem services at that level. How effectively these considerations may be brought into the delineation process requires ongoing discussion and testing.

3.29. Another point associated with this last consideration is the extent to which the LCEU are consistent with ecological factors. Thus, if the LCEU are to represent ecosystem assets for accounting purposes, it may be reasonable to suppose that they would also reflect spatial areas that ecologists would consider to be appropriate functional units.

3.5 Conclusions

3.7.1 Recommended activities and approaches

3.30. To be drafted pending further discussion

3.7.2 Issues requiring ongoing research

3.31. To be drafted and prioritised pending further discussion

4. Main ecosystem accounts

4.1 Introduction

4.1. The compilation of accounts is the most obvious task in ecosystem accounting. Consequently, the presentation of the main ecosystem accounts as explained in this chapter helps to frame much of the discussion concerning data sources and compilation methods that follows in the remainder of EEA TG. At the same time, the accounts should not be taken at face value and there are a number of aspects concerning the design of the accounts that should be considered before compilation. These aspects are outlined in section 4.2.

4.2. The remainder of this chapter describes the set of ecosystem accounts as shown in Table 4.1. As is shown in that table there are some accounts which are considered to be quite amenable to compilation based on generally available data and methods and for which the structure of the accounts is well advanced. These are the primary ecosystem accounts in the top right of Table 4.1. The compilation of these ecosystem accounts is expected to be complemented and supported by a range of component accounts that focus on particular ecosystem components. Generally the development of these accounts is well advanced.

4.3. In the bottom part of Table 4.1 a number of accounts are listed for which further work on the structure and compilation methods is required. The first two accounts of this type, the ecosystem capacity account and the asset account for ecosystems are described further in this chapter. The second two accounts are described in Chapter 9 when the EEA TG discusses issues of integrating ecosystem accounting data within the structures of the standard national accounts.

Table 4.1: Set of ecosystem accounts

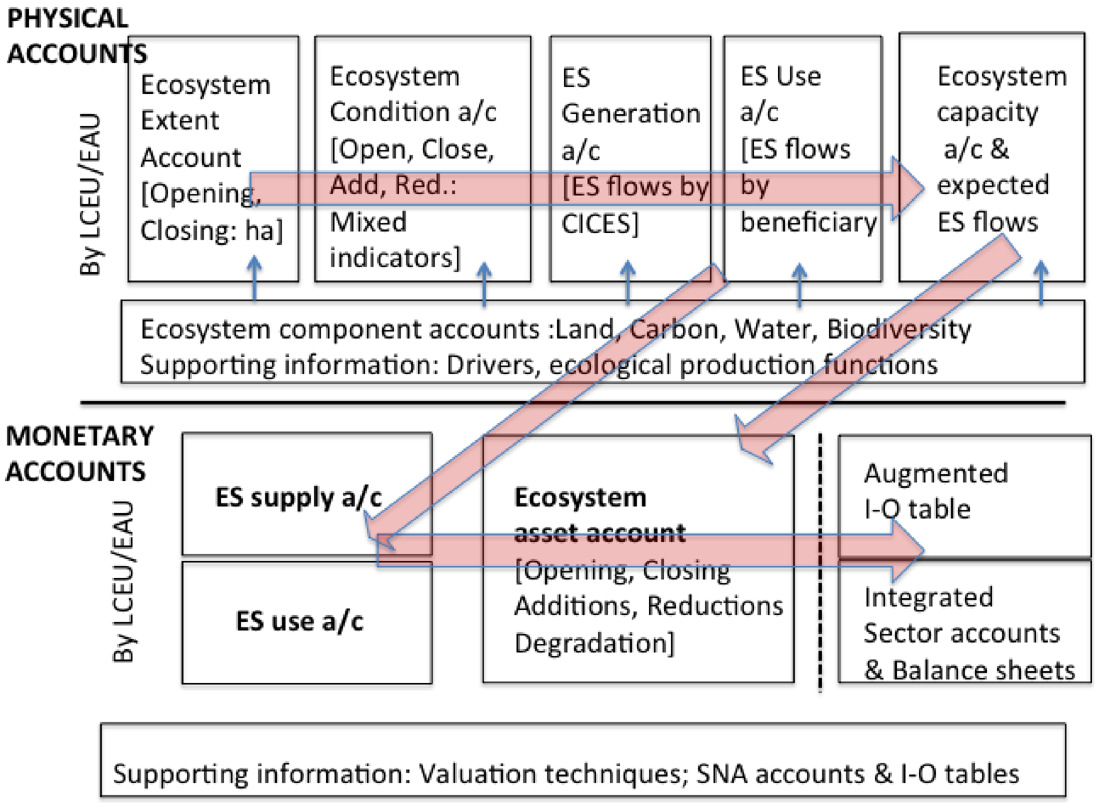
	Primary ecosystem accounts	**Ecosystem component accounts and related information**
Feasibility and structure of accounts well advanced	Ecosystem extent account	Land cover account
	Ecosystem condition account	Carbon account
	Ecosystem services supply account	Water resources account
	Ecosystem services use account	Biodiversity account
		Drivers of ecosystem condition & change
Structure of accounts under development and discussion	Ecosystem capacity account	Valuations of ecosystem services
	Asset account for ecosystems	Reference conditions
	Augmented input-output table*	
	Integrated sector accounts & balance sheets*	

* These accounts reflect the integration of ecosystem accounting based information into the standard set of national accounts

4.4. While each account stands alone, there are also important connections between the accounts. These connections reflect the accounting relationships between stocks and flows that underpin the application of various accounting identities such as the supply and use identity. Thus, for example, changes in the asset account for ecosystems must be consistent with recorded changes in the ecosystem condition account.

4.5. The ultimate ambition from a SEEA perspective is to integrated information on ecosystems into the standard national accounts. It is clear however that this achieving this ambition will require a series of steps to be completed. On the whole, this series of steps reflects following a path from the ecosystem extent account down the first column in Table 4.1 towards integrated sector accounts. In effect, each account provides a base for compilation of the next account in the series. This series of steps is portrayed more clearly in Figure 4.1 below.

Figure 4.1 Steps in the compilation of ecosystem accounts (building on Figure 2.2)



4.6. At this stage of development of ecosystem accounting it seems most likely that efforts will should be placed on compiling physical accounts (in the top half of Figure 4.1) and potentially on compiling the values of the supply and use of ecosystem services in monetary terms. Beyond this, there remains an ongoing discussion about the relevant methods and accounting structures and hence these accounts remain clearly on the development and research agenda.

4.2 Key considerations in defining ecosystem accounts

4.7. Six key considerations emerge in understanding the nature of the set of ecosystem accounts as presented in the EEA TG. First, it is a set of accounts that is presented each of which contains specific pieces of information applicable to one part of the ecosystem accounting model outlined in Chapter 2. There is not a single "ecosystem account" and it would be inconsistent with accounting principles to force all information on stocks and flows into a single account while retaining notions of internal consistency and coverage.

4.8. Second, as far as possible the accounts are designed to link together such that information can be readily compared between accounts. Thus while there is more than one account and each can stand alone in accounting terms, there are relationships between the information in different accounts that can be drawn out by structuring the information appropriately.

4.9. Third, a very specific design feature of the ecosystem accounts is that ultimately the information should be able to be integrated with the standard national accounts that record economic activity. This design feature does not impact on all accounts but is a particularly relevant consideration for accounts concerning ecosystem services.

4.10. Fourth, the structures presented should not be considered unchangeable with regard to the level of detail they contain. For example, the accounts concerning ecosystem assets tend to be structured to show high-level LCEU types within an EAU. In practice it may be relevant to provide finer detail on specific land cover types (e.g. by type of forest) and to include in the accounts a number of EAU. The accounting principle of working from the outside-in (see Chapter 2) implies that rearrangement of information inside the boundary is perfectly reasonable and the level of detail should be determined based on requirements.

4.11. Fifth, the accounts described in this chapter present information regarding one accounting period. Most commonly the interest in accounting information stems from its presentation of time series of information. Presuming that time series of accounts are compiled, users of accounting information are likely to require a re-organisation of the information such that time is one of the dimensions recorded. In practice, this is an issue of data management and dissemination rather than a conceptual matter. Compilers should feel free to restructure accounts in such a way to best suit the presentation and analysis of data.

4.12. Sixth, the structure of accounts will generally represent the level of detail suitable for presentation and analysis. It represents the level of detail at which accounting relationships (e.g. supply and use, balancing end of period stocks and changes in stocks) are applied. However, it will generally be relevant for underlying information to be compiled at different, usually lower, levels of aggregation before entry into the accounts. Put differently, it is not necessary for the structure of the input data to match the structure of the output data.

4.13. In the case of ecosystem accounting, it is likely to be ideal to compile data at an appropriately detailed level, e.g. by BSU, and then aggregate to the relevant LCEU or EAU level for accounting purposes. This does not require that accounts are developed at the BSU level but rather that the input data and the output data contained in the accounts are managed distinctly. Making this distinction is essential if changes in input data – which is by far the most common situation – are to be managed without affecting the integrity of the time series of data contained in the accounts themselves.

4.14. With all this in mind the following accounts should be taken as a guide to the types of information that can be organized following an accounting logic. Countries are encouraged to compile accounts using structures that are most appropriate to analyzing the aspects of ecosystems that are most material to understanding the relationship between ecosystems and the economy in their country.

4.15. The following accounts should also be considered as a guide in the sense that further testing and discussion is required before a more definitive set of ecosystem accounts can be articulated. This is true from both a measurement perspective and from a user perspective. These accounts reflect the most current understanding of likely data availability and the most useful level for analysis but both of these issues are matters of ongoing discussion.

4.3 Ecosystem extent accounts

4.16. The starting point for ecosystem accounting is most likely organizing information on the extent or area of different ecosystems across a country. This is important for three reasons. First, the task of establishing the ecosystem of interest for accounting purposes is by no means straightforward and a balance between scales of analysis, available data and policy questions will need to be found. Starting the discussion of the balance by looking at the most conceptually straightforward issue of area is very appropriate.

4.17. Second, the organisation of information and data sources required to establish an ecosystem extent account is likely to be a good entry point for establishing the spatial infrastructure required for ecosystem accounting. As described in more detail in Chapter 3 the delineation of spatial units will require the co-ordination of a range of information. Ecosystem extent accounts will be a first application of this process.

4.18. Third, the structure of the ecosystem extent account, as shown below, gives a clear indication of the nature of accounting for assets in a SEEA context. The requirement to produce a time series of data to allow meaningful comparison between the opening and closing of an accounting period is clear but one that is likely to be challenging in a spatial data context.

4.19. Fourth and finally, while the ecosystem extent account provides a clear base for the development of the other ecosystem accounts it also provides important information in its own right. Commonly, higher level extent accounts will be based primarily on land cover information. It is generally recognised that monitoring changes in land cover is an important and effective high-level monitoring approach that should reflect the most significant changes in ecosystem condition and biodiversity (e.g. PBL Globio modelling, Costanza et al change in ecosystem service values, others??).

4.20. A structure of a basic ecosystem extent account is shown in Table 4.2. The structure of the columns reflects the basic logic of asset accounts as described in the SEEA Central Framework with an opening extent (likely in hectares), closing extent and both additions and reductions. The rows reflect the chosen classification to reflect the ecosystem types across a country. The proposed structure here uses LCEU classes based on the interim LCEU classification in the SEEA EEA. Additional classes may be added depending on the ecosystem types of most relevance within the country.

Table 4.2 Ecosystem extent account

Cover	Urban and associated		Rainfed herbaceous cropland		Forest tree cover		Inland water bodies		Open wetlands	Total
Use	Infrastructure	Residential	Permananet crops	Maintenance	Forestry	Protected	Infrastructure	Aquaculture	Maintenance	
Ownership	Government	Private	Private	Private	Private	Government	Government	Private	Government	
Units	hectares									
Opening Stock										
Additions to Stock										
Managed expansion										
Natural expansion										
Reductions to stock										
Managed regression										
Natural regression										
Closing stock										

4.4 Ecosystem condition accounts

4.21. The natural extension of the ecosystem extent account from an ecosystem accounting perspective is organizing biophysical information on the condition of different ecosystems across a country. The account in Table 4.3 is compiled in physical terms only using a variety of indicators for the selected characteristics of different ecosystem assets.

4.22. Generally, it will be relevant to compile these accounts by type of LCEU within an EAU (as shown in Table 4.3). This is so because each type of LCEU (e.g. forests, wetlands, deserts, coral reefs) will have distinct characteristics that should be taken into account in assessing condition. This approach also recognizes that much information on ecosystem condition is structured by type of ecosystem rather than by landscape or administrative boundaries. Consequently, harnessing available scientific information and expertise may be more readily achieved through a focus on LCEU types.

4.23. Underpinning these accounts will be information from a variety of sources on different topics that may itself be organized following accounting approaches. Most relevant in this context are accounts for land cover, water resources, carbon and biodiversity. These accounts are referred to in the EEA TG as "supporting accounts". In this regard it is noted that accounts for these components of the environment provide information not only for the assessment of ecosystem condition but also for the measurement of various ecosystem services. For example, accounts for water resources provide information for the measurement of water related ecosystem services such as abstraction. Accounts for these topics are discussed in Chapter 6 with much relevant material provided in the SEEA Central Framework, the SEEA EEA, the SEEA Water, and the CBD ENCA QSP.

Table 4.3 Ecosystem condition account (similar to SEEA EEA Table 4.3: see also SEEA EEA Table 4.4 with changes in condition account)

Ecosystem type	Ecosystem extent	Ecosystem condition					
	Area	Vegetation	Biodiversity	Soil	Water	Carbon	Index
	hectares						
Urban and associated							
Rainfed herbaceous cropland							
Forest tree cover							
Inland water bodies							
Open wetlands							

NB: There are a few issues linked here that need discussion as I'm not quite sure where to take this at the moment:

- There is a question as to whether to implement a classic asset account structure – i.e. opening and closing stocks, additions and reductions.
- Michael B notes that it may be sufficient at this stage to look at only changes in characteristics – i.e. condition indicators. This would (I think) avoid the need to focus on reference conditions but limit the potential of the accounts in terms of providing aggregate comparisons across ecosystem – i.e. there would be no sense of relative significance of change in different ecosystems or of the actual level of condition

- I’m not sure what advice we are thinking of giving countries on condition accounts. Part of it seems to be that the condition accounts provide a place whereby a lot of useful information can be brought together which is OK but perhaps some more focus is needed.
- Do we have a good example of a condition account that we can refer to?
- Some discussion on the choice of characteristics that would be relevant in monitoring condition is appropriate but I think this would be placed in Chapter 7.

4.5 Ecosystem services supply account

4.24. The supply of ecosystem services by ecosystem assets is perhaps one of the most important aspects of ecosystem accounting since this is the flow that reflects the link between ecosystems and economic and human activity. This account records the actual flows of ecosystem services supplied by ecosystem assets during an accounting period within an EAU by type of ecosystem service and by type of LCEU. The account may be compiled in either physical or monetary terms.

4.25. The challenge in compiling this account may be attributing the generation of ecosystem services to a specific LCEU. This is unlikely to be an issue for provisioning or cultural services but it may be of concern for regulating services in cases where the service is effectively provided through a combination of ecosystem types.

4.26. Given this, it is recommended that, as a first step in accounting for ecosystem services, compilers create a table showing which ecosystem services are likely to be generated from each LCEU type for their country or target EAU area. In undertaking this task, it is relevant to use a classification of ecosystem services such as CICES as a type of checklist. It is to be expected that for some services, particularly regulating services, the same service is generated by more than one LCEU type.

4.27. It may be relevant to use this initial table as a discussion document to get input from various experts. At the same time it is important the development of such a table be informed by people experienced in considering the link between ecosystems and economic and human activity such that commonly overlooked services are not ignored.

4.28. This table would also serve as a basis for scoping and prioritising the required work, and comparing compilation exercises across countries (for example comparing lists of ecosystem services attributed to forests). Completing such a table is also a good expression of the accounting approach of working from the outside-in, in contrast to the measurement of selected ecosystem services for specific ecosystem types.

4.29. The proposed ecosystem services supply account (Table 4.4) has rows reflecting the various ecosystem types and columns reflecting the range of different ecosystem services, in this case classified following CICES. Note that in this table there is no direct recording of the beneficiaries or users of ecosystem services, this takes place in the ecosystem services use account. At the same time, it may be relevant to compile information on the combination of ecosystem, ecosystem service and beneficiary at the same time.

4.30. The choice of indicators for measuring the flows of different ecosystem services is discussed in Chapter 5 and relevant data sources and examples are provided in that chapter. Recommendations for countries and avenues requiring further testing and research are also discussed in Chapter 5.

Table 4.4 Ecosystem services supply account (LCEU by CICES)

Ecosystem service		Units	Land cover type								
			Urban	Pasture	Cropland	Forest	Heath	Peat	Water	Other nature	**Provincial total**
Provisioning	Hunting	kg meat	-	9,100	14,732	8,100	678	70		1,513	**34,193**
	Drinking water extraction	10^3 m^3 water	4,071	7,026	11,227	3,117	214	-	478	862	**26,995**
	Crop production	10^6 kg produce	-	-	1,868	-	-	-	-	-	**1,868**
	Fodder production	10^6 kg dry matter		533	251						**784**
Regulation	Air quality regulation	10^3 kg PM_{10}	272	404	717	700	45	7	40	69	**2,254**
	Carbon sequestration	10^6 kg carbon	875	8,019	273	50,664	393	149	-	1,056	**61,429**
Cultural	Recreational cycling	10^3 trips	2,690	1,863	2,611	1,565	30	3	139	220	**9,121**

4.31. The ecosystem services supply account shown in Table 4.4 is intended to be compiled in physical terms. Thus for each ecosystem service there will be a different indicator of the flow. One consequence is that there can be no aggregation of ecosystem service flows either across different ecosystem types or across different ecosystem service types. Further, no relative importance of individual ecosystem services can be immediately determined.

4.32. For accounting purposes, the primary approach to aggregation and assessing relative importance is the use of monetary valuation. The ecosystem services supply account can be compiled in monetary terms by applying appropriate prices to the physical flows of each ecosystem service. The ecosystem services supply account shown in Table 4.4 is then extended with additional rows and columns to record the total flows of ecosystem services. The estimation of prices for ecosystem services is discussed in Chapter 8.

4.6 Ecosystem services use account

4.33. This account builds on the ecosystem services supply account. However, unlike the supply account, the focus is not on use within defined spatial areas. Rather, the primary focus is on understanding the link between type of ecosystem services and types of beneficiaries. These beneficiaries include economic units classified by industry, government sector and household sector units, following the common conventions of organising the national accounts.

4.34. This focus arises because, while the supply of ecosystem services can be directly linked to a spatial area (e.g. to an LCEU), there is no requirement that the location of the beneficiary and the location of the area in which the ecosystem service is supplied are the same – this is especially the case for regulating services but also for some cultural services.

4.35. Given the lack of a definitive spatial link, the design of the ecosystem services use account must be guided by possible uses and analysis of data. The choice made here is to structure the ecosystem services use account for an EAU (possibly at national level) showing the total supply of each ecosystem service (in the first column) and the allocation of this supply to the various economic and other units. This allocation provides the first sense of a direct link to the national accounts datasets. The ecosystem services use account is shown in Table 4.5.

Table 4.5 Ecosystem services use account

Service Type	Ecosystem Type	Use			
		Enterprises	Households	Government	Rest of the world
Provisioning	Urban and associated				
	Forest tree cover				
	Agricultural land				
	Open wetlands				
Regulating	Urban and associated				
	Forest tree cover				
	Agricultural land				
	Open wetlands				
Cultural	Urban and associated				
	Forest tree cover				
	Agricultural land				
	Open wetlands				

4.36. While a precise link between beneficiaries and the spatial areas from which ecosystem services are supplied may be difficult to define, it is likely to be useful to consider, for different ecosystem services, whether the beneficiaries are, in general terms, local, national or globally connected. For example, in the case of most provisioning services the direct beneficiaries will be located within the supplying spatial area (e.g. farmers, foresters, fishermen, water supply companies). This will also be true of many cultural services where there is a recreational or touristic component. However for many regulating services the beneficiaries will be located in neighbouring ecosystems (for example air filtration) or will be global beneficiaries (for example with respect to carbon sequestration).

4.37. As for the ecosystem services supply account, this account may be compiled in both physical and monetary terms. In physical terms entries will be limited to measures of indicators for each ecosystem service noting that since supply must equal use, the unit of measure applied for each ecosystem service must be the same in both the supply and use table in order for a balance to be obtained.

4.38. In monetary terms entries for the total use of ecosystem services will also be able to be derived both for individual ecosystem service types and for total use by each beneficiary. The estimation of prices for ecosystem services is discussed in Chapter 8.

4.39. The presentation of accounts outlined here may suggest that the supply of ecosystem services would necessarily be compiled before measuring the use of ecosystem services. In practice the reverse may be the case or at least compilation of the accounts should take place in an iterative fashion. For example, measures of provisioning services are likely to be determined in the first instance by the extraction of materials or energy from the environment by economic units, i.e. a use perspective. It is then this perspective then drives the estimation of supply. Since for all final ecosystem services there must be some link to economic units and other human activity, there is a strong case for compiling both the supply and use of ecosystem services in tandem.

4.7 Additional accounts for ecosystems

4.7.1 Introduction

4.40. Most measurement effort in the scope of ecosystem accounting has focused on the four accounts just described concerning ecosystem extent, ecosystem condition, ecosystem services supply and ecosystem services use. Generally not all of these accounts have been compiled within a single project but there is a steadily increasing body of practical knowledge on approaches to measurement, including on the valuation of ecosystem services.

4.41. Nonetheless from a complete ecosystem accounting perspective these four accounts do not cover the full range of information that would lead to ecosystem accounting data being fully integrated with the standard national accounts. This section describes the four accounts that are relevant in this context – the ecosystem capacity account, the asset account for ecosystems, the augmented input-output table and the integrated sector accounts and balance sheets.

4.42. These accounts are currently considered to be on the research agenda for ecosystem accounting although many ideas for relating to these accounts are quite well developed or at least well understood if not resolved. Three of the accounts, all except the capacity account, can be compiled only in monetary terms and hence, in addition to resolving any conceptual issues, their development and testing relies both on advancing the techniques for valuation of ecosystem services and also on decisions about whether monetary valuation should be undertaken.

4.7.2 Ecosystem capacity account

4.43. The accounts to this point have contained information on the state and changes in state of ecosystem assets and on the flows of ecosystem services from those assets to beneficiaries including into the economy. These two broad sets of information are important and useful and cover the key parts of the ecosystem accounting model. What is missing however are accounts that highlight the relationship between the assets and the services and that start to aid discussion of the complexities around the issues of trade-offs and sustainability that lie at the heart of ecosystem accounting.

4.44. In this context, research and discussion on ecosystem accounting is working towards defining the concept of ecosystem capacity and the design of an ecosystem capacity account. In principle, this account would record information on the capacity of different ecosystem assets to supply ecosystem services into the future and record the nature of any changes (increases or decreases) in this capacity.

4.45. The idea of ecosystem capacity is mentioned in SEEA EEA (Chapter 4) but a definition appropriate for measurement and accounting purposes was not developed. Thus, ecosystem capacity accounts are also not presented in the SEEA EEA. A summary of current thinking on ecosystem capacity is presented in Chapter 7 and work on developing accounting structures will emerge from this ongoing work.

4.46. Given this situation, it is not expected that countries compile ecosystem capacity accounts. However, it should be recognised that a general requirement to consider questions of capacity will emerge when interpreting and applying the ecosystem accounting information contained in the initial four tables. In effect, a focus on measuring ecosystem capacity becomes a natural extension of the initial accounting work.

4.7.3 Asset account for ecosystems

4.47. The SEEA Central Framework uses the asset account structure to record information on stocks and changes in stocks (additions and reductions) of individual environmental assets such as mineral and energy resources, timber resources, water resources, etc. This standardised approach to recording information about specific asset types is particularly useful way of structuring relevant information about changes in the asset base.

4.48. When focusing on individual environmental assets it is possible to develop asset accounts in both physical and monetary terms since the units of measurement in physical terms can be consistently used in a single account. For example, all timber resources can be measured in cubic metres.

4.49. For ecosystem assets, their measurement in physical terms is a much more complex process requiring the integration of data on a range of characteristics. Aggregation to form single measures of the opening stock of the condition of an ecosystem is not straightforward in physical terms and hence an asset account for ecosystems in physical terms is not developed in the SEEA EEA.

4.50. Aggregation through monetary valuation of ecosystem services does however provide a way of developing an asset account for ecosystems. Applying the standard national accounting technique of net present value, the opening and closing stock value of an ecosystem asset can be estimated by forecasting the future flows of ecosystem services and discounting these flows to provide a current, point in time, estimate of their value. Additions and reductions in the stock can be measured by recording the value of the relevant flows – e.g. reductions in stock due to extraction would be equal to the value of relevant provisioning services.

4.51. The relevant accounting structure is shown in Table 4.6. This structure reflects the proposal from SEEA EEA Table 6.1. The entries in the columns are relatively standard asset account entries similar to those from the SEEA Central Framework. In the columns different presentations are possible given that the data are in monetary terms. That is, the asset account may relate to an individual ecosystem asset (e.g. a specific wetland), to a type of ecosystem (e.g. all forests), or to an administrative region or country.

Table 4.6 Stylised ecosystem asset account entries (from SEEA EEA Table 6.1)

	Ecosystem accounting unit or LCEU
Opening stock	
Additions to stock	
Regeneration - natural (net of normal natural losses)	
Regeneration – through human activity	
Reclassifications	
Total additions to stock	
Reductions in stock	
Reductions due to extraction and harvest of resources	
Reductions due to ongoing human activity	
Catastrophic losses due to human activity	
Catastrophic losses due to natural events	
Reclassifications	
Total reductions in stock	
Revaluations	
Closing stock of ecosystem assets	

4.52. Entries in the asset account for ecosystems go beyond the measurement requirements of the ecosystem services supply account in monetary terms by incorporating the use of net present value techniques. That is, the focus is on the measurement of the value of ecosystem assets as distinct from ecosystem services. In measurement terms this represents a considerable increase in uncertainty given the general challenges of net present value based estimation.

4.53. Using the data recorded within an asset account it is possible to derive an estimate of ecosystem degradation in monetary terms. In general terms, ecosystem degradation will reflect the decline in the value of an ecosystem asset over an accounting period (i.e. between opening and closing positions) where the decline is considered to be due to human activity. However, further consideration of exactly how ecosystem degradation should be measured is required building on the discussion of this issue in SEEA EEA Chapter 4.

4.7.4 Integrating ecosystem accounts with standard national accounts

4.54. The structures of the previous accounts do not require any significant consideration of the links to the standard economic accounts of the SNA. In essence they are accounts that concern ecosystems in the first instance and consequently their structures reflect information relevant to both compiling and interpreting information about ecosystems. Certainly, the accounts use, as appropriate national accounting classifications (e.g. of beneficiaries) and follow standard accounting structures, but there is no integration with the national accounts beyond this.

4.55. There are two types of accounts that focus on the integration of ecosystem accounting data as developed in the accounts above with the standard national accounts. The first is an *augmented input-output table*. The logic for this table is recognising that as part of developing the ecosystem accounting model the production boundary for the national accounts has been extended to incorporate the flows of ecosystem services. Consequently, the standard input-output table can be augmented by including these additional "products" alongside the standard set of good and services. Further, this requires that ecosystems be recognised as additional "industries" in the input-output framework. Due to the objective of integration, the augmented input-output table would be compiled in monetary terms using as inputs valuations of flows of ecosystem services.

4.56. While the concept of an augmented input-output table is a natural application of the extended production boundary, this type of table was not developed in the SEEA EEA and further work is required to advance its design and potential role. A longer description of the proposed table, including its distinction from environmentally extended input-output tables (EE-IOT), is presented in Chapter 9.

4.57. The second type of accounts is integrated institutional sector accounts and balance sheets. These accounts, commonly referred to in national accounting as the sequence of accounts, record information on the generation and distribution of income, saving and investment by institutional sectors (e.g. household saving), transactions in financial assets and liabilities, and estimates of net wealth by sector.

4.58. Developing these accounts is important as they record the attribution of ecosystem degradation to economic units and the extension to the asset boundary in the measurement of net wealth. However, while the purpose of these accounts is clear there remain long standing issues, primarily about the allocation of degradation to economic units, that have meant a resolution to the design of these accounts has not been found. The SEEA EEA Chapter 6 discusses these issues and some further aspects are presented here in Chapter 9.

4.8 Ecosystem component accounts

4.59. Table 4.1 highlighted that, in addition to the primary ecosystem accounts that have been described in this chapter, there are also a number of ecosystem component accounts that may be compiled as part of an ecosystem accounting program of work. For component accounts are noted in Table 4.1 – land cover accounts, carbon accounts, water accounts and biodiversity accounts.

4.60. These component accounts are aimed at supporting the compilation of ecosystem accounts by organising underlying information in a manner consistent with the accounting framework. In addition the component accounts can stand alone and may provide very useful information in their own right. For example, the carbon stock account may be used directly to support estimation and analysis of GHG emissions.

4.61. A discussion of component accounts is provided in Chapter 6 building on descriptions of the four accounts in the SEEA Central Framework and in the SEEA EEA.

5. Accounting for flows of ecosystem services

5.1 Introduction

5.1. Ecosystem services are the glue that enables the connection to be forged between ecosystem assets on the one hand and measurement of economic production and consumption on the other. Their measurement is thus central to the ambition to integrate environmental information fully into the existing national accounts.

5.2. Recognition of the potential role of the ecosystem services concept in an accounting context however has come well after the development and testing of the concept in other disciplines. The reality that confronts the ecosystem accountant is one of multiple definitions, alternative boundaries and classifications and a wide array of measurement methods. The SEEA EEA attempted to chart a course through the various discussions on ecosystem services and consequently made a range of choices about the definition and measurement of ecosystem services for the purpose of integrating measures of ecosystem services within the national accounts framework.

5.3. This chapter summarises the main points from the SEEA EEA concerning ecosystem services, discusses possible refinements, describes the main measurement issues and outlines some of the remaining challenges. Further detail on the measurement and classification of ecosystem services is presented in Part II Chapter 10.

5.2 The definition of ecosystem services

5.4. Because of the ambition to integrate measures of ecosystem services with the standard national accounts, the measurement scope and definition of ecosystem services in the SEEA EEA must be defined in the context of the boundary used in the SNA to set the measurement scope for the production of goods and services, the production boundary. This boundary in turn sets the scope for the measurement of GDP and related measures of production, income and consumption.

5.5. An important part of the rationale for measuring ecosystem services is the understanding that much economic production (for example in agriculture, forestry and fisheries) utilizes inputs from ecosystems but these inputs are not recorded in the standard accounting framework. In these situations, the logic of the SEEA EEA is that ecosystem services should be differentiated from the goods and services that are produced and rather the ecosystem services represent the contribution of the ecosystem to the production of those goods and services. In effect this sets up an extended input-output or supply chain that includes ecosystems as a supplier whose contribution was previously not explicitly recognised.

5.6. A second important part of the rationale for measuring ecosystem services is the understanding that there are many benefits that economic units and society more generally receive from the functioning of ecosystems and that a full and proper accounting would incorporate this production of services by ecosystems, and the consumption of them in economic and human activity.

5.7. With these two rationales in mind, the SEEA measurement of ecosystem services recognizes all of the additional production by ecosystems. If accounting had been starting from a zero base of information on ecosystem services then it seems possible that measurement would be simply limited to this scope. However, as noted, the measurement of ecosystem services has a longer and wider history and consequently the following factors need to be taken into account.

5.8. Distinguishing ecosystem services and benefits: The SEEA EEA accounting model makes a clear distinction between ecosystem services and the benefits to which they contribute (see discussion in section 2.5). The distinction is important such that (i) ecosystem services can be integrated with the standard system of national accounts; (ii) that clear objects for measurement and valuation can be described; and (iii) to ensure that the contribution of ecosystems can be clearly described and changes in the contribution can be understood.

5.9. Distinguishing final and intermediate ecosystem services: The distinction between final and intermediate services reflects the principles of national accounting wherein aggregate production is measured by netting out flows along the supply chain such that double counting is removed. In the context of ecosystem accounting this means that cases where ecosystems provide services to a neighbouring ecosystem (e.g. via pollination, water filtration or soil retention) these should be considered intermediate and considered inputs to the generation of other ecosystem services. While straightforward in theory the complexity in the functioning of ecosystems means that in practice it can be difficult to make this distinction.

5.10. Further, while at an aggregate level a focus on only final ecosystem services is appropriate, this may not be the case when considering the contribution of individual ecosystems whose primary function might be to support neighbouring ecosystems.

5.11. Since the drafting of SEEA EEA, further consideration highlights another important issue in the treatment of intermediate services. In the SEEA EEA, the flows between ecosystem assets, if recorded, were considered inter-ecosystem flows and in turn these flows were equated with intermediate services. However, recording only the physical flows does not serve to highlight the dependencies between ecosystems and indeed there are many ecosystem services both final and intermediate for which there is no direct physical flow. For example, the filtering of air by trees happens in situ. It is important then to separate the issue of accounting for physical flows of materials and energy between ecosystems and accounting for flows of intermediate ecosystem services.

5.12. With a focus on intermediate services, the challenge from an accounting perspective is not that flows of services between ecosystem assets cannot be recorded in the system, but rather that defining the measurement boundary is quite unclear. That is, there is a general sense that it is not advisable to attempt to measure all flows and dependencies between ecosystems and, indeed, current ecological knowledge would seem to suggest this was not practical in any event. Consequently, it is an open question as to which intermediate ecosystem services should be considered within scope of ecosystem accounting.

5.13. In this situation the following observations are relevant

- One of the most important and common inter-ecosystem flows is water and hence it is likely that some of the most important intermediate ecosystem services are related to flows of water.
- A second area of likely importance is the provision of habitat services by certain ecosystem types where the role of these services is embodied in the mature animal that is an input to final ecosystem services, commonly in a separate ecosystem.
- One means by which the scope of intermediate services may be contained is to ensure recording only of those intermediate services from another

ecosystem asset that are considered a direct input to a final ecosystem service.

- It also seems appropriate - for accounting purposes, to ignore the flows within the bounds of an ecosystem asset since these services will be embodied within the final ecosystem services generated by the asset.
- Based on these last two observations the recording of intermediate services will be directly affected by the scale of analysis since with smaller ecosystem assets there will be an increased likelihood of intermediate services being recorded.
- While restricting the scope of intermediate services may seem limiting, it is appropriate to regard any measures of ecosystem services as reflecting a lower bound of the quantity of services that may be flowing between ecosystem assets.
- The recording of intermediate services would seem most useful for the purposes of management information. In aggregate, at national level, it is likely that most intermediate services will offset each other since ultimately their value is embodied in final ecosystem services. However, recognizing the relative value of different ecosystems within a country is likely to be very relevant for management purposes.
- Increasing the measurement scope to include certain intermediate services causes no specific issues in terms of accounting structure. The changes needed would be to recognize additional service types and also to recognize flows between ecosystem assets in addition to those flows of final ecosystem services from ecosystems to economic and human activity.

5.14. The treatment of other environmental services: As noted in the SEEA EEA Table 2.3, not all flows from the bio-physical environment to the economy and society can be considered ecosystem services. There are a range of so-called "abiotic" services reflecting the flows we receive in the form of mineral and energy resources, flows of renewable energy such as solar, wind, wave and geo-thermal energy, solar energy for photosynthesis, oxygen for combustion, air for respiration and more generally, the space for people to live, work and play.

5.15. Since the focus of the SEEA EEA is on ecosystems accounting for these various flows is not considered in the ecosystem accounting model. Many of these flows are considered in specific accounts described in the SEEA Central Framework (e.g. mineral and energy accounts, energy supply and use tables and land use accounts). At the same time, the spatially explicit approach outlined in the SEEA EEA may mean that it is highly relevant to consider incorporating measures of abiotic services to consider the full range of issues within a defined area. The extension of the accounting tables to consider this aspect has not been developed at this stage.

5.16. Determining the link between biodiversity and ecosystem services: This is a complex issue. On the whole, the perspective taken for ecosystem accounting in the SEEA EEA is that biodiversity is more fundamentally a characteristics of ecosystems – that is, changes in biodiversity are more directly reflected in changes in the condition of ecosystems. The exact nature of the relationship between biodiversity and ecosystem condition is a matter of considerable uncertainty but in principle the discussion of that issue lies in that part of the ecosystem accounting model.

5.17. At the same time it is recognised that there are some aspects of biodiversity, especially species diversity, that supply final ecosystem services. This includes, for example, the cultural service of iconic species or the recreational services from a zoo.

There are most likely other examples in this area. The issue from an ecosystem accounting perspective is to aim to discuss biodiversity in a manner that does not aim to place all information on biodiversity in one place but to recognise that measures related to biodiversity may be appropriate in different contexts.

5.18. The treatment of ecosystem disservices: Ecosystem disservices pertain to cases where the interaction between the ecosystem and humans is considered to be bad. Usually this refers to things such as pests and diseases that emerge from ecosystems to negatively affect economic production and human life. The SEEA EEA recognises the frequent discussion on the measurement of ecosystem disservices but does not propose a treatment in accounting terms.

5.19. This is because, unfortunately, accounting principles do not work well when trying to make a distinction between products that may be considered as either “goods” and “bads”. Accounting makes no assumptions as to the welfare effects of use and focuses instead on the activity associated with the generation of products and the associated patterns of use by economic actors. As a consequence all flows between producers and consumers have positive values in the accounts irrespective of their possible welfare effects. The positive values arise since it is difficult to envisage either component of value, prices or quantities, being negative.

5.20. A related matter is the treatment in ecosystem accounting of negative externalities, such as carbon emissions, where economic and human activity leads to changes in the condition of ecosystems. Any associated environmental flows, pollutants, emissions, etc are not considered ecosystem disservices and their negative impacts on welfare are not captured directly in the accounting system.

5.21. For both disservices and negative externalities work is ongoing to outline the appropriate treatment in the context of the ecosystem accounting model.

5.3 The classification of ecosystem services

5.22. The classification of ecosystem services is an important aspect of measurement since classifications can provide important guidance to ensure that the appropriate breadth of measurement is undertaken or, at least, that partial measures are understood within a broader context.

5.23. The classification included in the SEEA EEA is the Common International Classification of Ecosystem Services version 3 (CICES v3). It was considered an interim version and subsequent releases have been made with the latest being CICES version 4.3.

5.24. While this classification has been adopted for work on the EU MAES project it must be recognised that alternative approaches to the classification of ecosystem services are under development and over time it will be necessary to consider the different merits and roles that might be played by the different classifications. Perhaps the most important alternative approach is the work by the US EPA on FEGS which places it attention on the links between ecosystem types and the classification of beneficiaries from the final services supplied by those ecosystem types.

5.25. One of the most important roles of a classification of ecosystem services is that it can be used to frame a discussion on the measurement and significance of ecosystem services. In effect, a classification can operate as a checklist and be applied in initial discussions by considering each LCEU type in turn and noting those ecosystem services that are considered most likely to be generated from that LCEU. The resultant “baskets” of services for each LCEU type can aid in discussion of the role of accounting, the structuring of information, the assessment of resources required for compilation and generally communicating the message about the breadth of the relationship between ecosystems and economic and human activity.

5.26. A clear finding of work on ecosystem services is that the choice of words to describe an ecosystem service can have significant impact on how it is visualized and understood by those involved. In particular for regulating services the choice of words to distinguish the benefit that people receive (e.g. reduced risk of landslide) from the corresponding ecosystem service (e.g. soil retention) can be very material in the selection of indicators. Much further discussion across the full suite of ecosystem services and the related benefits is required to ensure that the measures and the concepts are appropriately aligned.

5.27. There is commonly misunderstanding of the role of classifications with regard to the distinction between final and intermediate ecosystem services. Unfortunately, from the perspective of the classification of ecosystem services, it is not the case that ecosystem services can be neatly classified between those that contribute directly to economic and social beneficiaries and those that are directly beneficial to ecosystems. For example, when a household abstracts water from a lake and a wild deer drinks from the same lake, the ecosystem flow of the provisioning of water is the same.

5.28. However, a similar situation arises in economic statistics. The classification of products (e.g. following the international standard Central Production Classification) includes, appropriately, a large number of products that may be considered intermediate or final depending on the beneficiary. For example, the purchase of bread is considered final if purchased by a household but intermediate if purchased by a restaurant. However, the CPC appropriately only contains one product, bread, rather than two (or more) products.

5.29. Given this situation, the CICES and other classifications of ecosystem services, must be used in conjunction with an understanding of the beneficiaries that are within scope of the measurement concept. Without clearly defining the beneficiaries there is likely to be an overestimation of the quantity of ecosystem services by adding together the intra- and inter-ecosystem flows that reflect the operation of an ecosystem, and the “final” ecosystem services that are direct contributions to economic and social beneficiaries.

5.30. These considerations on the role of classifications are important in developing agreed accounting structures both in the case of ecosystem services alone and in the context of integrating measures of ecosystem services within standard accounting structures such as input-output and supply and use tables.

5.4 The role and use of biophysical modelling

5.4.1 Introduction

5.31. Biophysical modelling, in the context of this guidance document, is defined as the modelling of biological and/or physical processes in order to understand the biophysical elements to be recorded in an ecosystem account. These elements are part of either ecosystem asset (including ecosystem condition and the ecosystem’s capacity to generate services) or ecosystem services flow. In this chapter the focus is on ecosystem services flow and modelling as applicable to ecosystem assets is discussed in Chapter 7.

5.32. The intention here is to provide some general guidance on the type of biophysical modelling approaches that can be used to analyse ecosystem service flow as distinct from models that can be used to analyse ecosystem processes for the purpose of understanding ecosystem processes (e.g. nutrient cycling, energy flows). In the scientific literature, a wide range of different modelling approaches have been described in the fields of ecology, geography, and hydrology, many of them potentially relevant to ecosystem accounting depending upon the environmental characteristics and the uses of the ecosystem, the scale of the analysis, and the available data. It is impossible to describe all these different modelling approaches in one document, and thus this guidance provides an overview of the different approaches, and their main uses for the biophysical modelling of ecosystem services.

5.33. An important aspect of applying biophysical models in ecosystem accounting is recognising the nature of the connections between ecosystem service flows and the condition of the relevant ecosystem asset. This connection is reflected in the concept of ecosystem capacity. Although the definition of ecosystem capacity remains a matter of ongoing discussion (see section 7.4), it is accepted broadly that modelling ecosystem service flows must take into consideration the current and expected condition of the ecosystem and its various functions and processes.

5.34. ANCA Research Paper #3 “Guidance for the Biophysical Modelling and Analysis of Ecosystem Services in an Ecosystem Accounting Context” provides more detail and relevant references on this topic.

5.4.2 Overview of biophysical modelling approaches

5.35. The two most relevant forms of modelling are spatial and temporal modelling techniques. Spatial modelling is required to produce wall-to-wall maps of ecosystem services for a complete EAU, including to national level. Thus where data is lacking in relation to some spatial areas, spatial modelling can fill the gaps. Spatial modelling is most commonly undertaken using GIS packages such as Arc GIS and Quantum GIS. There are also several ecosystem services specific modelling tools such as ARIES, MIMES and InVEST. Further discussion on these models is presented in ANCA Research Paper #3.

5.36. Within the general GIS packages, spatial modelling tools including the use of look-up tables, and the application of statistically based approaches such as Maxent (Philips, et al 2006). There are a range of geostatistical interpolation techniques such as kriging rely on statistical algorithms to predict the value of un-sampled pixels on the basis of nearby pixels in combination with other characteristics of the pixel. The basic interpolation methods use simple interpolation algorithms, for instance nearest-neighbor interpolation, but there are more sophisticated geostatistic tools that also considers sets of correlated variables. For instance, timber productivity may be related to productivity in nearby pixels, but in a more comprehensive approach it may also be related to factors such as soil fertility or water availability for which spatial maps are available. Critical in applying geostatistics is that a sufficiently large sample size is available, and that samples are representative of the overall spatial variability found.

5.37. In ecosystem accounting, temporal modelling is required to forecast the capacity of an ecosystem to generate ecosystem services. The modelling approach most consistent with coming to an understanding of flows of ecosystem services is a dynamic systems approach, which can also be applied in combination with a spatial model. This approach is based upon modelling a set of state (level) and flow (rate) variables in order to capture the state of the ecosystem, including relevant inputs, throughputs and outputs, over time. Dynamic systems models use a set of equations linking ecosystem state, management and flows of services. For instance, a model may include the amount of standing biomass (state), the harvest of wood (flow), and the price of wood (time dependent variable).

5.38. The systems approach can contain non-linear dynamic processes, feedback mechanisms and control strategies, and can therefore deal with complex ecosystem dynamics. However, it is often a challenge to understand these complex dynamics, and their spatial variability, and data shortages may be a concern in the context of ecosystem accounting that requires large scale analysis of ecosystem dynamics and forecasted flows of ecosystem services.

5.39. In some cases, spatial and temporal modelling approaches need to be combined. For instance, process based models are generally required to model regulating services such as erosion control, or ground and surface water flows. Erosion, and erosion control is often modelled with the USLE (Universal Soil Loss Equation) approach (even though its reliability outside of the USA (where it was developed) has proven to be variable). Other examples of process based models are the hydrological models such as SWAT and (CSIRO) SedNet. These models are both temporally and spatially explicit, using a dynamic systems modelling approach integrated in a GIS environment.

5.5 Data sources, materials and methods for measuring ecosystem service flows

5.5.1 Introduction

5.40. SEEA EEA Annex A3.1 provides some stylised figures to help articulate the measurement required to estimate flows of ecosystem services. The models included in that annex only relate to selected services but the basic logic of the models can be applied more generally. Of particular importance is recognising the distinction between the ecosystem service and the associated benefit and the choice of words to reflect this distinction.

5.41. It will generally be helpful for measurement purposes to distinguish clearly between provisioning, regulating and cultural services. For this task the use of a clearly defined classification of ecosystem services, such as CICES, can serve as a useful checklist. Further, it is likely to be useful to consider measurement of ecosystem services in relation to broad ecosystem types such as forests, wetlands, and agricultural areas.

5.42. A useful structuring of indicators is presented in Chapter 5 of the EC *Mapping and Assessment of Ecosystems and their Services, Final report* (February 2014). In this chapter indicators for different ecosystem services are mapped out within four broad ecosystem types – forest, cropland and grassland, freshwater and marine. A review of this material highlights the likely broad range of data sources that will need to be considered in generating a full coverage of ecosystem services for ecosystem accounting purposes.

5.43. In a different setting, the World Bank working paper "Designing Pilots for Ecosystem Accounting" Chapter 3 provides some suggested approaches and indicators for provisioning and regulating services using a case study in San Martin, Peru.

5.44. Other relevant materials on the measurement of ecosystem services include:

- books and text books
- journal articles,

- ecosystem services databases (e.g. PAGE, ESVD, EVRI)
- national and other projects (e.g. UK NEA, MEGS, EU MAES, Limburg province)
- other datasets

NB: This section of text needs expansion to provide some guidance to compilers.

5.45. While there is an increasing amount of information and examples of measurement of ecosystem service flows, a challenge is likely to lie in adapting and scaling the available information for ecosystem accounting purposes. The issue of scaling is considered further in Chapter 7 and is lso discussed further below (section 5.6). From a practical perspective it is sufficient to note here that, when accounting for multiple ecosystem services, the aim must be to measure the generation of ecosystem services at a broad landscape scale (ideally up to national level) and also over a series of accounting periods. As appropriate, adjustments to ensure that measures of different ecosystem services align to the same spatial areas and same time periods should be made.

5.5.2 Measuring the supply of ecosystem services

5.46. Commonly in the discussion of ecosystem accounting, a focus is placed on the measurement of regulating services. This is so for two reasons. First, regulating services are, by and large, the most significant environmental flows that are not captured in standard economic accounting. Second, provisioning services are considered quite straightforward to measure and cultural services often considered too difficult to measure. While these characterisations are not inappropriate, it is relevant to ensure that measurement does not consider only regulating services.

5.47. The measurement of provisioning services can generally be linked to measures commonly available in statistical systems. Thus production of crops, livestock, other agricultural products, forestry products and fisheries products are all of direct relevance in the estimation of provisioning services. In some cases, data may be available at a fine level of spatial detail, for example from an agricultural census. In other cases it may be necessary to allocate national or regional level estimates to the spatial units being applied for ecosystem accounting using spatial modelling techniques.

5.48. For some cultural services particularly those relating to tourism and recreation, the use of available administrative and survey based information is also appropriate. The measurement of so-called non-use cultural services is more problematic and is considered further in section 5.6.

5.49. For regulating services some specific suggestions for measurement using bio-physical models are suggested in Table 5.1 (from ANCA Research Paper #3). These are intended as guide only and consideration of the applicability of these approaches should be made in each circumstance. Also, some specific considerations with respect to the measurement of ecosystem services related to carbon and water are discussed in ANCA Research Papers #7 and #8)

Table 5.1: Indicators and mapping methods for selected ecosystem services (Source: ANCA Research Paper #3 – Lars Hein Biophysical modelling)

Service	**Potential indicator**	**Description**
Carbon storage	Ton of carbon (or carbon-dioxide) per hectare or square kilometer.	Carbon storage includes storage in vegetation (above ground, root, dead wood, and litter carbon) and soil carbon. Soil carbon may be low compared to vegetation carbon, as in some types of poor fertility tropical forest soils, or it may be by far the largest component of total carbon storage, as in peatland soils in deep peat (World Bank, 2014). Above ground carbon can be measured with radar remote sensing, but the measurement of below-ground carbon with optical techniques is generally not possible. Instead, for this part of the carbon stock, soil sampling and interpolation of data points is required. Carbon maps are increasingly available for different parts of the world (see also Chapter 4), and the capacity to map above ground carbon stock globally also increases with the launch of the Sentinel radar satellites.
Carbon sequestration	Ton of carbon (or carbon-dioxide) sequestered per year, per hectare or per square kilometer.	Carbon sequestration can be related to net ecosystem productivity (NEP), i.e. the difference between net primary productivity (NPP) and soil respiration. NPP can be derived from the Normalized Difference Vegetation Index (NDVI) that can be measured with remote sensing images. However care needs to be taken that the relation between NDVI and NPP is well established for the ecosystems involved, and that accuracy levels are calculated based on sample points. It is often difficult to find credible values for the spatially very variable soil respiration rate, which depends on bacterial and fungi activity which are in turn guided by the local availability of organic matter (e.g. fallen leaves), temperature, moisture, etc.
Maintaining rainfall patterns	mm water evapotranspiration per hectare per year, mm rainfall generated per hectare per year.	Rainfall patterns depend on vegetation patterns at large scales. For instance, it has been estimated that maintaining rainfall patterns in the Amazon at current levels requires maintaining at least some 30% of the forest cover in the basin. Reductions in rainfall in the Western Sahel and the Murray Basin in Australia have also been correlated to past losses of forest cover. This is a significant ecosystem service, however the value of individual pixels is difficult to establish since it requires understanding large scale, complex climatological patterns, large scale analyses of potential damage costs, and interpolations of values generated at large scales to individual pixels with detailed climate-biosphere models.
Water regulation	- water storage capacity in the ecosystem in m3 per hectare (or in mm); - difference between rainfall and evapo-transpiration in m3/ha/year;	Water regulation includes several different aspects, including (i) flood control; (ii) maintaining dry season flows; and (iii) water quality control – e.g. by trapping sediments and reducing siltation rates). Temporal, i.e. inter-annual and intra-annual, variation is particularly important for this service. Modelling this service is often data-intensive and also analytically complex. SWAT is a model often used to model this kind of flows, however extensions of the SWAT model are needed to link land use to water flows, see also Chapter 4.
Surface water modelling; Flood protection	Surface water modelling can be deployed to analyze reductions in flood risk, expressed either as reduction in probability of occurrence, reduction in average duration of the flood, or reduction in water level depending on context	Flood protection depends on linear elements in the landscape that act as a buffer against high water levels (e.g. a mangrove, dune or riparian system). Modelling this service requires modelling flood patterns and the influence of the vegetation. It may not always be needed to model flood protection in physical terms in order to understand the monetary value of the service - in particular in those areas where it is certain that natural systems, if lost, would be replaced by artificial ones (e.g. a dyke), as would be the case in most of the Netherlands, for instance. In this case, valuation may be done on the basis of a replacement cost approach that does not require understanding the physical service in full.
Erosion and sedimentation control	- difference between sediment run-off and sediment deposition in ton/ha/year	There is relatively much experience with modelling this service. Erosion models can be integrated in a catchment hydrological models (such as SWAT or CSIRO SedNet, both freeware) to predict sediment rates. In SWAT, a watershed is divided into Hydrological Response Units (HRUs), representing homogeneous land use, management, and soil characteristics. Erosion rates need to be estimated for each HRU, for instance on the basis of the MUSLE or RUSLE erosion models or alternatively SWAT landscape can be used which includes grid based land cover units.
Water purification	Amount of excess nitrogen and or phosphorous removed in the ecosystem	Various hydrological models, including SWAT include modules that allow estimating the nutrient loads in rivers as a function of streamflow, discharge, temperature, etc. Nitrogen is broken down by bacterial activity, phosphorous is typically removed in ecosystems by binding to the soil particles. Modelling

		these processes in SWAT requires large datasets, preferably with daily time-steps, of nutrient concentrations in various sampling stations along the river course. Simulation in SWAT using predefined modules allows calculating the nutrient concentrations in other parts of the river.

5.5.3 Recording the beneficiaries of ecosystem services

5.50. Within the ecosystem accounting model all benefits must have a corresponding beneficiary. Given that ecosystem services are “contributions to benefits” this implies that all ecosystem services also have a corresponding beneficiary. Using broad national accounting categories these beneficiaries can be grouped as being corporations, governments and households. Another perspective of grouping is to consider industry groupings whereby individual establishments or businesses are grouped into those that undertake similar activities such as agriculture or manufacturing.

5.51. When measuring the generation of ecosystem services and mapping out their generation across a specific ecosystem type (e.g. forests) it is likely to be useful to consider the range of beneficiaries. This approach has been extensively applied in the development of the Final Ecosystem Goods and Services (FEGS) concept by the US EPA and its associated classification system.

5.52. To support integration with the national accounts and its tables such as input-output tables, it is recommended that the matching of ecosystem services to beneficiaries use the classification of beneficiaries used by the national accounts either by institutional sector or by industry/economic activity.

5.6 Key issues and challenges in measuring ecosystem service flows

Suggestions for topics include (some of which are introduced in section 5.2 above).

- Distinguishing final and intermediate services, and benefits.
- Measurement of non-use cultural services
- Linking biodiversity and ecosystem services
- Scaling data for measuring ecosystem services
- Benefit transfer methods
- Valuation – link to chapter 8

5.7 Conclusions

5.7.1 Recommended activities and approaches

To be determined : Suggestion to focus on (i) using a classification of ecosystem services to list out relevant ecosystem services for each main ecosystem type; (ii) to consider this list in the context of likely beneficiaries both local and national/global; (iii) to develop indicators of physical flows of each ecosystem service. This would form the basis for an ecosystem services supply account and a use account. Issues of valuation and aggregation would remain on the research agenda.

5.7.2 Issues requiring ongoing research

To be determined.

5.53.

6. Accounting for specific ecosystem components

6.1 Introduction

6.1. The main ecosystem accounts are described in Chapter 4. Their structure reflects the ambition of ecosystem accounting to integrate a wide range of information on a variety of ecosystem components and for a number of ecosystem services. As with the national economic accounts, the compilation of ecosystem accounts of such an integrated nature requires the use of multiple data sources. In that sense, ecosystem accounting should not be considered as reflecting a single data set but rather as a synthesis of many data sets each of which will have its own methods and techniques.

6.2. In the development of the SEEA EEA, four data sets in particular have emerged as central to the measurement of ecosystem assets and ecosystem services. These four data sets concern land cover, water, carbon and biodiversity. For all of these ecosystem components there are separate measurement techniques and guidelines that have developed over time resulting in a varying mix of definitions and measurement scopes that are appropriate for specific circumstances. For the purposes of integration within ecosystem accounting there is a need to seek some alignment and co-ordination in the measurement of these different components both in terms of alignment among components and in terms of alignment with SEEA and SNA accounting principles.

6.3. In the case of two components – land cover and water – the SEEA Central Framework and the SEEA Water provide the conceptual grounding for integration. For carbon, as a single element, it is actually quite well suited as a subject for accounting. It has thus been relatively straightforward to consider adapting the measurement of carbon into a broad accounting structure. The relevant concepts are described in the SEEA EEA. For biodiversity the situation is still developing. SEEA EEA section 4.5 introduces relevant ideas for the measurement of biodiversity in accounting terms but more work is needed.

6.4. Aside from contributing to the bigger ecosystem accounting picture, accounts for land cover, water, carbon and biodiversity also contain much relevant information in their own right. Consequently, compilers of ecosystem accounts are encouraged to seek opportunities to promote and use the information presented in these supporting accounts to support discussion of environmental-economic issues.

6.5. This chapter provides a summary of the relevant accounting issues for each of these four areas. More detailed descriptions are provided in the four ANCA Research Papers #2, 7, 8 and 9. The issue of aggregating across these and other components to provide a more complete ecosystem level assessment is discussed in Chapter 7.

6.2 Accounting for land cover

6.2.1 Introduction

6.6. Accounting for land cover and land cover change will be the most common starting point for compilers of ecosystem accounts. As part of the accounts compilation process the information in land cover accounts can be used to help define the relevant spatial units, to determine the extent of different ecosystem types at a broad level, to support understanding the links between ecosystem services supply and the beneficiaries of those ecosystem services and finally, to facilitate the scaling of other data to finer and broader levels of detail.

6.7. Generally, the initial focus of land cover accounting is on terrestrial areas of a country including freshwater bodies. Within this scope land cover must be classified into various classes. Often there will be relevant national classifications and datasets but alignment or correspondence to international classifications is likely to be a positive step. Chapter 3 discusses issues of classification in more detail.

6.8. The basic structure of a land cover account follows the structure of an asset account as described in the SEEA Central Framework. That is, there will be an opening stock, closing stock and additions and reductions in stock. Ideally, changes in stock over an accounting period would be separated into those that are naturally driven and those due to human activities. Both the SEEA Central Framework and the SEEA EEA describe the structure of a land cover account.

6.9. In addition to an asset account information on land cover may be organised in the form of a land cover change matrix which shows how, over an accounting period, the composition of land cover has changed between different types of cover. An example of such a matrix is provided in the SEEA Central Framework.

6.10. Using different data sources, additional information on land may also be organised into accounts. For example, information on land use and land ownership or tenure may be accounted for.

6.2.2 Relevant data and source materials

6.11. ANCA Research Paper #2 discusses the compilation of land cover accounts in more detail. In terms of data requirements, that paper distinguishes between dynamic and permanent features. Dynamic features include information on land use, land cover and vegetation type. Permanent features include information on administrative boundaries, ecological regions, and river basins.

6.12. The compilation of accounts will generally require bringing these various data together using GIS methods to form maps for a country as a whole. The ambition in accounting terms is to generate harmonised maps over time such that the stock and changes in stock can be consistently accounted for.

6.13. Materials to support land cover accounting including the SEEA Central Framework, the SEEA EEA and the ENCA QSP which has an extensive discussion of land cover accounting and associated data sources and methods.

6.14. Additional support and guidance is available in looking at country examples and case studies. Relevant examples include the work of the European Environment Agency, the Australian Bureau of Statistics, Statistics Canada, the Victorian Department of Sustainability and Environment and in Mauritius.

6.2.3 Key issues and challenges in measurement

6.15. There is a range of measurement challenges in land cover accounting. An immediate challenge is being able to integrate the various data to produce harmonised maps. This requires that all relevant data be aligned with a standardised grid and while a seemingly simple objective this may be harder to achieve in practice since data sets will be held with multiple agencies.

6.16. A related issue will be the choice of scale and resolution for the maps. In general terms higher levels of detail will be better but will also have higher resource costs. Balancing the work required with the degree of accuracy required will be important. A relevant issue in this context are approaches to the validation of data particularly since much data will be derived from remote sensing and satellite imagery. Ideally some degree of sampled ground truthing should be undertaken – for example using Google Earth.

6.17. An integrated approach involving sampled reference points to measure land use and land cover across Europe - LUCAS - has been developed in recent years by Eurostat. This approach may provide additional ideas for possible measurement approaches at national level.

6.18. The approach to classifying land cover is particularly important in communicating message on the changing composition of land cover at national level. At a base level there is now an ISO standard Land Cover Classification Scheme (LCCS) developed by the FAO. This classification provides the structure by which each type of land cover around the world can be consistent classified and thus provides a way of linking the various classifications that are in use in different countries and regions.

6.19. While this provides a base classification, more challenging has been the formation of higher level classes that can be used to summarise land cover in meaningful ways. There are a number of options, one of which is the interim land cover classification presented in the SEEA Central Framework. Determination of a broadly accepted set of high level (say 10-15) classes of land cover (and the associated definitions of these classes) would be an significant step forward in coordinating information and underpinning greater alignment in ecosystem accounting discussions and applications.

6.2.4 Conclusions, recommended activities and research issues

6.20. To be determined

6.3 Accounting for water related stocks and flows

6.3.1 Introduction

6.21. Water is a fundamental resource and accounting for the stocks and flows of water is a key feature of both the SEEA Central Framework and the SEEA EEA. This short section is intended only to provide direction to relevant technical and compilation materials rather than reproduce or summarise the content of those materials.

6.22. Water is relevant in ecosystem accounting in a number of ways. First, water is a key component of ecosystems and hence assessment of the condition of ecosystem assets will, in most instances, require the measurement of the stocks and changes in stocks of water resources.

6.23. Second, there are a number of ecosystem services which related directly to water. These include the provisioning service of water when it is abstracted for use (irrigation, drinking, hydropower), the role of water in filtering pollutants and residual flows, and the cultural services associated with water such as fishing and other recreational activities. In addition, there are a number of ecosystem services to which water is linked, for example, the regulation of water flows to provide flood protection and the filtration of water by the soil in catchments.

6.24. Measurements in all of these areas are ultimately important within a complete set of ecosystem accounts. The accounts of the SEEA Central Framework for water focus on two areas – the supply and use of water and the asset account for water.

Information from both of these accounts is relevant for ecosystem accounting purposes, in addition to being of importance in other contexts.

6.3.2 Relevant data and source materials

6.25. There are many relevant materials to support the compilation of water accounts. Aside from the content in the SEEA Central Framework and the SEEA EEA, there is a specific SEEA Water and the associated International Recommendations on Water Statistics. Also in relation to accounting for water Chapter 6 of the ENCA QSP has much relevant information.

6.26. There is a wide range of data sources, including global data sets that might be considered for use in water accounting. ANCA Research Paper #8 provides a good overview and links to these data sources and also provides a description of some relevant country examples. To date, over 50 countries have trialled the development of SEEA based water accounts and it is now a legislated statistical output within the EU. Consequently there is a increasing body of knowledge and experience in water accounting that can be drawn on.

6.3.3 Key issues and challenges in measurement

6.27. There remain some specific challenges in accounting for water, especially in an ecosystem accounting context. Linked to the issue of defining spatial units there is the need for clarity on the delineation of wetlands with the scale of analysis being a particular area of concern. Many wetlands may be quite small but disproportionately important within larger land cover types (for example in grasslands) and being able to recognise these areas and hence better understand the stocks and flows of water resources is important.

6.28. On a related note integrating information on groundwater within the ecosystem accounting framework requires further consideration given that generally the ecosystem accounts have considered primarily surface water resources.

6.29. Given that flows of water are often key pathways between different ecosystems, more work is needed to understand and account for flows of ecosystem services between ecosystem assets that are related to water. For example, how should the services of soil retention in the upper reaches of water catchments be considered in the context of the services provided by an entire river basin. SEEA EEA largely ignored flows between ecosystems but further reflection suggests that incorporating certain intermediate ecosystem services is required.

6.30. A general challenge in water accounting from a national accounts perspective is that, often, national level data are not overly meaningful and instead information at a basin or catchment level is required. While it may be straightforward to propose measurement at this level of detail, developing estimates at a catchment level may be resource intensive.

6.3.4 Conclusions, recommended activities and research issues

6.31. To be determined

6.4 Accounting for carbon related stocks and flows

6.4.1 Introduction

6.32. Carbon has a central place in ecosystem and other environmental processes and hence accounting for carbon stocks and changes in stocks must be seen as an important aspect of environmental-economic accounting. This short section is intended only to provide direction to relevant technical and compilation materials rather than reproduce or summarise the content of those materials.

6.33. Accounting for carbon in the context of the SEEA commenced in the context of accounting for carbon in forests and in accounting for GHG emissions. With the development of the SEEA EEA the scope of carbon accounting has been broadened and, following the scope of the carbon stock account in the SEEA EEA, ideally it encompasses stocks and changes in stocks of all parts of the carbon cycle. Thus it would cover geocarbon, biocarbon, atmospheric carbon, carbon in the oceans and carbon accumulated in the economy. In practice the scope of carbon stock accounting at this stage is focus on biocarbon and geocarbon.

6.34. In ecosystem accounting information on stocks and flows of carbon is used in two main areas. First, as part of the measurement of ecosystem condition, one broad approach is to use changes in net primary production as an indicator. This single indicator can capture changes in soil, vegetation and other biomass. Second, information on carbon stocks and flows relate directly to the ecosystem services of carbon sequestration and carbon storage.

6.4.2 Relevant data and source materials

6.35. The structure of a carbon stock account is presented in SEEA EEA Chapter 4. The compilation of this account, with a focus on biocarbon and geocarbon, will involve the collection of data on land cover and the capacity of different land cover types to sequester carbon, data on the carbon content of soils and information on sub-soil fossil fuel resources. A summary of relevant data sources and links to those sources is presented in ANCA Research Paper #7. A particular source that is noted here is information compiled by countries as part of reporting to the IPCC. The measurement boundaries and treatments are, on the whole , well aligned between the IPCC and the SEEA.

6.36. Advice on the compilation of carbon accounts is summarised in SEEA EEA. A more detailed explanation is provided in Ajani & Comisari 2014 which describes the development of a carbon account for Australia including discussion of the relevance and application of the account.

6.4.3 Key issues and challenges in measurement

6.37. Relative to other areas of measurement, the measurement challenges in relation to carbon are relatively limited. In large part this reflects the substantial resources that have been applied to this measurement task within the IPCC processes. Nonetheless there remain important issues of data quality to consider. In large part these relate to being able to accurately measure carbon stocks across the wide variety of vegetation and soil types since different carbon content ratios will apply. Related to this the sourcing of information via remote sensing and using local sources in a balance between coverage and accuracy is an ongoing challenge.

6.4.4 Conclusions, recommended activities and research issues

6.38. To be determined.

6.5 Accounting for biodiversity

NB: Text in this section to reflect a summary of key points from a forthcoming paper on biodiversity accounting and other sources as appropriate

6.5.1 Introduction

6.39.

6.5.2 Relevant data and source materials

6.40.

6.5.3 Key issues and challenges in measurement

6.41.

6.5.4 Conclusions, recommended activities and research issues

6.42.

6.6 Other supporting accounts and data

6.43. As noted in the introduction to this chapter a wide range of data will need to be integrated in the compilation of ecosystem accounts. Data on land cover, water, carbon and biodiversity are likely the key and essential items. Other components, for which accounting frameworks have been developed in some cases, include:

- Timber resources (accounting described in the SEEA Central Framework)
- Fish and other aquatic resources (accounting described in the SEEA Central Framework)
- Other biological resources including livestock, orchards, plantations, wild animals (accounting described in the SEEA Central Framework)
- Soil resources (accounting described in the SEEA Central Framework although further development is required)
- Data on production and use of outputs from agricultural, forestry and fisheries activity (accounting described in the SEEA Agriculture, Forestry and Fisheries (forthcoming))
- Data on tourism and recreation (some coverage of accounting in Tourism Satellite Accounts)
- Population data

6.44. It is likely that in order to generate the data at the appropriate spatial scale for ecosystem accounting some scaling and modelling of the information encompassed by the accounts listed above will be required. The issue of scaling is discussed in ANCA Research Paper #1 (Bordt, 2015). Further, particularly for the measurement of ecosystem services, it will be necessary to use relevant models of ecosystem processes to estimate the relevant flows. These models will require additional data of a scientific and ecological nature. Over time, as the accounts develop, it is likely to be possible to investigate the alignment and consistency between the scientific data and the socio-economic data, particularly as it pertains to specific spatial areas or ecosystems. In this sense, the ecosystem accounting model provides both a rationale and a place for data integration.

7. Accounting for ecosystem assets

7.1 Introduction

7.1. Accounting for ecosystem assets is a fundamental component of ecosystem accounting. Without accounting for ecosystem assets, ambitions to understand and monitor the changes in the natural capital base and hence consider issues of sustainability are not possible. Further, understanding the connections between the characteristics of ecosystem assets and the services that are supplied can form the basis for better planning and management of natural capital.

7.2. This chapter builds on the initial discussion of accounting for ecosystem assets in Chapter 4 of the SEEA EEA. When drafted there were many concepts and ideas about how ecosystem assets might be considered and in many respects, the text of the SEEA EEA represents a first attempt at synthesising approaches to environmental and ecosystem assessment within a national accounting framework.

7.3. Since the first release of the SEEA EEA in 2013 (white cover) further discussion and experience has refined some of the ideas although in number of respects there remains important testing and research to do. The material in this chapter thus represents an update, primarily aimed at updating and clarifying the material in SEEA EEA but also providing some additional guidance and direction for those involved in testing and research.

7.4. This chapter assumes, as outlined in Chapter 3 of EEA TG, that ecosystem assets are defined as spatial areas satisfying the requirements of a land cover / ecosystem functional unit (LCEU). The SEEA EEA was not clear on the appropriate spatial unit that should define an ecosystem asset but the position of EEA TG is clear. This approach remains consistent with the definition of ecosystem assets in the SEEA EEA as being "spatial areas containing a combination of biotic and abiotic components and other characteristics that function together" (SEEA EEA 4.1). However, by providing a clearer link to the LCEU level a better sense of scaling and of measurement approach can be undertaken.

7.5. The focus on LCEU level units as being ecosystem assets does not imply that more aggregated combinations of LCEU (i.e. EAU) such as river basins and administrative areas, cannot be the focus of accounting. Rather it suggests that the appropriate base level unit for asset accounting purposes is the LCEU as it is at this level that the characteristics of an ecosystem asset can be appropriately determined and monitored and it is at this level that an understanding of the relevant ecosystem services can be understood.

7.6. This chapter also takes as a starting point that information on specific components of ecosystem assets, such as information on land cover, water resources, biodiversity, soil, types of biomass (timber, fish, livestock, crops, etc.), has been appropriately estimated and attributed to LCEU level. Chapter 6 provides an overview of the relevant considerations concerning accounting for the components of ecosystem assets.

7.2 Dimensions in the measurement of ecosystem assets

7.7. SEEA EEA Chapter 4 outlines a number of dimensions that are relevant to the measurement of ecosystem assets. The three primary dimensions are ecosystem extent, ecosystem condition, and expected ecosystem services flows. A dimension or concept that has become increasingly of interest from an accounting perspective is that of ecosystem capacity. SEEA EEA notes that "the capacity of an ecosystem asset to generate a basket of ecosystem services can be understood as a function of the condition and the extent of that ecosystem" (SEEA EEA 4.1). While SEEA EEA does not provide a measurement definition for ecosystem capacity, there is recognition that it can provide a linking point between different dimensions in the measurement of ecosystem assets.

7.8. This section briefly outlines the different dimensions of ecosystem assets noted above with a more extended discussion on the measurement of ecosystem condition in the following section and a discussion on the definition of ecosystem capacity in section 7.5.

7.9. The most straightforward dimension is ecosystem extent. The preparation of ecosystem extent accounts, introduced in Chapter 4, is the appropriate starting point for ecosystem accounting since they will reflect fundamental choices on the delineation of spatial areas and also provide important information on the changing composition of ecosystem types at an aggregate level.

7.10. It is this second feature that is perhaps the most significant in accounting terms. Because accounts about ecosystem extent are compiled in a common unit of measurement, usually hectares, this permits aggregation and comparison at larger scales. Thus comparison of the relative proportions of different ecosystem types and the changes in these shares over time can be made. It is not as straightforward to undertake this scale of comparison when considering the quality or condition of ecosystem assets.

7.11. The second dimension is ecosystem condition. "Ecosystem condition reflects the overall quality of an ecosystem asset in terms of its characteristics" (SEEA EEA 2.35). The measurement of ecosystem condition, discussed at more length in section 7.3, requires the selection of specific characteristics and then measurement of relevant indicators pertaining to those characteristics.

7.12. Once indicators are measured, the task from a national accounting perspective is to develop methods that support aggregation and comparison. Being able to understand the relative significance of different ecosystem assets is core to the national accounting approach. The general approach to this task outlined in the SEEA EEA is the comparison of indicators to benchmark or reference condition. Guidance on this is provided in section 7.3.

7.13. The third dimension concerns expected ecosystem services flows. Since the release of SEEA EEA in 2013, this dimension of measuring ecosystem assets has not received much focus. This seems due to two related factors. First, the concept of expected ecosystem services flows is very much an application of standard capital accounting to the area of ecosystems. It thus stands somewhat removed from the experience to date in measuring ecosystems either in terms of their extent and condition or in terms of the actual flows of ecosystem services in a given period of time. Second, since the measurement of expected flows is forward looking and relates to a basket of ecosystem services, it relies on an understanding of the link between the future condition of ecosystem assets and a basket of services and also on measuring an entire basket of services for different ecosystem types. Neither of these measurement challenges are resolved and hence it is likely that progress toward measuring expected ecosystem services flows will be somewhat slower. The second challenge will be resolved as work on the measurement of ecosystem services progresses (see Chapter 5) and the first challenge will centre around the measurement of ecosystem capacity, a topic discussed in more detail in section 7.5 below.

7.14. Ultimately from an ecosystem accounting perspective the key ambition is for measures of ecosystem extent, condition, capacity and expected service flows to be able to be reconciled to provide a consistent picture of each ecosystem asset both it is own right and in terms of measures of other assets. To this point in time, the logic of the relationships established in ecosystem accounting is appropriate but further testing in practical situations is required to ensure the relevance and usefulness of the framework.

7.15. One perspective on ecosystem asset measurement not mentioned above concerns measurement in monetary terms through the valuation of ecosystem services. In concept, measurement in monetary terms permits aggregation and comparison among ecosystem assets, as well as supporting the integration of information on ecosystem assets with data on other assets currently included in the national accounts balance sheets. The measurement of ecosystem extent and ecosystem condition in monetary terms is not possible (at least not directly) and the focus of valuation of ecosystem assets is on the measurement of expected ecosystem services flows. More recently the idea of valuing ecosystem capacity has been raised although further discussion on this point is required.

7.16. Conceptually, the valuation of ecosystem assets is a seemingly neat step. However, there is a range of conceptual and practical challenges in valuation that may mean that progress toward the full valuation of ecosystem assets is a medium to longer term objective. A more complete discussion of the relevant issues is presented in Chapter 8.

7.3 Compiling ecosystem condition accounts

7.17. The intent of an ecosystem condition account is to bring together a range of information about the overall condition of different ecosystem assets. In general, most environmental accounting and indeed most measurement activities, tend to focus on specific characteristics in individual or multiple ecosystem assets. Thus there may be studies on ecosystem components such as carbon, water, timber, soil, biodiversity or characteristics such as resilience. The ambition for ecosystem accounting is to bring all of that information together to provide an overall assessment of ecosystem assets.

7.18. The basic approach is to identify and select certain characteristics of ecosystem assets whose measurement would provide an indication of ecosystem condition. Since the coverage of ecosystem accounting is national level, or at least multiple ecosystem type level, one way of selecting characteristics is to consider a small number that can be measured for all ecosystem types. This is the approach adopted for the ENCA QSP where indicators of carbon, water and biodiversity have been developed and measured for all ecosystems in a country.

7.19. The second way is to develop different indicators for different ecosystem types and perhaps, further by different uses of ecosystem types. This is the approach that has been used in the UK NEA, SANBI, MEGS and by the Wentworth Group in Australia.

7.20. While there is undoubtedly merit in developing broad based approaches as in the ENCA QSP, where resources are available, it would seem more ecologically well founded if the second method is used – i.e. developing measurement specific characteristics for different ecosystem services types. At the same time, given that the ENCA QSP provides a clear foundation for ecosystem condition accounting, an approach that may be considered is developing ENCA QSP based accounts for the whole country in an initial phase and then progressively expanding the set of indicators for different ecosystem types within the same spatial architecture. In this case the expansion may be staged with initial focus on those ecosystem assets showing the largest declines or lowest levels of condition.

7.21. It is not expected that the development of specific indicators for each ecosystem type would lead to the measurement of a vast number of characteristics for every ecosystem. From an ecosystem accounting perspective the intention remains to provide a broad indication of the level and change in condition rather than to fully map the functioning of every ecosystem. This is particularly the case since a key element of accounting is monitoring change over time and hence a focus on those characteristics that drive ecosystem condition is an important consideration.

7.22. In this respect, it has become clear that in selecting characteristics it is necessary but not sufficient to consider only ecological factors. It is also necessary to also take into consideration the type of use being made of an ecosystem asset. For example, the relevant characteristics to consider for a forest being logged are likely to be different from one which is being used primarily for recreation. In the first instance indicators of change in timber resource (e.g. mean annual increment) may be very relevant whereas in the second case an indicator impact of visitors (e.g. litter and garbage) might be more relevant.

7.23. While it may seem that the potential set of indicators is unbounded, testing to date suggests that for most ecosystem types a set of 4-6 indicators can provide a good set of information to enable assessment of the overall condition of an ecosystem asset.

7.24. Ideally, information on each selected characteristic would be measured or downscaled to the BSU level. In many cases this may be possible and indeed, for some ecosystem characteristics such as those pertaining to soil retention and water flow there may be notable spatial variability that should be considered.

7.25. However, there will be some situations in which this may make little conceptual sense or imply assumptions in the downscaling that are not appropriate. For example, a key issue in ecosystem condition is fragmentation which is only measureable at a multiple ecosystem asset or landscape level. Attribution of fragmentation indicators to lower levels may be challenging.

7.26. The SEEA EEA points to a number of different characteristics and indicators (see for example Table 2.3). This was done to provide an indication of the logic being explained rather than to provide definitive recommendations. ANCA Research Paper #5 provides a thorough assessment of the indicators in the SEEA EEA and also describes a number of other indicators that may be considered.

7.27. One type of indicator not mentioned in SEEA EEA but which is worthy of further consideration are holistic indicators of ecosystem health and integrity. To the extent that for particular ecosystems scientific research has established an overall indicator that relates well to the concept of condition being applied in ecosystem accounting then it may be that such indicators can be applied directly for ecosystem accounting purposes.

7.28. In terms of data sources these will be varied depending on the indicator selected. In the areas of carbon, water and biodiversity a range of potential data sources is introduced in Chapter 6 and it is noted that the ENCA QSP proposes many data sources in these areas. In many cases satellite based data are likely to be useful information especially in providing the breadth of data across different ecosystem assets that is required for ecosystem accounting purposes.

7.29. Four considerations that might be used in selecting indicators are (i) the sensitivity of ecosystem services supply to the indicator; (ii) the degree to which the indicator reflects the overall health of or key processes in the ecosystem; (iii) data availability; and (iv) the possibility to generate new data cost effectively.

7.30. Compilers are encouraged to consider the work described in the research paper, the outcomes from testing in different projects, and most importantly, to engage with national experts on ecosystems and biodiversity potentially different experts for different ecosystem types. In this regard, the ecosystem condition account is likely to be the primary account through which engagement with the ecological community can be fostered.

7.4 Aggregate measures of condition

7.31. The development of aggregate measures of the condition of ecosystem assets remains a challenge in measurement terms. This section outlines the logic of the approach proposed for ecosystem accounting and possible ways forward. The following text assumes that for any specific ecosystem asset a set of information for selected characteristics of that asset has been collated.

7.32. Given this information on characteristics is available, the question of aggregation here focuses on obtaining an overall measure of ecosystem condition for a single ecosystem asset. The focus is not on higher levels of aggregation, for example, to provide an aggregate measure of condition for all ecosystems in a country. The focus on single ecosystem assets is consistent with the ecosystem accounting focus on the capacity of ecosystem assets to supply ecosystem services and in assessing the degradation of ecosystems. Both capacity and degradation apply conceptually at the scale of individual assets in the first instance.

7.33. It is also noted that one approach to aggregation is to estimate prices for ecosystem services and derive a monetary value of ecosystem assets. This approach is not considered in this section (see Chapter 8) and, in any event, monetary valuation can only provide an indirect estimate of ecosystem condition via the lens of ecosystem services.

7.34. The approach to aggregation of individual condition indicators involves two steps. First, the indicators of the different characteristics must be transformed to be on a common measurement base and thus able to be compared. Second, a weighting of the relative importance of each characteristic must be assumed to provide an overall aggregate measure.

7.35. In the first step, the approach introduced in the SEEA EEA was the use of a reference condition. In this approach, each indicator is assessed in relation to a common reference or benchmark condition for a particular ecosystem asset. There is a range of alternatives in setting reference conditions. For example, in the ENCA QSP the reference condition is the beginning of the accounting period while in the work of the Wentworth Group the reference condition is pre-European settlement. ANCA Research Paper #5 (Bordt, 2015) provides a more fulsome consideration of different reference condition approaches. SEEA EEA also notes a number of conceptual considerations with respect to the use of reference condition approaches.

7.36. Having established a reference condition, the information for each indicator is normalised commonly with the reference condition reflecting a “score” of 100 and the actual condition as measured being between 0 and 100. A related approach used by SANBI is to grade ecosystems on a scale of A – E with A representing a characteristic associated with a reference or near reference condition ecosystem and E representing a characteristic with a heavily degraded ecosystem.

7.37. Establishing reference conditions and normalising scores is another task that should be conducted in close consultation with national experts in ecosystems and biodiversity. Indeed, it may well be the case that there are existing bodies of work in relevant government agencies and/or universities that can be used or built upon to support this type of assessment. It is important to recognise that the use of reference conditions is well known in ecological circles and it should be considered as an adaptation for ecosystem accounting purposes rather than reflecting the use of an entirely new measurement approach.

7.38. The second step is more complex and less developed. The ambition to weight together indicators of different characteristics is not new from a statistical perspective but, as for socio-economic indicators, the weighting of different ecosystem indicators is a matter of debate. By far the easiest solution is to give each indicator equal weight in an overall measure. However, this may not be appropriate from an ecological perspective with different characteristics possibly playing a relatively more important role. Also, equal weighting may not reflect the relative importance of different characteristics in the supply of ecosystem services.

7.39. An extended discussion on aggregation of ecosystem measures is provided in ANCA Research Paper #1 (Bordt, 2015). That paper points to a number of options and issues. At this stage no clear pathways forward on this have emerged but there are a number of areas for further testing and research described below in section 7.6.

7.5 Developing the concept of ecosystem capacity

7.40. Earlier in this chapter it was noted that in SEEA EEA the measurement of ecosystem assets considers three main concepts: ecosystem extent, ecosystem condition and expected ecosystem service flows. There are no significant additional conceptual points to be made in relation to ecosystem extent and condition and the key measurement issues are discussed above.

7.41. In relation to expected ecosystem service flows the concept remains unchanged but a clarification is made here to ensure that the concept is understood to relate to the actual flows of ecosystem services. That is, in any given accounting period, a quantity of ecosystem services (measured in terms of tonnes, m3, number of visitors, etc.) can be recorded and this would be considered the actual flow of ecosystem services. It is likely to be different from other estimates of what the flows of ecosystem services might have been in different situations (e.g. if prices for resources were higher, if pollution rates had been lower, etc.).

7.42. Given this, the concept of expected ecosystem service flows is applied by estimating what the flows of actual ecosystem services are likely to be in future accounting periods. There is no assumption that the expected flows will reflect sustainable management practice or some specific management regime. Nonetheless, in terms of the asset as a whole, some mixture or basket of ecosystem services will need to be assumed in order for an estimation to take place.

7.43. The main ecosystem asset concept not dealt with in SEEA EEA is the concept of ecosystem capacity. This concept is implicit in making the connection between ecosystem assets and ecosystem services but the nature of this connection was not articulated in SEEA EEA. This was due to two key factors

- First, recognition that the link between ecosystem assets and ecosystem services is hard to describe, particularly in terms of the link between changes in overall ecosystem condition and the generation of individual ecosystem services. Notions of threshold effects, resilience, ecosystem dynamics and other non-linear factors will be important to consider.

- Second, since the concept of capacity seemed to relate to the overall ecosystem asset, a requirement was defining the basket of ecosystem services that would be deemed in scope and discussion on this issue was not conclusive.

7.44. Since the drafting of SEEA EEA in 2012 it has become increasingly apparent that the concept of ecosystem capacity is a central one in both explaining the model and applying the model in practice, especially in terms of developing information sets that can support discussion of sustainability. The following points have emerged from recent discussion of the issue and help to better frame the discussion of ecosystem capacity in the context of the ecosystem accounting model.

- Ecosystem capacity is a function of ecosystem extent and condition
- Ecosystem capacity should be considered in reference to a specific set of ecosystem services
- Ecosystem capacity can be conceptualized and measured (i) in relation to an ecosystem assets capacity to supply an individual ecosystem service, i.e. there is a capacity measure corresponding to each ecosystem service within the chosen set; and (ii) in relation to the basket of ecosystem services as a whole
- Ideally, each individual capacity measure will be a function of the overall condition thus bringing together the two concepts just outlined.
- A distinction is needed between the capacity for an ecosystem to supply ecosystem services independent of expected use and the capacity to supply services taking into account likely use given levels of demand and the potential for extraction.
- Each individual capacity may be considered as a sustainable yield or flow relevant for the specific ecosystem service. The measure should reflect the estimated annual yield or flow for the forthcoming accounting period given the extent and condition of the ecosystem asset at that time, and under the constraint that the extent and condition remained unchanged over the accounting period.
- In cases where high levels of use of the ecosystem asset take place, e.g. through extraction or pollution, it is expected that the condition of the asset will fall and that actual flows of ecosystem services will be higher than the sustainable flow. This set of circumstances would reflect ecosystem degradation.

7.45. Considering capacity as relating to individual ecosystem services is an important step forward in an accounting context, since it permits a direct link to discussions of sustainable yield and flow that are well established in biological models and resource economics. However, there remains the significant challenge of understanding the links between ecosystem capacity for individual services and the overall ecosystem condition and the balances/trade-offs between different ecosystem services.

7.46. From an accounting perspective an important but as yet not developed aspect of defining ecosystem capacity concerns the link between ecosystem capacity and ecosystem degradation. In the SEEA EEA ecosystem degradation is defined in relation to the decline in condition of an ecosystem asset through economic and other human activity (SEEA EEA 4.31). This aligns with the approach in the national accounts and in the SEEA Central Framework for the definition of consumption of fixed capital (depreciation) and depletion.

7.47. The emerging idea is that ecosystem degradation may still be related to declining condition but more specifically in relation to declining condition as it affects the capacity of an ecosystem to supply ecosystem services in a sustainable manner into the future. Since both depreciation and depletion are concepts that imply a finite asset life the issue of the capacity for sustainable supply does not explicitly arise. However, exactly how capacity should be taken into account in relation to degradation and whether this can be done in a manner that remains consistent to the accounting principles of the SNA and SEEA Central Framework requires further investigation.

7.48. As discussion continues on defining ecosystem capacity, it is relevant to highlight that, from a compilation perspective, the lack of a definition in no way limits the potential to compile most other ecosystem accounts and indeed the compilation of these various accounts (extent, condition, ecosystem services supply and use) will be important in providing the measurement experience and detail for the refinement of measures of ecosystem capacity that are being discussed.

7.6 Conclusions, recommended activities and research issues

7.49. To be determined

8. Valuation in ecosystem accounting

8.1 Introduction

8.1. Regularly, the issue of valuation clouds and constrains discussion of ecosystem and natural capital accounting. This occurs for many reasons. For some, the concerns about valuation relate to valuation implying that a "dollar value" is placed on all environmental assets and services and that this is both inappropriate and misleading. For others, the measurement issues are too great and the environment too complex to consider that useful measures might be compiled. Finally, there are differences of view on the purposes, concepts and techniques in relation to monetary valuation with opinions often being well entrenched in different schools of thought.

8.2. Like SEEA EEA chapter 5, the ambition in this chapter is to provide a possible pathway through these various issues such that the discussion on valuation in the context of ecosystem accounting can be undertaken in as an informed way as possible. The ANCA Research Paper on valuation in ecosystem accounting (ref#) provides some additional details and in section 5.4 references are made to relevant documents and materials.

8.3. This chapter is structured in the following way. In section 8.2 the main valuation principles for ecosystem accounting are outlined drawing out the key points from the material presented in SEEA EEA chapter 5. In section 8.3 the key challenges in valuation are described. Section 8.4 considers relevant data and source materials. The final two sections provide a summary of recommendations in relation to valuation based on current practice and knowledge and a summary of the key issues requiring further research.

8.2 Valuation principles for ecosystem accounting

8.4. At the outset, SEEA EEA recognises that the term valuation can mean different things. For accountants and economists, valuation is almost always used in the context of placing a monetary price (dollar value) on assets, goods or services. In other contexts valuation may refer to a more general notion of recognising the significance of something. In SEEA EEA the focus is on valuation in monetary terms but this is not to discount the role or importance of other concepts of value. (A useful introduction to the way in which non-monetary valuation may be conducted is described in Maynard et al 2014)

8.5. Valuation in the SEEA EEA is applied to the valuation of ecosystem services and to the valuation of ecosystem assets. There is a direct connection made between these two distinct targets of valuation whereby the value of ecosystem assets at any point in time, for example at the end of an accounting period, is equal to the net present value of the future flows of ecosystem services that are expected to occur. The application of the net present value technique (explained at length in the SEEA Central Framework Chapter 5) is required since there are no markets that exist in the buying and selling of ecosystems in such a way that the value of all ecosystem services is captured.

8.6. From a practical perspective, the need to apply NPV techniques to value ecosystem assets implies that the valuation of ecosystem assets cannot be determined directly. Instead, the asset value relies on the estimation of the value of ecosystem services. Thus in an accounting context the valuation of ecosystem services and the valuation of ecosystem assets are seen as distinct but related tasks.

8.7. In terms of the valuation of ecosystem services the relevant valuation concept for ecosystem accounting purposes is that of exchange value. If there were observable markets in individual ecosystem services this value would reflect the actual prices paid by consumers of ecosystem services to the relevant producers (i.e. the ecosystems). Since transactions with ecosystems are not observable, these exchange values must be estimated using one of a variety of non-market valuation techniques.

8.8. Some non-market valuation techniques do not reflect only the value of the exchange but also incorporate the welfare effects that can arise to the consumer of the ecosystem service. For example, the value of water abstracted from a river might be increased if one also incorporated the positive effect that consuming water had on health and subsequently labour productivity. While values that incorporate welfare effects may be very useful for assessing differences between available choices, these welfare values are not of direct use in accounting contexts. Consequently, in the selection of non-market valuation techniques, if the objective is ecosystem accounting, then techniques must be found that estimate only the exchange value.

8.3 Key challenges in valuation

8.9. There is a wide range of challenges in valuation. The following section describes those that may be most commonly confronted.

8.10. The target of valuation. In the SEEA EEA ecosystem accounting model (see chapter 2) a clear distinction is made between ecosystem services and the benefits to which they contribute. Particularly for provisioning services, it is not uncommon to consider that the market price of the extracted good (e.g. fish caught or timber harvested) is equivalent to the price of the ecosystem service. In fact, the market price reflects the value of the benefit and the appropriate price for the ecosystem service must deduct the costs of extraction and harvest thus leaving residual.

8.11. Unfortunately, in some cases, this residual may be very small or negative (for example in the case of abstracted water or open access fishing) and consequently the implied price of the ecosystem service would be very low, zero or negative. A clear resolution of this matter is required since while the residual or resource rent technique would lead to the derivation of exchange values, these values would seem to not reflect the broadening of the production boundary that underpins the ecosystem accounting approach.

8.12. A second aspect concerning the target of valuation is the distinction between the valuation of ecosystem services and the valuation of ecosystem assets. Within ecosystem accounting, the valuation of ecosystem assets reflects the overall value of a given spatial area and is estimated by aggregating the net present value of all relevant ecosystem services.

8.13. Consistency in the use of valuation concepts and techniques. For ecosystem accounting, since the ultimate objective in valuation is the integration of data with the standard national accounts, it is essential to use a valuation concept that is consistent with the accounts. SEEA EEA describes the appropriate concept as exchange values, i.e. the prices that arise at the time of exchange between buyer and seller. If exchange values are not used to estimate the value of ecosystem services then there will be no consistent integration with the standard national accounts.

8.14. The use of a consistent valuation concept does not imply that the same estimation technique must be applied in all circumstances. Indeed, a variety of different techniques are likely to be required to cover the range of situations and the different types of ecosystem services. Section 8.4 discusses possible valuation techniques.

8.15. Scaling and aggregation. Often studies on the valuation of ecosystem services are completed with regard to specific ecosystem services in specific ecosystems. A significant challenge from an ecosystem accounting perspective is therefore translating these "point" estimates into information that can be applied at broader scales. This challenge is generally considered under the banner of "benefit transfer". A range of techniques have been developed some of which are considered more refined and appropriate than others.

8.16. Valuation of regulating services. For most provisioning services there is a connection to market values of benefits that can provide a base for measurement. This is also true for some cultural services (such as those relating to tourism and recreation). However in the area of regulating services such connections to marketed benefits is unusual. Indeed, for regulating services it can be difficult to appropriate define and measure the actual physical flow of the service since often the service is simply part of ongoing ecosystem processes rather than a function of direct human activity – for example air filtration and carbon sequestration.

8.17. The measurement of non-use values. An important part of the value of ecosystems from a societal perspective can lie in the non-use values that a reflected in various cultural services provided by ecosystem assets. These values include existence values (based on the utility derived from knowing that an ecosystem exists); altruistic value (based on utility derived from knowing that someone else is benefiting from the ecosystem) and bequest value (based on utility derived from knowing that the ecosystem may be used by future generations). At this point there are relatively few studies in this area of valuation and the methods by which exchange values for these types of use may be defined.

8.18. The valuation of ecosystem assets with respect to land. In estimating the value of ecosystem assets at exchange values one important consideration is the value of land that is commonly traded in markets. Depending on the circumstance, values of land will incorporate the value of some ecosystem services but they are unlikely to capture the value of all of the ecosystem services particularly those that are of a public good nature. Further, market based land values will incorporate elements of value that are not dependent on ecosystems. Consequently, when considering the integration of ecosystem asset valuations into existing national accounts balance sheets some adjustments will be required to ensure there is no double counting or gaps in valuation in the estimation of total net wealth.

8.19. The valuation of biodiversity and resilience. Biodiversity and resilience are considered in SEEA EEA more as characteristics of ecosystem assets and not as ecosystem services. Consequently, they are not directly valued using the general approach outlined and, even within the valuation of ecosystem assets the relative contribution of biodiversity and resilience are unlikely to be identifiable. Further consideration on how these aspects of ecosystem may be valued is required.

8.20. Uncertainty in measurement. While there is always uncertainty in measurement, the valuation of ecosystem services tends to bring together a number of uncertainties into one place. SEEA EEA (section 5.6.4) explains these uncertainties in more depth here they are simply listed: (i) uncertainty related to the physical measurement of ecosystem services and ecosystem assets; (ii) uncertainty in the valuation of ecosystem services and assets; (iii) uncertainty related to the dynamics of ecosystems and changes in flows of ecosystem services; (iv) uncertainty regarding future prices and values of ecosystem services.

8.4 Relevant data and source materials

8.21. The SEEA EEA Chapter 5 suggests a logic in the valuation process such that the first step must be to determine the purpose of valuation, with ecosystem accounting being one among a number of purposes. Based on the purpose, the appropriate valuation concept can be determined. For ecosystem accounting the exchange value concepts is appropriate. Finally, knowing the concept a choice can be made between various valuation techniques such that the exchange value concept can be consistently applied across different ecosystem services.

8.22. A number of valuation techniques have been considered appropriate for measuring exchange values although further discussion on this topic is required as it has generally not been a focus on the ecosystem services valuation literature. The SEEA EEA Chapter 5 outlines a number of these approaches and an updated summary of valuation techniques is provided in Table 8.1.

8.23. In terms of implementation, valuation exercises require, in the first instance, estimation of physical flows of ecosystem services. These flows are then multiplied by a relevant price in order to estimate the value of the flows. By their nature, flows of ecosystem services must be valued in this way. Measurement information on physical flows of ecosystem services, as outlined in Chapter 5, is thus of direct relevance.

8.24. In terms of estimating prices usually it is necessary to seek out studies that have estimated a price for the relevant ecosystem services in a particular ecosystem. There are a number of databases that house relevant studies including the Ecosystem Services Valuation Database (ESVD) that has built on the original work of the TEEB study and the Ecosystem Valuation Toolkit by Earth Economics. A useful link to these and other valuation databases is on the Ecosystem Services Partnership website (see http://www.fsd.nl/esp/80136/5/0/50).

8.25. Additional support for applying valuation in national accounting contexts includes materials from the UNEP Ecosystem Services Economics unit, the materials developed as part of the TEEB study, and work undertaken within the World Bank WAVES project. It is noted however, that generally these materials are not explicit about the valuation concept being applied and hence it is often unclear as to whether the approaches and recommendations are suitable for ecosystem accounting purposes in terms of measuring exchange values. Nonetheless, in conjunction with the discussions in SEEA EEA Chapter 5, these materials should provide a reasonable base for investigating the valuation of ecosystem services at national level.

Table 8.1 Summary of valuation methods and their use in ecosystem accounting

Valuation method	Description	Comments	Suitability for ecosystem accounting
Unit resource rent	Prices determined by deducting costs of labour, produced capital and intermediate inputs from market price of outputs.	Estimates will be affected by the property rights and market structures surrounding production. For example, open access fisheries and markets for water supply often generate low or zero rents.	In principle this method is **appropriate** but consideration of market structures is required.
Production function methods	Prices obtained by determining the contribution of the ecosystem to a market based price using an assumed production function.	In principle analogous to resource rent but generally focused on the valuation of regulating services. May be difficult to estimate the production functions.	**Appropriate** provided the market based price being decomposed refers to a product rather than an asset – e.g. value of housing services rather than the value of a house.
Payment for Ecosystem Services (PES) schemes	Prices are obtained from markets for specific regulating services (e.g. in relation to carbon sequestration)	Estimates will be affected by the type of market structures put in place for each PES (see SEEA EEA 5.88-94)	**Possibly appropriate** depending on the nature of the market structures.
Hedonic pricing	Prices are estimated by decomposing the value of an asset (e.g. house block) into its characteristics and pricing each characteristic through regression analysis	Very data intensive approach and separating out the effects of different characteristics may be difficult.	**Appropriate** in principle. Heavily used in the pricing of computers in the national accounts.
Replacement cost	Prices reflect the estimated cost of replacing a specific ecosystem services using produced capital and associated inputs.	This method requires an understanding of the ecosystem function underpinning the supply of the service and an ability to find a comparable "produced" method of supplying the same service.	**Appropriate** under the assumptions (i) that the estimation of the costs reflects the ecosystem services being lost and is least-cost treatment and (ii) that it would be expected that society would replace the service if it was removed. (Assumption (ii) may be tested using stated preference methods.)
Damage costs avoided / Costs of treatment	Prices are estimated in terms of the value of production losses or damages that would occur if the ecosystem services were lost or degraded.	May be challenging to determine the contribution of an ecosystem service.	**Appropriate** under the assumptions (i) that the estimation of the costs reflects the ecosystem services being lost and is least-cost treatment and (ii) that it would be expected that society would repair the

			damage if it occurred. (Assumption (ii) may be tested using stated preference methods.)
Averting behaviour	Prices are estimated based on individuals willingness to pay for improved or avoided health outcomes.	Requires an understanding of individual preferences and may be difficult to link the activity of the individual to a specific ecosystem service.	Likely **inappropriate** since it relies on individuals being aware of the impacts arising from environmental changes.
Restoration cost	Refers to the estimated cost to restore an ecosystem asset to an earlier, benchmark condition. Should be clearly distinguished from the replacement cost method.	The main issue here is that the costs relate to a basket of ecosystem services rather than a specific one. More often used as a means to estimate ecosystem degradation but there are issues in its application in this context also.	**Inappropriate** since it does not determine a price for an individual ecosystem service.
Travel cost	Estimates reflect the price that consumers are willing to pay in relation to visits to recreational sites.	Key challenge here is determining the actual contribution of the ecosystem to the total estimated willingness to pay. There are also many applications of this method with varying assumptions and techniques being used with a common objective of estimating consumer surplus.	**Possibly appropriate** depending on the estimation techniques and whether the approach provides an exchange value, i.e. excludes consumer surplus.
Stated preference	Prices reflect willingness to pay from either contingent valuation studies or choice modelling.	These approaches are generally used to estimate consumer surplus and welfare effects and within the range of techniques used there can be potential biases that should be taken into account.	**Inappropriate** since does not measure exchange values
Marginal values from revealed demand functions	Prices are estimated by utilising an appropriate demand function and setting the price as a point on that function using (i) observed behaviour to reflect supply (e.g. visits to parks) or (ii) modelling a supply function.	This method can use demand functions estimated through travel cost, state preference, or averting behaviour methods. The use of supply functions has been termed the simulation exchange method (Campos & Caparros, 2011)	**Appropriate** since aims to directly measure exchange values but the creation of meaningful demand functions and estimating hypothetical markets may be challenging.

8.5 Conclusions

8.26. To be developed based on further discussion. A key focus will need to be the need for research on the development of valuation techniques aimed at measuring exchange values. Based on Table 8.1 there are quite number of candidate methods but more direct accounting related valuation investigation is required.

9. Integrating ecosystem accounting with standard economic data

9.1 Introduction

9.1. Ultimately, the integration of ecosystem accounting based information with standard economic data is the key driver for this work within the context of the SEEA. This reflects that the SEEA has been developed as a system that extends and complements the standard economic accounts structured following the SNA. Indeed, for many, the prime ambition of applying the SEEA is the development of adjusted measures of national income that take into account environmental information, for example in the form of depletion or degradation adjusted measures of GDP.

9.2. The reality that emerges from the development of the SEEA EEA and its testing is that adjustments to national income for ecosystem degradation cannot be regarded as straightforward or direct. Indeed, what has emerged in recent years is the need to consider the series of issues outlined through the SEEA EEA and in this Technical Guidance concerning spatial units, scaling and aggregation, ecosystem services, ecosystem condition and capacity and valuation, among others.

9.3. As a result while a theoretical framework for integrated accounting of ecosystems and economic activity is largely in place, its implementation represents the end point of a series of steps of compilation (described in section 9.2) and also requires a range of assumptions on the nature of the require valuation and integration. Compilers should recognise that these long standing matters are still the subject of ongoing discussion and no definitive resolution has yet been found.

9.4. This chapter builds on the text provided in SEEA EEA Chapter 6 and summarises some of the key points that should be recognised in pursuing full integration with standard economic data.

9.2 Steps required for full integration with the national accounts

9.5. Historically, the approach to integrating ecosystem related information with the national accounts has moved directly to the question of the valuation of degradation and the appropriate recording and allocation of degradation in the accounts. This is characteristic of the primary approaches outlined by national accountants (see for example, Harrison 1993 and Vanoli 1995) and again demonstrated by Bartelmus (2015). However, the question of exactly how the integration should be undertaken has never been fully resolved.

9.6. As explained in SEEA EEA and also in recent literature (e.g. Edens and Hein, 2013) the emergence of the concept of ecosystem services has allowed a reconceptualization of the integration with the national accounts. It is this new basis for integration that is reflected in the SEEA EEA.

9.7. Through the concept of ecosystem services the following (generalised) steps toward integration become apparent

i. Delineate the relevant spatial areas to create mutually exclusive ecosystem assets

ii. Measure the generation of ecosystem services from each ecosystem asset

iii. Measure the monetary value of all ecosystem services

iv. Measure the condition of each ecosystem asset

v. Assess the future flows of ecosystem services from each ecosystem asset based on consideration of the condition and capacity of ecosystem assets

vi. Estimate the net present value of the future flows of each ecosystem service and aggregate to provide a point in time estimate of the monetary value of each ecosystem asset

vii. Estimate the change in net present value over an accounting period and determine the monetary value of ecosystem degradation

viii. Integrate values of the production and consumption of ecosystem services, the value of ecosystem degradation and the value of ecosystem assets into the standard economic accounts.

9.8. It is clear from this list, which itself is somewhat stylised, that the full integration of ecosystem accounting information into the standard national accounts is not straightforward. At the same time, maintaining what must be a longer term objective of integration gives a clear purpose and rationale for the selection and structuring of the ecosystem information that is required in the early phases. Further, the information organised in the early phases is likely to be of direct usefulness for decision making and monitoring in its own right. Consequently, while the objective of full integration may be challenging, it plays an important part in framing the SEEA EEA approach to ecosystem accounting.

9.9. The measurement issues relating to the initial steps outlined above have been described in earlier chapters in this Technical Guidance. This chapter discusses measurement issues related to steps vi to viii. It is important to recognise that the content of this chapter is largely in the realm of ongoing research and at this stage full integration of ecosystem accounts with the standard national accounts is likely to be a medium to longer term objective at national level.

9.3 The role of combined presentations

9.10. A more immediate means of combining the information from ecosystem accounting with the standard national accounts is by means of so-called combined presentations.

9.11. Combined presentations are described in the SEEA Central Framework Chapter 6. In essence they are tables that support the presentation of information from a variety of sources in a manner that facilitates comparison between economic and environmental data. This is achieved by consistent use of common classifications and accounting principles.

9.12. Two examples with respect to ecosystem accounting are (i) the provision of information for specific ecosystem assets (spatial areas) of changes in condition of the asset alongside information on the expenditure on environmental protection in that same area; and (ii) information on the flows of ecosystem services generated by an ecosystem asset combined with information on the value of economic production from that asset (a specific example here might be comparison of a farm's income with the value of ecosystem services generated from the same farm area).

9.13. SEEA EEA Chapter 6 provides some additional comments in relation to combined presentations. The main point here is that there is considerably flexibility in the design of combined presentations. While they do not represent a full integration of information they may support a more informed discussion of the relationship between ecosystems and economic activity, and they may help underpin presentation of monitoring type information and indicators.

9.4 *Integrated accounting structures*

9.14. Chapter 4 introduced two types of integrated accounts in the context of the broad suite of ecosystem accounts. In this section those two types of accounts – augmented input-output tables and integrated sector accounts and balance sheets are described in more detail.

9.4.1 Augmented input-output tables

9.15. The augmented input-output table represents the first account in which explicit consideration must be given to the boundaries between the current economic measures and measures of ecosystem services in terms of the structure of the accounts. The ambition in the augmented input-output table is to present the information on the supply and use of ecosystem services as extensions to the standard input-output table.

9.16. There are two key aspects to this extension. First, recalling that the ecosystem accounting model implies an extension to the standard production boundary, the set of products within scope of the input-output table is broader and hence the size of the input-output table must grow. This can be done through the addition of new rows (representing the ecosystem services).

9.17. The requirement here is to ensure that these ecosystem services are distinguished clearly from the products that are already within the standard input-output table – i.e. the SNA benefits. For these benefits the relevant ecosystem services represent the intermediate consumption of the producers of the SNA benefits. For ecosystem services that contribute to non-SNA benefits then both the ecosystem services and the new benefits need to be added in – in effect the ecosystem services are inputs to the production of the non-SNA benefits.

9.18. It is noted that while conceptually it would be possible to extend the input-output table to incorporate both final and intermediate ecosystem services, it is recommended that the extension be limited to final ecosystem services. In part this reflects that if intermediate services were also to be added then the complexity of the table would be increased but also that from an analytical perspective there is little gain. The focus of the augmented input-output table is on the link between the economy and ecosystems and this requires only inclusion of final ecosystem services. Put differently, from a production perspective the intermediate services net themselves out. Further, the analysis of the intermediate services and hence flows between ecosystems may be analysed using data from the ecosystem services generation and use tables.

9.19. The second key aspect to the augmented input-output table is that additional columns are required to take into account the production of ecosystem services – i.e. the ecosystems are considered additional producing units alongside the current set of establishments classified by industry (agriculture, manufacturing, etc). Given that input-output tables are generally compiled at national level it may be sufficient to introduce simply one additional column to cover the production of all ecosystem services. In this case the detail would be covered in the ecosystem services generation account. However, there may be interest in adding columns by type of LCEU (ensuring aggregation to national level) or by specific EAUs that cover the country.

9.20. While in principle the structure of an augmented input-output table may be estimated in both physical and monetary terms, here it is suggested that only compilation in monetary terms is undertaken. The problem in physical terms is that the table can only be interpreted and balanced if the same measurement unit is applied for all of the products in scope (both ecosystem services and others). The measurement of economy wide - material flow accounts has developed over the past 20 years where all products inside the standard production boundary are measured in tonnes but this approach is not advocated in the SEEA CF and its extension to cover ecosystem services has not been developed.

9.21. A related augmentation of standard input-output tables are environmentally-extended input-output tables (EE-IOT). These tables are increasingly compiled, including at regional and world levels, for the analysis of embodied GHG emissions, water and similar environmental flows. An introduction to EE-IOT is contained in SEEA Applications and Extensions Chapter 3.

9.22. The distinction here is that for EE-IOT information on environmental flows is simply appended to the standard input-output table and then matrix algebra is used to integrate the data for analytical purposes. What is required is that the information on environmental flows is classified and structured in the same manner as for the standard input-output data. Further, the additional information may be in physical or monetary form even while the standard input-output data remain in monetary form.

9.23. For the augmented input-output table envisioned here, the ecosystem services are integrated within the standard input-output table reflecting the extension of the production boundary. This is an important and significant development. It is noted however that using EE-IOT techniques it is possible to analyse selected ecosystem services without developing a full augmented input-output table.

9.24. An important result of integrating the flows of ecosystem services in this way is that it is clear how the commonly discussed topic of “double counting” is managed in a straightforward manner in a national accounting setting. Quite commonly, there is concern that integrating ecosystem services with the national accounts will result in double counting if certain flows are included. The stylised presentation in Table 9.1 demonstrates that double counting is avoided provided that the series of entries from production to use through the supply chain are recorded appropriately. The gross basis of recording that is used in Table 9.1 is by far the most transparent manner in which double counting is dealt with for accounting purposes.

9.25. Table 9.1 is a stylized supply and use table and is divided into three parts. Part A reflects a standard recording, i.e. no ecosystem services, of timber production for furniture purchased by households. The recording ignores all other inputs and potentially relevant flows (e.g. labour costs, retail margins).

9.26. Part B extends this recording to include the flow of the provisioning service of timber from the ecosystem asset (the forest) to the forestry industry. The main effect is to partition the value added of the forestry industry between the industry and the ecosystem asset. Note that the overall value added is unchanged (at 80 currency units) even though total supply has increased. This reflects the increase in the production boundary and demonstrates how the accounting framework deals with the challenge of double counting.

9.27. Part C introduces a second ecosystem service, air filtration, which is generated by the ecosystem asset. Again total production is increased but in this case value added also rises since the additional production is not an input to existing products. The increase in value added is also reflected in increased final demand of households.

Table 9.1: Integration of final ecosystem services with current national accounts estimates

	Ecosystem asset (Forest)	**Forestry industry**	**Manufacturing industry**	**Households Final Demand**	**TOTAL**
PART A					
Supply					
Logged timber		50			50
Furniture			80		80
Use					
Logged timber			50		50
Furniture				80	80
Value added (supply less use)		50	30		80
PART B					
Supply					
Ecosystem service – growth in timber	30				30
Logged timber		50			50
Furniture			80		80
Use					
Ecosystem service – growth in timber		30			30
Logged timber			50		50
Furniture				80	80
Value added (supply less use)	30	20	30		80
PART C					
Supply					
Ecosystem service – growth in timber	30				30
Ecosystem service – air filtration	15				15
Logged timber		50			50
Furniture			80		80
Use					
Ecosystem service – growth in timber		30			30
Ecosystem service – air filtration				15	15
Logged timber			50		50
Furniture				80	80
Value added	45	20	30		95

9.4.2 Integrated ecosystem institutional sector accounts and balance sheets

9.28. Beyond the augmented input-output table which integrates ecosystem services information into the standard structures for measuring production and consumption, it is relevant to also integrate ecosystem information into the broader sequence of accounts and balance sheets of the SNA. The general logic and structure of the sequence of accounts is described in detail in the SNA and summarised in the SEEA Central Framework, Chapter 6. The focus in these accounts moves away from industry level information on production and consumption and instead focuses on sector level (i.e. corporations, governments, households) income, saving, investment and wealth.

9.29. Chapter 6 of SEEA EEA describes the possible sequence of accounts where there is integration of information on ecosystem degradation in particular. The SEEA EEA is not definitive however and no clear resolution of the way in which degradation might be allocated has been determined. Determining an appropriate allocation of degradation requires making judgements on the attribution of the impacts of economic activity on the environment. These impacts may occur in areas well away from the source of the impact, may occur in time periods well in advance of the impact, and may be unknown to the relevant unit. In addition it is not necessarily clear in what way the loss of benefits applying to the impacted sectors should be related to the income of the sector causing the impact. These matters have been debated at length in the national accounting community without any clear resolution. It may well be that, as stated in the SEEA EEA, the choice of structure for the sequence of sector accounts should depend on the type of question being posed.

9.30. One of the main functions of the sequence of accounts is to demonstrate the linkages between incomes, investment and balance sheets and in this context, a key feature of the standard sequence of accounts is the attribution of consumption of fixed capital (depreciation) to sectors as a cost against income.

9.31. The significance of developing a sequence of accounts that integrates ecosystem information is two fold. First, it is in these accounts that the cost of ecosystem degradation can be attributed to individual sectors and linked, at the same time, to changes in net wealth. Second, the effect of extending the asset boundary of the standard national accounts to include various regulating and cultural services from ecosystems can be seen in an extended balance sheet.

9.32. From an implementation perspective, it should be recognised that the compilation of a sequence of institutional sector accounts and balance sheets is not at all straightforward. It relies on compilation of aggregated data for ecosystem services and ecosystem assets in monetary terms and hence information in all of the accounts described above will be required before a sequence of accounts can be compiled. In that sense, the completion of these accounts should be considered of low priority and it is likely that significant benefits can arise from placing priority on the completion of the accounts listed above in the first instance, particularly those concerning ecosystem condition and the generation of ecosystem services.

9.5 Key challenges in full integration

9.5.1 Allocation of ecosystem degradation to economic units

9.33. One of the most longstanding challenges in developing fully integrated accounts is the measurement and allocation of ecosystem degradation. The SEEA Central Framework proposes a means by which the depletion of natural resources can be incorporated within the standard sequence of accounts of the SNA. This step recognises that the using up of natural resources is a cost against future income of the extractor that should be attributed to the extractor.

9.34. While such depletion due to natural resource extraction is a component of ecosystem degradation, in concept degradation is broader since it also incorporates the cost of reducing the future generation of all ecosystem services, not only the provisioning services from natural resources in ecosystems. Unfortunately, it is commonly the case that the loss in ecosystem condition and capacity that arises due to economic and human activity may be difficult to directly attribute to individual economic actors.

9.35. A number of alternative approaches to dealing with this allocative issue have been suggested. Perhaps the most obvious is that the degradation should be attributed to the economic unit that caused the degradation, presuming that this can be determined. It may be made difficult due to distance (i.e. impacts are felt in neighbouring ecosystems) or due to time (i.e. when the impacts become evident after the activity occurred). Due to both of these factors the appropriate economic unit (i.e. the unit who should be shown as bearing the cost) may not be the manager or owner of a particular ecosystem asset. Further, since physical degradation of an ecosystem is likely to impact on the generation of multiple ecosystem services received by various beneficiaries assessing the overall impacts is complex.

9.36. These factors are all quite distinct from the estimation of depreciation (or consumption of fixed capital) for produced assets. Depreciation can be directly attributed since there is only one owner/user who receives all of the benefit/services of the asset (in the generation of output and income).

9.37. Overall, the issue of allocation ecosystem degradation has not been resolved and remains on the research agenda.

9.5.2 Valuation of ecosystem degradation

9.38. Together with this challenge of attribution, a range of valuation approaches for ecosystem degradation have been suggested. These are described in SEEA EEA section 6.3.3. The approach that emerges from the ecosystem service based valuation approach described here is that the value of ecosystem degradation will be equal to the change in the net present value of an ecosystem asset putting aside changes in value that are not due to economic and human activity. In this sense the valuation will directly reflect the loss of future ecosystem services.

9.39. The most commonly used alternative to valuing ecosystem degradation is the use of restoration (maintenance) cost approaches. Such approaches were suggested in the original 1993 SEEA and have been applied more recently in the CBD ENCA QSP. Generally speaking, restoration cost approaches are not well accepted by the economic community (need references). In accounting terms as well, recent work suggests that they are not, as commonly implied, equivalent to what is done in estimating depreciation of fixed capital (see Obst and Vardon, 2014). There is no doubt that estimating potential restoration costs supplies an important piece of information, particularly for planning purposes. It is less clear that it supplies a good estimate of the value of ecosystem degradation.

9.40. A more recent suggestion for the valuation of ecosystem degradation has emerged from discussion on ecosystem capacity. Through this discussion the idea has arisen of estimating the net present value of the flow of services represented by an ecosystem's capacity at any given point in time. This is distinct from the net present value of the flow of services that are expected to occur. The change in the NPV of the ecosystem capacity might be a more appropriate estimate of the effect of the reduction in future income that arises from a decline in ecosystem condition. However further investigation of the national accounting aspects of this approach is required.

9.5.3 Integrating balance sheet valuations

9.41. Perhaps the most significant measurement challenge in full integration is the need to generate balance sheet values for ecosystem assets on a consistent basis with the items already recorded on the national balance sheet as defined by the SNA. In the absence of observed market prices for ecosystem assets the logic of the SEEA is that the value of the asset would be equal to the net present value of the future flows of all relevant ecosystem services.

9.42. As with all NPV based approaches this requires various assumptions (see SEEA Central Framework Chapter 5) including estimating the future rates of use and extraction and applying appropriate discount rates. Estimating the future rates of use of ecosystems must in turn imply an understanding of the likely mix or basket of ecosystems that will occur in the future and also the likely impact of generating this assumed basket on the future condition of the ecosystem asset. As discussed in Chapter 7, reaching these understandings on ecosystem capacity is a significant challenge.

9.43. It is the case that some parts of the value of ecosystem assets are reflected in the value of assets currently recorded on national balance sheet. The most obvious example is the value of agricultural land which must, reasonably, be considered to incorporate the value of some of the ecosystem services used by farmers in the production of agricultural goods. Similar logic would apply in the case of forests.

9.44. However, as explained at some length in SEEA EEA section 6.4.2, untangling the overlap in valuations is likely to be complex. It is certainly not simply a case of adding on to the current balance sheets the value of ecosystem assets obtained by summing the NPV of a basket of ecosystem services.

9.45. Given this challenge, an intermediate step may be the compilation of an ecosystem asset account that shows, in monetary terms, the opening stocks, additions and reductions in stocks and closing stocks for ecosystem assets as a stand alone account. This may then be compared to current SNA based balance sheet entries, particularly for land and natural resources, as a means of understanding the potential differences and the significance of the recognition of ecosystem services that are currently outside the production boundary.

9.46. In the comparison of values of ecosystem assets with values currently incorporated into SNA balance sheets, it is important to recognise the different scopes of environmental assets. In broad terms, the SNA balance sheets will have lower values for environmental assets as a result of the SEEA EEA including 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 sub-soil mineral and energy resources. Hence the value of ecosystem assets derived following the SEEA EEA will be lower than the value of environmental assets given this smaller scope. The effects of these two differences will vary from country to country.

9.5.4 Application of integrated approaches for individual ecosystem assets

9.47. A final challenge in the area of integrating the accounts arises when aiming to apply the accounting approach at the level of individual ecosystem assets. Recall that the valuation of an ecosystem asset is directly related to the basket of final ecosystem services that are expected to be generated from an asset. At the level of individual ecosystem assets however, there will be cases where an asset supplies few or no final ecosystem services (for example, a high mountain forest) but rather plays a supporting role in supplying services to neighbouring ecosystems. In this situation an ecosystem asset may be recorded as having zero monetary value and instead its value is embodied in the value of the neighbouring ecosystems. While at an aggregate, national type level this 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 sub-national scales. Resolution of this issue requires the incorporation of intermediate services into the ecosystem accounting model in a far more explicit manner, something that is high on the research agenda.

9.6 Alternative approaches to integration

9.48. If in fact the longer term objective is not full integration with the standard national accounts, then integration of ecosystem and economic data may be considered in different ways. Three alternative integrated approaches are summarised here.

9.49. A well developed approach is usually referred to as wealth accounting which has developed as a branch of economics since the mid 1970s. Underpinning its approach is that sustainability in aggregation consumption and incomes requires non-negative changes in aggregate wealth based on the seminal work of Weitzman (1976). Wealth accounting seeks to aggregate the value of all relevant assets/capitals including produced, natural, human and social capital. The most prominent work has been completed by the World Bank (The Changing Wealth of Nations, 2011) and measures of inclusive wealth by UNU-IHDP and UNEP. Their methods vary in the detail but they are broadly similar approaches.

9.50. In concept, wealth accounting aims to value each form of capital in terms of its marginal contribution to human welfare (Dasgupta, 2009). By doing so shadow prices are estimated for each asset type. From a national accounting perspective while a focus on marginal prices is appropriate, estimation of the contribution to welfare is different from a focus on exchange value. Nonetheless given the purpose of wealth accounting the conceptual approach to integration is quite appropriate. In practice however, often values for produced capital from the standard national accounts are used which are based on exchange values and hence there may be a lack of alignment between the valuation approaches for different capitals. For natural capital, it is clear that the use of exchange values for ecosystem services would not correspond directly to the conceptual requirements of wealth accounting although there will be strong connections between the two approaches.

9.51. Another approach to integration builds on the use of restoration costs as a measure of ecosystem degradation to create ecological liabilities on the national balance sheet. That is, unpaid restoration costs that arise when an ecosystem declines in condition are treated as a liability. This approach is described in the CBS ENCA QSP and has also been suggested for use at the corporate level by the UK Natural Capital Committee. From a national accounting perspective there are a number of difficulties with this approach

- First, there is the question of whether restoration costs are a suitable estimate of ecosystem degradation. This is discussed in Chapter 8.
- Second, there is a question of when liabilities should be recognised. If there is no expectation that the restoration will take place then, at least for accounting purposes, no liability should be recognised. In effect, recognising these liabilities is a policy or analytical choice rather than an application of accounting principles.
- Third, if a liability is recognised then all else being equal net wealth will fall. However, since the recognition of the liability reflects the degradation of an asset there will be both a fall in an asset and an increase in a liability for the

same event thus implies a double counting on the balance sheet. This issue does not arise in accounting for depreciation where the only balance sheet change is the fall in the asset value. A solution would be to record the liability but keep the ecosystem asset value unchanged but this seems quite counter-intuitive.

9.52. Overall, while recording ecological debts seems attractive 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.

9.53. The final integrating approach noted here is that of full cost accounting which is an accounting approach that has developed in the corporate accounting world. The intent behind full cost accounting is to estimate and record the broader costs of a companies activities on the environment as part of their ongoing operating costs. For example, the costs of GHG emissions and the release of pollutants are common areas of interest. Such information may be helpful in a range of management situations.

9.54. From an ecosystem accounting perspective a few points can be noted. First, the approach largely excludes consideration of ecosystem services in terms of these flows representing inputs to the production process. Hence, within the full cost accounting approach there is no change in the standard production or income boundaries.

9.55. Second, there is no recognition of ecosystem assets as part of capital base of a company and hence no impact on the companies balance sheet or recording of ecosystem degradation.

9.56. Third, the incorporation of costs associated with residual flows (emissions, pollutants etc) is not something undertaken directly in ecosystem accounting. In broad terms this 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 these costs is part of a measure of ecosystem degradation but further work to understand the links between the valuation of externalities and ecosystem accounting is required to consider this question.

9.57. Overall, while full cost accounting does represent a form of integration it is somewhat limited in scope relative to the ambitions of ecosystem accounting.

9.7 Conclusions

9.58. To be drafted following further discussion